Arizona Water Company
W-01445A-15-0277

Amendment to Application

PART 5 OF 12

Arizona Corporation Commission
DOCKETED
AUG 21 2015
DOCKETED BY

Western Group Rate Case

Exhibit FKS-14

National Research Council Canada | Conseil national de recherches Canada

NRC · CNRC

Failure modes and mechanisms in gray cast iron pipe

Makar, J.M.; Desnoyers, R.; McDonald, S.E.

NRCC-44218

A version of this paper is published in / Une version de ce document se trouve dans :
Underground Infrastructure Research: Municipal, Industrial and Environmental Applications, Proceedings, Kitchener, Ontario, June 10-13, 2001, pp. 1-10

www.nrc.ca/irc/ircpubs

Institute for Research in Construction | Institut de recherche en construction | IRC

Failure Modes and Mechanisms in Gray Cast Iron Pipes

J. M. Makar, R. Desnoyers and S. E. McDonald
Institute for Research in Construction, National Research Council Canada, Ottawa, Ontario, Canada

Presented at Underground Infrastructure Research 2001, Waterloo, Ontario, June 10-13

© 2000 Government of Canada

ABSTRACT: Failures in cast iron water mains are more complex and diverse than is widely understood in the industry. This paper discusses the modes and causes of pipe failures that have been encountered during a three year investigation by the National Research Council Canada. In addition to corrosion, manufacturing defects, human error and unexpected levels of pipe loading all play a role in the large number of pipe failures that occur each year.

1 INTRODUCTION

Gray cast iron is the most common material used in North American water systems, representing about 50% of the total length of installed water mains (Kirmeyer, Richards and Smith, 1994). It is also the material that is most prone to failure. A large water utility may experience 300 or more water main breaks a year. Each such main failure causes disruptions to water supply and may require emergency repairs. If a large diameter main fails, millions of dollars of damage may result. Even without a large main failure, the total cost of small diameter water main breaks represents a significant portion of the annual operating budget of most water utilities.

Despite the economic and social significance of water main breaks, little work has been done to analyse the failures and understand the mechanisms that cause them. Past research has concentrated on soil and corrosion behaviour (Romanoff, 1964; Zamanzadeh, 1990; Fitzgerald, 1968). The work that has been done to investigate the failures themselves has largely been for legal purposes to determine liability for a particular single water main failure. This has led to a widely held belief that the failure process is a simple one, where a pipe corrodes to the point at which it can no longer withstand the applied internal and external forces, resulting in a main break.

However, recent work at the National Research Council Canada (NRC) has shown that the failure process is much more complex than expected. Corrosion plays a significant role in gray cast iron water main failures, but soil-pipe interactions, poor pipe casting techniques and human error are also important factors. Failures also often take place in multiple stages, rather than in a single episode. This paper discusses the different modes of failure in gray cast iron pipes and the causes behind those failures. Individual examples of ductile iron failures will also be examined. A number of photographs of pipes are presented in order to assist practitioners in identifying similar problems in other water systems. Finally, a case study will be presented that briefly discusses the failure analysis process.

2 FORCES ON IN-SERVICE PIPES

At the most basic level pipe failures are caused by applied forces exceeding the residual strength of the metal. The forces applied to pipes have been investigated in detail elsewhere (Rajani, Zhan and Kuraoka, 1996), but a brief summary will be presented here to provide the context for the remainder of the paper. The forces applied to water pipes can be considered as five groups: those produced by internal water pressure; bending forces; crushing forces; soil movement induced tensile forces; and temperature induced expansive forces. Gray cast iron pipe systems were generally designed to withstand only internal pressure and crushing forces (AWWA, 1975). The loads that produced the latter forces were assumed in the standards to be due to ground weight or truck loading above the pipe. However, frost loading and expansive clays may also produce similar loads above the pipe. Crushing failures appear to be very uncommon in gray cast iron pipes. None of the eighty four pipe failures investigated by NRC have shown evidence of this type of failure. Many of the same loads can also produce bending in pipes, which is a common failure mode. Additional loading conditions that can produce bending include some forms of soil movement and

possibly thermal forces due to differences between the temperature of the water in the pipes and the surrounding soil. Another possible loading condition that can cause pipe failures is one produced by soil locking to the pipe wall through friction. Soil movements may then produce tension in the pipe, producing simple tensile failures. Finally, leadite, a sulphur based joint sealing compound used in the 1940s and 1950s appears to produce pipe failures due to the difference between its coefficient of thermal expansion and that of the metal in the pipes it seals. This mechanism is discussed further in Section 3.3

3 FAILURE MODES

The term "failure modes" refers to the actual manner in which cast iron pipes fail, rather than the mechanism that causes the failure. These modes vary depending on the diameter of the pipe. Smaller diameter pipes have lower water pressure but also smaller moments of inertia, which makes them more susceptible to longitudinal bending failures. Larger pipes have higher water pressure and higher moments of inertia, producing a tendency to longitudinal cracking and shearing at the bell.

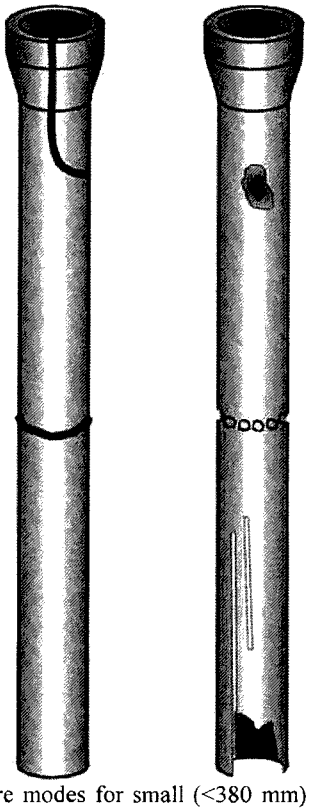


Figure 1. Failure modes for small (<380 mm) diameter pipe. Left pipe: bell splitting at top of pipe, circumferential cracking at middle of pipe. Right pipe: corrosion through-hole at top of pipe, chain created corrosion pitting at middle of pipe, elongated corrosion pitting with blow out hole at bottom of pipe. Generally these failure modes will not be seen on the same pipes.

3.1 *Blowout holes*

As discussed in the following sections, corrosion plays a role in many mechanical failures. However, corrosion by itself or in conjunction with internal water pressure can also cause pipe failures. In this case corrosion pitting occurs until the pipe wall has thinned to the point where the water pressure blows out the remaining, very thin pipe wall. This type of corrosion failure may produce a very small hole or a large one, depending on how localised the corrosion process has been and the pressure experienced by the pipe.

3.2 *Circumferential Cracking*

Circumferential cracking is the most common failure mode for small diameter (<380 mm diameter) gray cast iron pipes (Figure 1). Typically this type of failure is caused by bending forces applied to the pipe. The resulting failure occurs in a manner similar to a twig snapping, with the failure crack propagating across the circumference of the pipe. This type of failure may also be caused by soil movements producing tensile forces on the pipe, producing a simple tensile failure.

3.3 *Bell Splitting*

This failure mode also appears to be most common in small diameter pipe. Joints in cast iron pipes were originally sealed using rope packed between the bell of one pipe and the spigot of the other. Molten lead was then poured into the joint to complete the seal. Leadite, a rigid, sulphur based compound was used in the 1930s and 1940s as a substitute for lead. However, as a non-metallic compound, leadite has a different thermal co-efficient of expansion than lead. Consequently, very cold temperatures at the pipe can cause the bell to split as shown in Figure 1. This failure mode is different from the longitudinal splitting shown in Figure 2 both because of different causes and because the crack terminates just below the bell of the pipe once the stresses produced by the thermal expansion have been relieved.

3.4 *Longitudinal Cracking*

Longitudinal cracking appears to be confined to large diameter pipes. This failure mode may be due to internal water pressure, to crushing forces acting on the pipe or possibly to compressive forces acting along the pipe. Any of these loadings could result in a longitudinal crack. Once the crack has initiated, it may travel the length of the pipe. In some instances cracks have formed on opposite sides of the pipe. The end result has been the removal of a section of the top of the pipe, producing a hole that may be as

long as the pipe and taking up a third of its circumference.

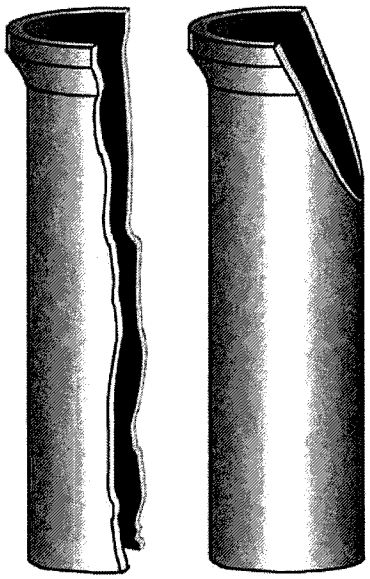


Figure 2. Failure Modes for large (>500 mm) diameter pipe. Left pipe: Longitudinal splitting. Right pipe: Bell shearing. Corrosion pit failure modes are also common on these pipes.

3.5 *Bell Shearing*

Large diameter pipes generally have too high a moment of inertia to produce the circumferential failures shown in Figure 1. However, large diameter gray cast iron pipes do fail by having a section of the bell shear off as shown in Figure 2. A possible cause of this failure mode is compressive forces pushing the spigot of a pipe into the bell of the next pipe in the pipeline. However, bending forces are more likely to be the cause of this type of failure. Simple compressive loading would tend to produce a crack that propagates down the length of the pipe, but a bending force would produce the type of shearing shown in the figure. An example of this mode was seen in a 1998 failure of a 914 mm diameter main in Boston.

3.6 *Spiral Cracking*

Some medium (380 mm –500 mm) diameter pipes experience a unique failure mode where the crack in the pipe appears to start in a circumferential fashion and then propagates down the length of the pipe in a spiral fashion. This failure mode has been seen in Des Moines, St. Louis and Ottawa. In the two former cases the failures were associated with pressure surges. The appearance of this failure mode also suggests that the failure is produced by a combination of bending forces and internal pressure.

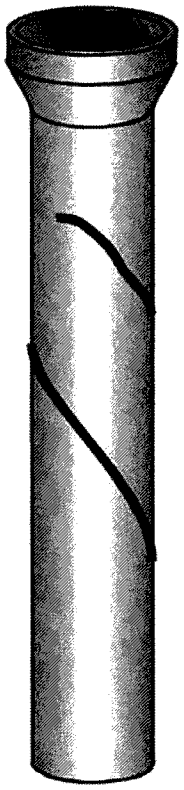


Figure 3. Spiral failure mode in mid-diameter (380 mm –500 mm) pipe. Corrosion pitting failures have also been seen in these pipes.

4 CAUSES OF FAILURE

4.1 *Corrosion*

Corrosion induced failures are common to all pipe diameters. Although many of the failure modes described in section 3 are mechanical in nature, corrosion pitting is frequently associated with these failures, having produced the weakening in the fabric of the pipe that allowed the failure to occur. As an example, twenty three out of the twenty five circumferential failures investigated by NRC have been associated with corrosion pitting. Other failures are due to corrosion alone (Figure 4). Simple corrosion pitting is a minor failure mode in small diameter pipes, but more important in diameters above about 300 mm.

Investigation of the effects of corrosion on gray cast iron failures in particular is complicated by the presence of two separate but closely related corrosion processes that may affect the pipes. Simple corrosion pitting can occur in much the same way as steel pipes. However, graphitisation can also take place. This process removes some of the iron in the pipe, but leaves behind a matrix of graphite flakes that is held together in part by iron oxide.

Figure 4. Heavily corroded gray cast iron pipe. (City of Toronto)

Graphitisation can form a solid substance on the pipe, producing the appearance of an undamaged material. In many cases this corrosion product may also be strong enough to temporarily resist the pipe's internal water pressure. Cleaning the pipe surface using sand blasting or other methods is frequently the only way to determine the full extent of the corrosion damage to the pipe.

Areas of graphitisation are often thought to be composed solely of the graphite flakes. In reality, chemical analysis shows the presence of iron oxide, which appears to be essential for the process. NRC has used high speed corrosion cells on gray cast iron pipe in order to produce artificial corrosion pits. These cells are capable of producing a 5 mm deep, 7 mm wide hole in one to two hours. This corrosion process left behind the graphite in the pipe, but as soft, easily removable carbon flakes, not hard graphitisation. Iron oxide therefore appears to be necessary to form the corrosion product known as graphitisation. In addition, it also suggests that a slow corrosion process is required for the graphite to bond with the iron oxide.

Unlike gray cast iron, ductile iron does not have a matrix of cast iron flakes. Instead, its manufacturing process produces fine carbon spheres in the metal. This produces a stronger, more ductile material than gray cast iron, with the greater ductility giving the alloy its name. The lack of connection between the graphite spheres in this material was assumed to mean that graphitisation could not occur.

However, the Water Research Centre in the United Kingdom has observed examples of graphitisation in ductile iron pipe (De Rose and Parkinson, 1985). NRC has investigated ductile iron pipe failures from the cities of Ottawa and Toronto where graphitisation was also observed (Figure 5). An elemental analysis of the graphitisation from the Ottawa pipe showed high amounts of carbon, iron and oxygen in approximately the same proportions as seen in graphitisation in gray cast iron pipes. Additional trace elements from the surrounding soil were also identified. While graphitisation is less common in ductile iron pipes than in gray iron pipes, it is clearly still a possibility. Visually undamaged ductile iron pipes should not, therefore, necessarily be assumed to be without corrosion damage.

Figure 5. Cross-section of ductile iron pipe showing graphitisation. (City of Ottawa)

4.2 *Manufacturing Flaws*

Gray cast iron pipe was manufactured using a number of different methods, with the two most common being pit casting and spin or centrifugal casting (Talbot, 1926). In the former method a vertical mould was built from sand inside a pit. Molten cast iron was poured into the mould, which then slowly cooled until the pipe could be removed and tested. Spun cast pipe was produced in horizontal, spinning metal or sand moulds, with the former approach requiring water cooling of the mould. In this method a ladle entered the centre of the mould and poured molten cast iron down its length while the mould rotated. The spinning of the pipe caused the molten metal to be distributed evenly about the surface of the mould. Centrifugal casting also produced a stronger pipe due to differences in the microstructure produced by the two processes (Makar and Rajani, 2000).

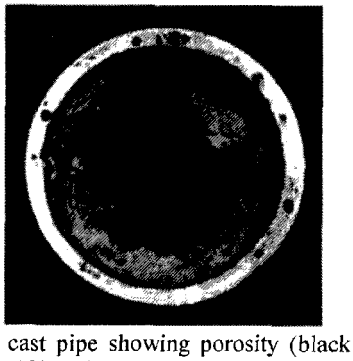


Figure 6. Pit cast pipe showing porosity (black dots on cut metal surface). (City of Toronto)

NRC has identified manufacturing flaws in both types of gray cast iron pipe. The more recent ductile iron pipe is also made by spin casting, but none of the ductile iron failures investigated by NRC has been due to manufacturing flaws. Porosity (Figure 6) is the most common manufacturing defect in pit cast pipe. It is produced by air being trapped in the metal as it solidifies. Air in pit cast pipe may have had to travel from the bottom of the pipe to the top to escape, providing much greater opportunities for entrapment than in spun cast gray iron pipe, where the air only needed to reach the inner wall of the pipe surface to escape. However, NRC has found smaller pores than those shown in Figure 6 (2 mm diameter as compared to 8-9 mm) in clusters in poorly manufactured spun cast pipe.

Inclusions are unintentional objects created in metals during manufacturing that are not part of the continuous fabric of the material (Figure 7). They weaken the pipe metal by acting as crack formers, reducing the total cross-section of metal in the pipe and producing stress concentrations. The inclusion shown was formed from iron oxide, but a more common inclusion is undissolved ferrosilicon. The latter material was a common means of adding silicon to cast iron, which lowers the melting point of the metal and makes it easier to cast. However, if the metal cools too quickly, the ferrosilicon will not completely dissolve, leaving behind a black, spherical inclusion.

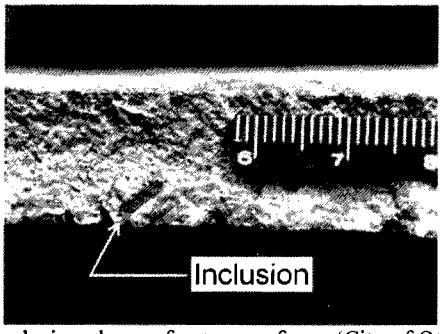


Figure 7. Inclusion along a fracture surface. (City of Ottawa)

Spun cast pipes generally appear to have fewer casting defects than pit cast ones. However, they do experience a variety of defects that can only be produced by the spin casting process. Figure 8 shows an example of a longitudinal surface defect. The particular pipe photographed here and in Figures 9 and 10 had numerous examples of this type of defect on its outer surface, which would have been in contact with the pipe mould. In some cases these defects were detached from the pipe surface as shown in Figure 8, while in others they appeared only as parallel lines on the pipe.

Figure 9 shows a cross-section of the pipe wall across one of these longitudinal flaws. Both the flaw material and the pipe itself are composed of cast iron. However, a noticeable pore is located directly below the flaw and an iron oxide boundary layer was identified between the flaw and the pipe wall. The presence of the boundary layer and the semi-circular shape of the flaw cross-section suggests that the flaw material solidified before the bulk of the pipe. The iron oxide layer was produced by contact with the air as the flaw metal cooled, while the elongated shape and the observed cross-section was produced by a combination of surface tension and the centrifugal "forces" produced by the spinning mould.

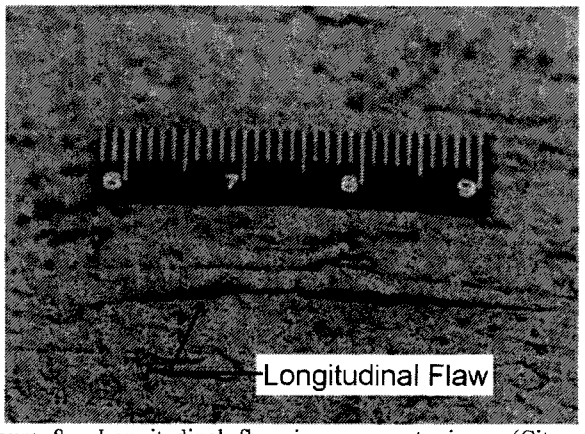


Figure 8. Longitudinal flaw in spun cast pipe. (City of Ottawa)

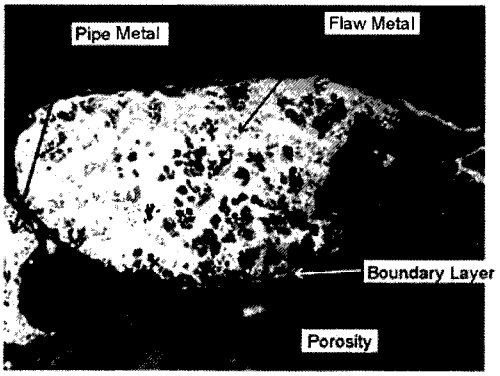


Figure 9. Cross-section of longitudinal flaw. (City of Ottawa)

The same pipe also had lumps of metal standing proud of the pipe surface (Figure 10). Normally molten metal would be spread out by the spinning process. The presence of the lumps suggests that the pipe metal was cooler than desirable during the casting process, allowing the lumps to solidify in place.

Changes in the pipe wall thickness can also weaken cast iron pipes. Pit cast pipes often have non-uniform thickness around the circumference of the pipe due to the inner sand core of the mould used to make the pipe being off-centre from the outer mould. These differences can be quite large, with a variation from 8 mm thickness at one side of the pipe to 14 mm at the other. Spun cast pipes do not

experience this type of problem due to the nature of the casting process, which evenly distributes the molten metal around the pipe wall. However the pipe shown in Figures 7 to 10 also had a wall thickness that varied along the length of pipe, changing from 18 mm to 15 mm over a 2 m distance. This amount of change was significant since the maximum operating pressure allowed for the pipe under the applicable standards could be significantly less for the thinner walled pipe. This latter type of manufacturing defect could only be produced by a reduction in the amount of metal per second flowing onto the pipe mould.

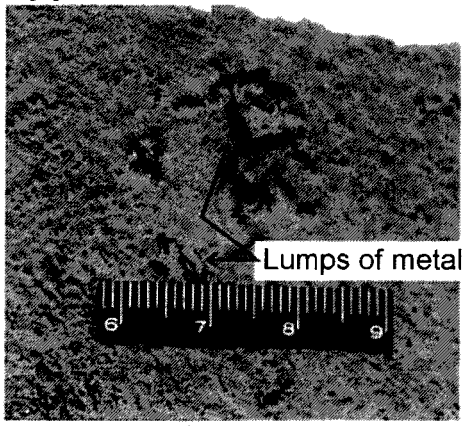


Figure 10. Lumps of metal on pipe surface. (City of Ottawa)

A final type of manufacturing flaw observed in a number of cast iron pipes is the presence of iron phosphide networks throughout the pipe metal (Figure 11). Phosphorus was added to molten cast iron in order to lower the melting point of the metal and its viscosity. This meant that lower casting temperatures could be used, reducing the total cost

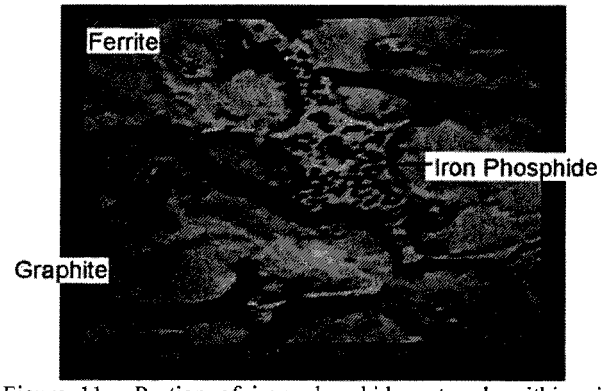


Figure 11. Portion of iron phosphide network within pipe metal. (City of Moncton)

of manufacture. However, the presence of phosphorus can also produce the type of network shown in Figure 11. This iron phosphide compound is even more brittle than gray cast iron and its presence weakens the pipe. Most modern steel and cast iron manufacturing attempts to minimise the phosphorus content, with specifications calling for a value that depends on the quality of the steel but is typically below 0.1 percent by weight (wt%) and often below 0.03 wt%. Gray cast iron pipes may have phosphorus contents as high as 0.9 wt% and are often in the range of 0.4-0.6 wt.%

4.3 *Excessive Forces*

Most observed pipe failures are due to a combination of some form of damage or manufacturing flaw and applied forces from the pipe's environment. However, it is also possible for pipes to fail without the presence of either corrosion pitting or a manufacturing flaw at the point of failure. In some cases damage elsewhere along the pipe may contribute to the failure. An example of this happening would be where the pipe has failed in tension due to ground movement forces being transferred to the pipe by corrosion pitting. In other cases the applied forces may cause the pipe to fail even without any previous damage to the pipe.

These failures may be particularly perplexing to the practitioner, since they have no apparent cause. In addition, this type of failure has sometimes been observed where there has been no apparent additional loading to the system (i.e. no truck loads, frost loads, changes in temperature or changes in water pressure that might have affected the pipe and caused the failure). Such an event may result in replacement of the failed pipe and little further analysis.

However, there is always a cause for pipe failures. If no defects or corrosion pits are found on the failed pipe, the most likely cause is that the forces applied to the pipe have exceeded its resistance capacity. These forces may have built up gradually over time and be difficult to detect, but their size and direction can be determined by the nature of the failure mode observed in the pipe. They are often produced by ground movements and may have originated at a significant distance from the failed pipe. Failure may occur at a change in pipeline direction at a thrust block, for instance, when the ground movement that caused the applied forces happened farther away along the line.

A major question related to this type of failure is whether the forces on the pipeline were relieved by the failure and the subsequent replacement process. If they were not, the pipeline should be assumed to be at a higher than normal risk of further failures. Further research is required to determine the best way of making this assessment. One part of the process is the establishment of the forces that were likely to be responsible for the failure itself. This determination will require investigating the failure mode, the mechanical strength of the pipe and also the manner in which the pipeline was designed. In some cases the resistance capacity of the line may have been overestimated by mistakes in the assump-

tions made about ground cover, maximum truck loads or maximum water pressure experienced by line. It is also possible that installation procedures that are now recognised as incorrect were used on early pipelines. An example of the latter problem was the use of wooden blocks under the pipe to raise it above the floor of the trench. This approach was later recognised to contribute to pipe failures due to forces being concentrated on the pipe at the blocks, rather than distributed along the length and width of the pipe by the bedding material. It is important to recognise, however, that failures due to excessive forces can also take place even when there are no errors in the design and installation of the pipeline.

4.4 *Human error*

Design problems are one type of human error that can contribute to pipeline failures. However, there are other practices during construction and after that can also promote or cause pipe failures. In particular, some types of corrosion induced failures have been identified as being due to poor installation or movement techniques. Figure 12 shows an example of a pipe that failed due to a large blow out of the side of the pipe. This pipe had a pair of very long corrosion pits that appear to have formed where the black coating on the pipe was scratched during installation. Some additional scratches could also be seen on the pipe. The coating is also seen on ductile iron pipe and is a natural iron oxide byproduct of the manufacturing process that provides some corrosion protection to the pipe. Both spun cast gray

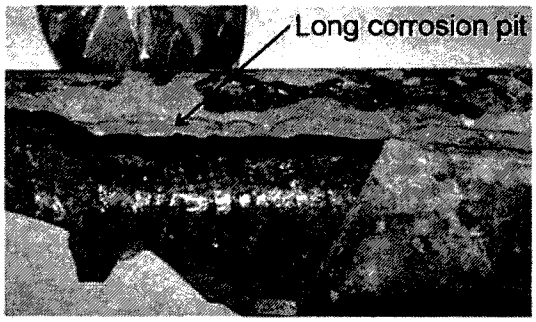


Figure 12. Elongated corrosion pits caused by scratching pipe. (City of Ottawa)

iron and ductile iron pipes have been observed to corrode without noticeable coating damage, but damage to the coating enhances the probability of significant corrosion in the damaged area. In the case shown in the figure, the long thin pits corroded to the point where the metal was paper thin at the bottom of the pit. A pressure surge caused the pipe to fracture along the pit, followed by a full blow out. Similar damage has been observed on ductile iron pipes from the City of Toronto. In this case an unpadded chain was placed around the pipe when it was being moved. Each link of the chain damaged the pipe coating, resulting in a series of corrosion pits located around the circumference of the pipe (see Figure 1 for a sketch of this failure).

Another common source of failures due to human error is third party damage. Excavations made on or near pipelines without accurate knowledge of their location frequently causes pipeline damage or failure (Figure 13). This type of failure is common to all buried utilities, including both pipelines and other services such as telephone and television cabling.

Figure 13. Dent and hole in ductile iron pipe due to third party damage. (City of Toronto)

Sometimes problems can be perpetuated through simply following a water utility's standard operating procedures. Figure 14 shows two pieces of a single pipe that experienced four distinct failures in the length shown. The back of the left pipe section was connected to the front of the right one by the clamp that is shown in the picture. Each of the failures was associated with corrosion pitting. These failures appear to have taken place over a significant length of time, with the response to the first three cases being to place a stainless steel clamp over the damaged area. The pipe was not removed until the very long corrosion pit on the left section developed.

An examination of the damage to the pipe makes it clear that it was located in a very corrosive environment. The stainless steel clamps held the pipe together, but did not prevent further corrosion in a nearby location. In fact, a number of pipe failures observed by NRC occurred next to previous failures covered by stainless steel clamps. It is possible that some aspect of the repair procedure itself may be responsible for the subsequent failures. More research is required to investigate this possibility.

This result suggests that alternate approaches to simple clamping for dealing with corrosion related failures may be desirable. One method used by some cities is to add a sacrificial anode to the pipe at the site of each failure. This should protect the pipe for the duration of the anode's life. The anodes can

also be checked and replaced if necessary on a scheduled basis, rather than through emergency repairs.

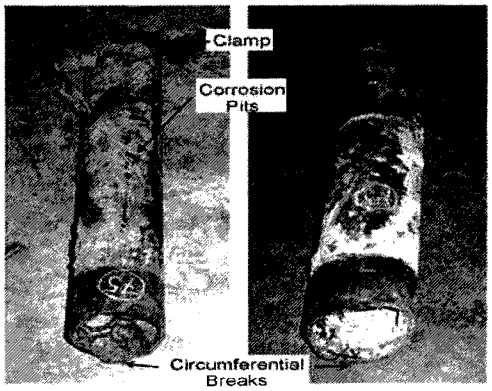


Figure 14. Multiple failures on same pipe. (City of Toronto)

5 MULTIPLE EVENT FAILURES

Until recently, most mechanical failures of gray cast iron pipe were assumed to have occurred in a single event, with the pipe cracking to the point of failure due to one incident of applied forces exceeding the strength of the pipe material. Recent work at NRC has shown that many circumferential and bell split type failures occur as a series of multiple events (Makar, 2000). In these cases the pipe cracks part way through and may start leaking water. If the damage is not detected, a second or even third cracking event may take place, with the process continuing until the pipe fails completely or is removed from service due to a leak detection campaign.

Figures 15 and 16 show two examples of multiple event failures. Their role in a pipe failure can be detected by carefully examining the fracture surface of the pipe. In the case of the pipe shown in Figure 16, only about 80% of the pipe circumference had been cracked through at the time it was removed from service. The intact circumference, labeled as region 3 in the figure, was broken in the laboratory using a stress testing machine. Examination of the entire fracture surface afterwards showed that two cracking episodes had taken place while the pipe was in use. Region 1 was covered with a relatively thick layer of corrosion products that had an orange colour and regions of gray material. The regions labeled 2 in the figure had a much thinner layer of corrosion product with a dark red colour. The gray colour of the graphite flakes that give gray cast iron its name could also be seen below the corrosion products.

Although the pipe in Figure 16 clearly shows that not all circumferential failures require complete cracking around the pipe, visual identification of different cracking episodes can be very subjective in nature. Further evidence for this phenomena is provided by elemental analysis of the fracture surface.

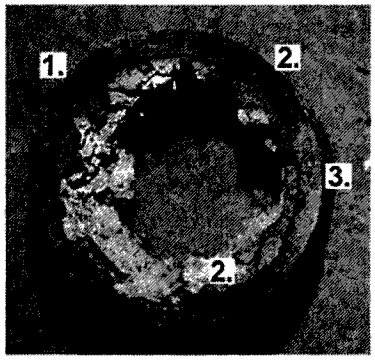


Figure 15. Multi-event circumferential failure. "1" indicates the first cracking event, "2" indicates the second cracking event and "3"indicates the region that was intact until broken in the laboratory. (City of Toronto)

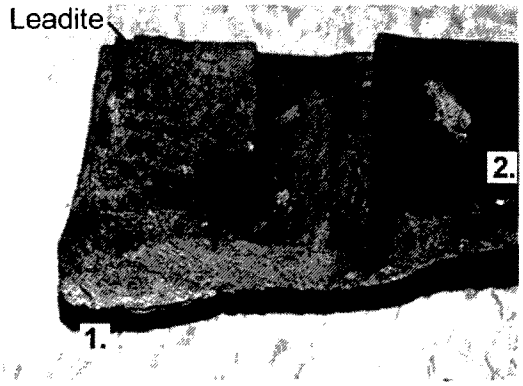


Figure 16. Multi-event bell splitting failure. "1" indicates the start of the first cracking event at a small corrosion pit while "2" indicates the start of the second cracking event. (City of Ottawa)

In the case of Figure 16 the visual examination showed evidence of two cracking episodes, with one region near the bell having thick corrosion products and an orange-gray colour and the other region closer to the end of the crack having thin corrosion products with a dark red colour. An elemental analysis shows the presence of a number of elements on both regions of the fracture surface that are not present in the pipe metal. These elements were therefore acquired from the surrounding soil. However, the region with thicker corrosion products showed the presence of sulphur, aluminum, potassium and a high quantity of calcium, while the region with the thinner layer of corrosion products showed considerably smaller amounts of the last three elements and no sulphur at all. This difference indicates that the fracture surface under the thicker layer had been exposed to the surrounding soil for a longer period of time than that under the thinner layer, providing

further evidence for a multi-event cracking process. Elemental analyses have been done for other fracture surfaces with similar results.

The cause of the multi-event fractures is unclear. Normally brittle fractures would be expected to propagate quickly across an entire object. More research, including both finite element modelling and fracture mechanics studies, will be necessary to completely understand this aspect of cast iron behaviour.

6 THE BATHGATE MAIN – A CASE STUDY

NRC was asked to conduct a failure analysis on a broken 410 mm water main in the summer of 2000 by the Regional Municipality of Ottawa-Carleton (now part of the City of Ottawa). This main had experienced a spiral failure (Figures 3 and 17) and appeared to have failed in a brittle manner. However, the Region's records showed the pipe as being ductile iron rather than gray cast iron. The unusual failure mode, the uncertainty in the records and the need to determine the vulnerability of the rest of the line led to the need for the failure analysis.

The sample delivered by the Region to NRC consisted of only half the failed pipe. In addition, a section of the pipe at the point where the crack likely initiated was missing. These missing sections of pipe meant that the exact cause of the failure could not be determined. However, it was possible to examine the rest of the pipe and determine its quality.

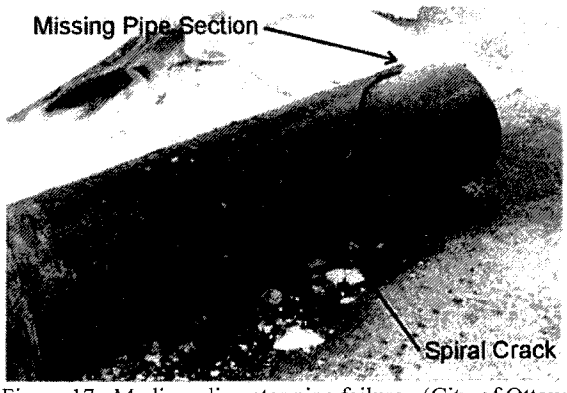


Figure 17. Medium diameter pipe failure. (City of Ottawa)

The first step in the examination was to cut up the pipe and expose the fracture surface. No evidence for a multi-event failure was seen, but the fracture surface did show a change in the direction of the fracture part way through the pipe (Figure 18). This change in the direction of the surface had not been seen in other pipes that had been investigated by NRC.

Subsequent investigation did not identify any significant areas of corrosion on the fracture surface or on the pipe in general. However, a large number of manufacturing defects were found. Numerous small pores were seen in the metal of the pipe and along the pipe surfaces. Each of the casting defects shown in Figures 7 to 10 were found on this pipe. As noted earlier, the longitudinal flaws in Figures 8 and 9 occurred frequently on the outer pipe surface. This pipe also experienced the change in wall thickness mentioned earlier.

As shown in Figure 9, the microstructure of the pipe was investigated in order to determine the type of pipe. The presence of graphite flakes in the metal, rather than spheres showed that it was gray cast iron. An elemental analysis confirmed that the pipe metal did not have the small amount of magnesium necessary to produce ductile iron. The microstructural analysis did show that the type and form of the graphite flakes in the pipe changed part way through the pipe wall. This change was responsible for the change in the fracture surface shown in Figure 18.

The mechanical properties of the pipe were also investigated, with five tensile tests and seven four point bending tests being conducted on samples from the failed pipe. Multiple tests have been found to be necessary due to the high variability of gray cast iron. Some pipes have shown a variation of as much as 100% between the weakest sample and the strongest (Rajani, Makar and McDonald, 2001). In this case the samples were all taken from sections of pipe without manufacturing defects. The tensile tests all showed pipe strengths above the 124 or 145 MPa called for by the two standards (ASA 1953, AWWA 1967) that may have been applicable to the manufacture of this pipe. However, one of the four point bending tests produced a modulus of rupture significantly below that allowed by either standard (224 MPa versus 276 MPa or 310 MPa). Six of the seven tests were below the 310 MPa standard.

Figure 18. Change in fracture surface along spiral crack. (City of Ottawa)

A second pipe was removed from the line to act as a control sample for the investigation. It did not show any of the manufacturing defects identified on the failed pipe. The mechanical tests conducted on the control pipe also showed values that were consistently above those required by the standards.

The analysis concluded that the failure was due to the manufacturing defects in the pipe. The inherent

resistance of the pipe to bending was marginal at best compared to the values required by the applicable standards. The frequency of the observed defects was such that there was a very high likelihood of one occurring at the failure site. The combination of a weak pipe material and an inclusion, longitudinal flaw or cluster of pores lowered the pipe's resistance capacity to point where the failure occurred.

7 CONCLUSIONS

Cast iron pipe failures are more diverse and complex than is usually appreciated by the water industry. Failure modes include not only corrosion blow outs and circumferential breaks, but also include longitudinal cracking, bell splitting, bell shearing and spiral cracking. The causes of failure go beyond corrosion and mechanical loading to include manufacturing defects and a variety of human factors. Many failures also occur as multiple events, rather than as a single cracking episode.

Understanding the nature and causes of pipe failures is important in making decisions about pipeline rehabilitation and replacement. Pipeline failures are normally unexpected and often produce emergencies. This is especially the case for medium and large diameter lines, which may supply water to large numbers of people. A water utility's major goal in resolving such a failure situation is naturally to prevent water damage to the area around the pipe and restore water supply as soon as possible. However, gathering the information and samples necessary to complete a failure analysis should be considered a necessary part of the repair process. Conducting an engineering analysis after a major pipeline failure is essential to determining the risk of a subsequent failure on the same line. The complex nature of pipeline failures and the inherent variability of gray cast iron pipes mean that the information about the pipe and its failure necessary for the engineering analysis can only be acquired by the failure analysis process.

ACKNOWLEDGEMENTS

Pipes analysed in this work were provided by the City of Toronto through the Civil Engineering Department of the University of Toronto, by the Regional Municipality of Ottawa-Carleton (now part of the City of Ottawa), and the City of Moncton. The assistance of Professor Jeffrey Packer and Micheal Seica of the University of Toronto in providing access to the City of Toronto pipes is gratefully acknowledged. The elemental analysis in this paper was carried out by Jeffrey Fraser, Ed Quinn and Jim Margeson, all employees of the National Research Council Canada. Figures 7 to 10 were photographed by Jim Margeson.

REFERENCES

ASA (American Standards Association), 1953. American Standard Specifications for cast-iron pipe centrifugally cast in metal molds, for water or other liquids. A21.6-1953/AWWA C106-53

AWWA (American Water Works Association) (1975). USA Standard for Thickness Design of Cast-Iron Pipe. USAS A21.1-1967/AWWA H1-67, Denver, Colorado.

De Rose, P.J. and Parkinson, R.W., 1985, Corrosion of Ductile Iron Pipe, Report TR241, WRc Engineering, Water Research Centre, Swindon, United Kingdom.

Fitzgerald, J. H., 1968, Corrosion as a Primary Cause of Cast-Iron Main Breaks, Journal of the American Water Works Association, vol. 60., no. 8, p.882.

Kirmeyer, G. J.,Richards, W., and Smith, C.D., 1994. An Assessment of Water Distribution Systems and Associated Research Needs, American Water Works Association Research Foundation, Denver, Colorado.

Makar, J.M., 2000, A preliminary analysis of failures in grey cast iron water pipes, Engineering Failure Analysis 7, pp. 43-53.

Makar, J.M. and Rajani, B.B., 2000, Grey Cast Iron Pipe Metallurgy, Journal of Materials in Civil Engineering, vol. 12, no. 3, pp. 245-253, August.

Rajani, B.B., Zhan, C. and Kuraoka, S., 1996. Pipe-soil interaction analysis of jointed water mains., Canadian Geotechnical Journal, Vol. 33, No. 3.

Rajani, B.B., Makar, J.M. and McDonald, S., 2001, The mechanical properties of grey cast iron mains, to be submitted to the Journal of Construction Materials

Romanoff, M., 1964, Exterior Corrosion of Cast-Iron Pipe, Journal of the American Water Works Association, vol. 56, no. 9, p. 1129.

Talbot, A.N., 1926, Strength Properties of Cast Iron Pipe Made by Different Processes as Found by Tests, Journal of the American Water Works Association, Vol. 16, July, pp.1-44.

Zamanzadeh, M., et. al., 1990, Analysis of Failures in Water Mains, Materials Protection, August, pp. 50 – 53.

FKS-15

Western Group Rate Case

Exhibit FKS-15

National Research Council Canada | Conseil national de recherches Canada

NRC · CNRC

Failure conditions of asbestos cement water mains in Regina

Hu, Y.; Hubble, D.W.

NRCC-48148

A version of this document is published in / Une version de ce document se trouve dans :
Canadian Society of Civil Engineering (CSCE) 33rd Annual Conference,
Toronto, Ontario, June 2-4, 2005, pp. 1-10

http://irc.nrc-cnrc.gc.ca/ircpubs

1st CSCE Specialty Conference on Infrastructure Technologies, Management and Policy
1ere conférence spécialisée sur la gestion, les politiques et les technologies des infrastructures

Toronto, Ontario, Canada
June 2-4, 2005 / *2-4 juin 2005*

FAILURE CONDITIONS OF ASBESTOS CEMENT WATER MAINS IN REGINA

Y. Hu[1] and D.W. Hubble[1]
1. Centre for Sustainable Infrastructure Research, Institute for Research in Construction, National Research Council Canada, Regina, SK, Canada

ABSTRACT: Approximately two thirds of the water mains in the City of Regina are asbestos cement (AC) pipes. These pipes are experiencing more and more failures in recent years and account for almost all of the water main breaks in the city. The AC water main failures, along with the failure of other types of water mains in general, are a result of various factors, some of which are site specific. To assess the condition and identify the factors that significantly influence the breakage of AC water mains, the historical failure data for AC water mains in the City of Regina have been collected, along with their corresponding working environments, including soil type, water quality, weather, etc. The AC water main break data were analyzed for correlation between pipe breakage and all known physical, environmental and operational factors. The predominant factors that influence the AC pipe breaks were identified. It was observed that pipe age, diameter, climate, soil and construction and repair methods all influence the condition of the AC water mains in Regina, with climate and soil conditions being the two critical factors. Water quality is not a major determinant of the AC water main condition for the city. The observations will serve as a basis for further research on the failure mechanisms of the AC pipes, which is essential for the performance prediction of these water mains and, therefore, the management of the city's AC water main assets.

1. INTRODUCTION

In the City of Regina, approximately 531 km, or two-thirds, of the water mains are asbestos cement (AC) pipes. These pipes are experiencing more and more failures in recent years and account for almost all of the water main breaks in the city. In many municipalities, AC pipes are replaced whenever their performance and condition warrant extensive repairs. This is not an option for the City of Regina because of its large inventory of AC water mains and funding constraints. To ensure that the city's administration can manage its AC water main assets to continue to provide an adequate supply of safe water in a cost-effective, reliable and sustainable manner, it is essential that a clear understanding be developed of AC pipe failure conditions and the mechanisms behind the failures.

The failure conditions and their corresponding mechanisms are dependent on a number of factors. These factors may be grouped into three general categories: (a) physical characteristics of the pipes themselves (e.g. flexural strength), (b) the environments in which the pipes are working (e.g. climate, soil type, groundwater properties, water table), and (c) operational characteristics (e.g. water quality, operation and maintenance, repair or replacement procedures) (NRC 2002; Rajani and Kleiner, 2001). The interplay of these factors determines the failure processes and modes. However, the role played by each factor may vary due to site-specific conditions. Therefore, identification of factors contributing to the occurrence of water main failures in a given site should be the first step towards understanding of the failure mechanisms.

Previous studies on the performance of AC water mains have stemmed from two concerns. One was a health concern related to the release of asbestos fibres into the drinking water due to chemical attack on the asbestos cement material and the erosion of the internal surface of the pipe by the water. It was found that in some environments, AC pipe materials are subject to damage due to various chemical processes that either leach out the cement material or penetrate the pipe wall to form products that weaken the cement matrix (Mordak and Wheeler 1988). Nebesar (1983) did a comprehensive review of these "corrosion" mechanisms in AC pipes. A number of chemical agents were identified including acids, sulphates, magnesium salts, alkaline hydroxides, ammonia and soft water. Some organic compounds were found to be "corrosive" as well. Pits and holes on pipe walls are indicators of corrosion. External corrosion of AC pipes follows the same principles as internal corrosion, i.e., pH, alkalinity, sulphates contained in the soils or groundwater will attack AC pipes (Jarvis 1998).

The other concern was related to the asset management of AC water mains, which requires a condition assessment of the pipes for determining the remaining service life and improving the service condition. AC water mains were observed to deteriorate with pipe age and a linear relationship was identified between the breakage rate and the pipe age (Kettler and Goulter 1985). It was also noted that the breakage rate of AC pipe was influenced by pipe diameter, with a lower breakage rate for larger diameter (Guan 1995, Mordak and Wheeler 1988), which was attributed to the thicker wall and higher bending moment resistance associated with larger diameter pipe (Mordak and Wheeler 1988). The greater wall thickness provided an inherently more robust pipe, which was not as likely to fail structurally as a result of chemical attack and external loading (Kettler and Goulter 1985).

AC water mains may also fail due to other operational, environmental and physical factors. For example, it was observed by Mordak and Wheeler (1988) that the distribution of failures through the year has been fairly random for areas where sandy/gravel soils commonly occur, whereas in areas with cohesive clay soils, most failures occur during the dry summer months. Cohesive clay soils are also associated with high incidence of circumferential fractures, which are commonly related to bending stresses. Construction/repair methods may also contribute to the failure of AC water mains (Mavin 1996; Guan 1995). Pipe breakage is more likely to occur when the environmental and operational stresses act upon pipes whose structural integrity has been compromised by corrosion, degradation, inadequate installation or manufacturing defects (Rajani and Kleiner 2001).

All the aforementioned studies show that AC water main failure, along with the failure of other types of water mains in general, is a result of various factors, some of which are site specific. To assess the condition and identify the factors that significantly influence the breakage of AC water mains in the City of Regina, the historical failure data of AC water mains in the city has been collected and analyzed, along with their corresponding working environments, including soil type, water quality, weather, etc. In this paper, the information was evaluated to determine the failure conditions of the AC water mains in the city. The predominant factors that contribute to the AC pipe failure were identified.

2. REGINA'S WATER DISTRIBUTION SYSTEM

2.1. History of the Water Distribution System

Regina, Saskatchewan, Canada, was founded in 1903 and had a population of around 200,000 in 2003. The earliest construction of the water distribution system was in 1904. Cast iron (CI) pipes were first used in the water distribution system and were predominant until the 1940s. The use of asbestos cement pipes was adopted in the middle 1940s and became predominant in the 1950s and 1960s. Since they were considered by the city to have better performance than CI pipes, AC pipes were used in all the new subdivisions, as well as to replace failed CI pipes.

In the early 1980s, health concerns with the asbestos fibres and the wide acceptance of polyvinyl chloride (PVC) pipe by the water works industry changed the landscape of the water distribution system in City of Regina. Since then, PVC pipes have been used in the construction of new developments and in the replacement of CI and AC pipes.

Besides CI, AC and PVC, steel pipes were also used. Steel pipes have a good service performance but are more costly. Most steel pipes in Regina are used for large diameter (> 500 mm) transmission mains. Other materials that were used to a much less extent are polybutylene and concrete.

Currently, Regina has approximately 753 kilometres of water mains within the city limits. These mains vary in size from 100 to 600 mm in diameter. With about 531 km in service, AC comprises about two-thirds of the total length of the pipe network. The length of AC pipe in service has not changed significantly since 1986, except for small reductions due to replacement during repairs. The pipe sizes for asbestos cement water mains in Regina include 100, 150, 200, 250, 300 and 400 mm. The 150 and 200 mm pipes comprise a large percentage of the system. There are only a few sections of 100 and 400 mm pipes.

2.2. Data Collection

The AC pipe repair information used in this study was acquired mainly from the Engineering and Works Department of the City of Regina. The original records show that the earliest installation of AC pipe was in 1945. With the development of the city and the construction of new residential, commercial and industrial areas, the water distribution system expanded. The dates of pipe construction, repair and replacement were recorded and are available for most streets. However, these records are not complete and some data are missing.

The data recorded on the water main repair report sheets include leak location, dates received and repaired, pipe material, size, leak type, repair material and length and connection information. Some particular situations were noted in a Remarks portion of the repair report. The installation year for each AC water main can be found on the Water Main Distribution System Map of the City of Regina. However, some AC pipes have been replaced with PVC pipes since the mid-1980s and the installation year data for the original AC water mains were not available.

3. CONDITIONS OF AC WATER MAINS

3.1. Installation of AC Water Mains

Figure 1 shows the length of AC pipes installed each year from 1945 to 1986. The annual installation lengths shown in this figure represent the AC water mains currently in service. Three peak periods can be identified in Figure 1. The first one is from 1953 to 1959 with around 20 km of AC water mains installed each year. The second one is from 1964 to 1966 with about the same length of AC pipes installed annually as the previous peak. The third peak period lasted from 1972 to 1980 with the highest annual installation length of 42.8 km of AC water mains in 1976 falling in this period.

The annual installation length for the period between 1983 and 1986 was reduced gradually to zero when use of PVC was fully adopted. It should be noted that the annual installation lengths may not be accurate, especially for the earlier period, because of water main repairs. Some AC water mains are likely to have been replaced during these programs and their records removed from the City's database.

3.2. History of AC Failure

The service condition of AC pipes is evaluated in terms of the number of breaks of water mains based on the available data collected by the City of Regina. The term "break" in this study is taken to correspond to an entry on a water main repair report sheet and constitutes a single repair event. The AC water main breaks during the period from 1994 to 2003 were analyzed and a total of 911 breaks were recorded for this period. Figure 2 shows the annual number of breaks. The plot indicates that the number of breaks has, in general, been increasing steadily. Also included in this figure is a fitted exponential curve. The good correspondence (the square of the correlation coefficient, R^2, =0.83) between the fitted curve and the historic data points indicates that the number of breaks is increasing at an accelerated (exponential) rate and the overall system condition is deteriorating.

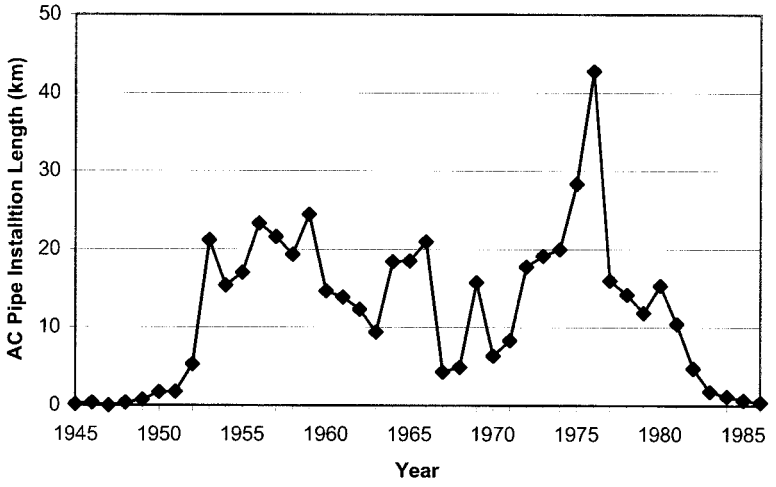


Figure 1. Annual installation length of AC water mains (1945 -1986)

The historic data plot shows that two peaks of breakage occurred in 2001 and 2003. The abnormal weather in these two years might be the major factor inducing more pipe breaks. In 2001, a record rainfall was noted in July followed by extremely low rainfall in August and September. City staff has reported that the higher number of breaks in 2003 might have been due to the high temperature and dry weather during the summer period of this year.

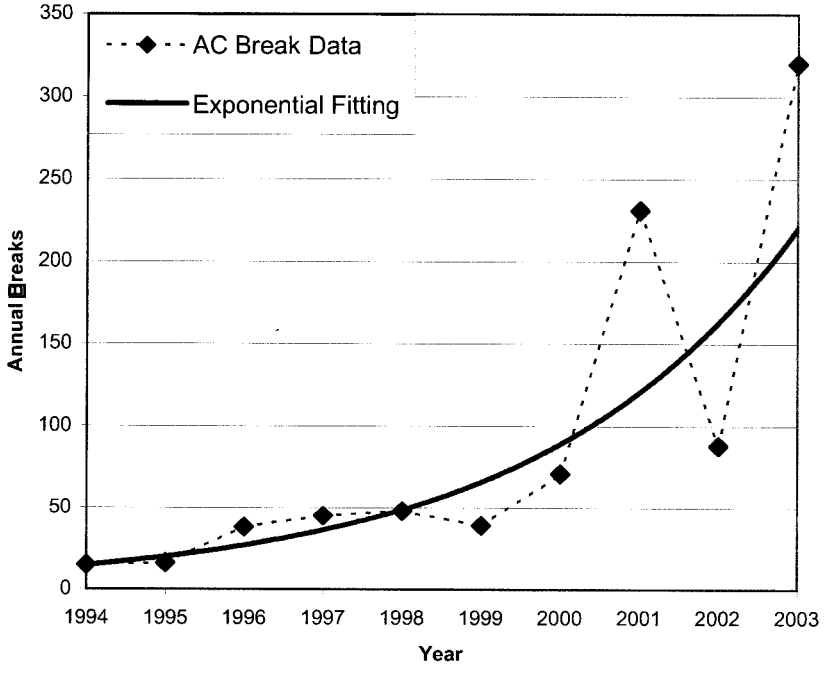


Figure 2. Break history of AC water mains (1994~2003)

3.3. Monthly Failure Conditions

The monthly breakage numbers are shown in Figure 3 for AC water mains in Regina. There are three curves, which represent the monthly break numbers for 2001, 2003 and the average number for the 10-year period from 1994 to 2003, respectively. The monthly break numbers for 2001 and 2003 are also included for comparison. This figure shows that high breakage rates occurred in August and September and sometimes in February and March. The highest breakage of water mains occurred in September.

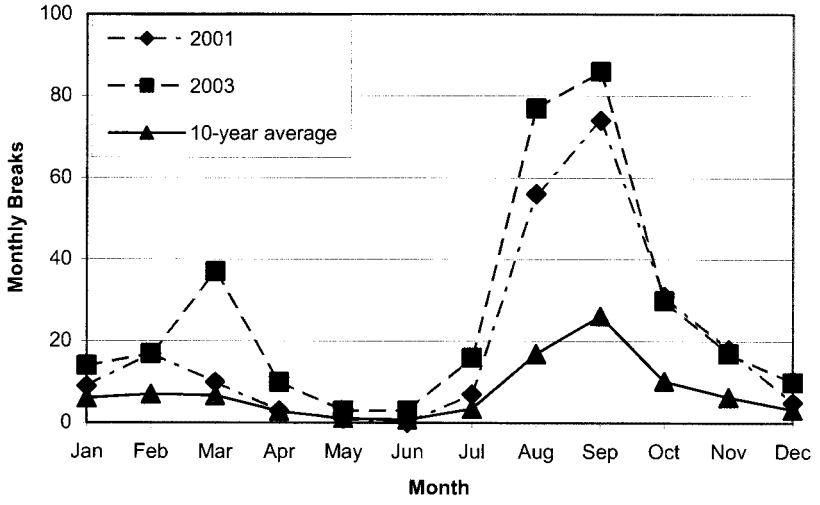


Figure 3. Monthly breaks of water mains in Regina fro 2001, 2004 and the 10-year average (1994 to 2003)

The higher breakage in the summer season for both normal and off-normal years may be attributed to different factors. The high temperature combined with relatively low precipitation will desiccate the soil, inducing shrinkage and, consequently, differential movement, uneven bending support and/or uneven loading conditions. More traffic in summer may also impose extra loading on the buried pipes. The second peak for the two off-normal years may be related to extended periods of cold temperatures in these particular winter seasons. If a decrease in the ambient temperature is sustained, the frost will penetrate deeper into the ground, causing increased frost loads on the buried pipes, even though they are buried at some distance below the maximum frost penetration depth (Bahmanyar and Edil 1983).

3.4. Spatial Failure Conditions

To assess the system failure condition in the entire city, the breakage distribution for the AC water mains in the city was investigated. Figure 4 presents the breaks of AC pipes during a one-year period in 2003. It can be seen from Figure 4 that the water main breakage was not evenly distributed within the city. The breakage of AC pipe was most serious in the southern areas. Other areas that have a high concentration of AC pipe breakage include the central, central west and northern parts of the city. These areas were the earliest ones constructed using AC pipes. The southeast and northwest areas were developed since the 1980s and PVC pipes were used.

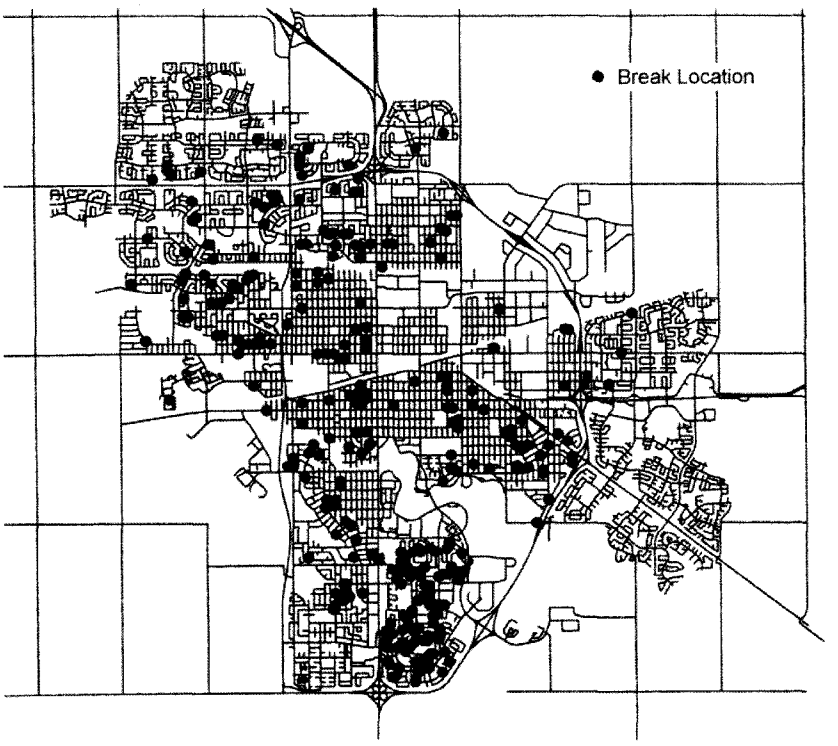


Figure 4. Water main breaks in 2003

There are a few factors that may account for the spatial pattern of AC water main breaks as shown in Figure 4. In addition to the earlier development period and greater age of the pipes, the pipe length per unit area in these areas may also be a factor, i.e., the areas with greater pipe length per unit area may have more breaks. The higher density of pipe breakage in the southern area may be affected by low elevation and soil conditions as well.

3.5. Failure Modes

All breaks are divided into five categories: longitudinal, circumferential, hole-in-main, pinhole and other. Although hole-in-main and pinhole are both primarily due to chemical attack, their failure modes are different in that a hole-in-main failure requires internal pressure or external loading whereas pinhole fails due to chemical attack only. A few breaks are characterized as "other", which include everything from joint failure to subsequent leakage at a clamped repair location. Table 1 lists the different failure modes and their corresponding percentages. Among the 911 breaks from 1994 to 2003, circumferential breaks comprise the predominant failure mode (90.9%).

Table 1. Failure modes and their percentage

Failure Modes	Longitudinal	Circumferential	Hole-in-main	Pinhole	Other
Breaks	5	828	7	2	69
Percentage	0.5%	90.9%	0.7%	0.2%	7.6%

This table indicates that corrosion is not a big problem for the AC water mains, as the breaks due to corrosion (hole-in-main and pinhole) account for less than 1% of the total breaks for this period. Because the longitudinal break number is very small, internal water pressure, soil stresses and other circumferential loading (e.g., traffic) also do not have a major influence on the breakage of AC pipe. The high rate of

circumferential failure suggests that axial bending (or beam action) is the predominant loading condition leading to failure.

3.6. Failure Pipe Size

The pipe breakage for different pipe sizes was also analyzed. Table 2 summarizes the break numbers of AC water mains for the four major pipe sizes (150, 200, 250 and 300 mm diameter) during the 10 year period, 1994 to 2003. Table 2 shows that most repair work was related to the 150 mm pipes and more than 94% of the breaks occurred in the 150 and 200 mm pipes. The City of Regina provided the 1993 percentages of the four pipe sizes: 62.4%, 21.1%, 10.7% and 5.8%, respectively (Guan 1995). Based on this information. When converted to the number of breaks per unit length (km) per year for AC water mains (Table 2) the break rate decreases with increased pipe size. This finding agrees with that of previous researchers, e.g., Mordak and Wheeler (1988), among others. For Regina, the rate for 150 mm pipes (0.22 breaks per km per yr) is nearly double the rate for 200 mm pipes (0.13 breaks per km per yr), which is nearly 4 times the rate for 250 and 300 mm pipe (about 0.04 breaks per km per yr).

Table 2 Number of breaks of various diameter pipes (1994-2003)

Diameter (mm)	150	200	250	300	Others*	Total
No. Breaks	719	149	20	14	9	911
Percentage	78.9%	16.4%	2.2%	1.5%	1.0%	100%
Breaks/km/year	0.215	0.132	0.035	0.044		

* Others include 100 mm, 400 mm and unknown pipe sizes (not recorded)

The reasons for the tendency for decreasing pipe breakage with increasing pipe diameter may be attributed to higher bending moment resistance associated with larger diameter pipes, as suggested by Mordak and Wheeler (1988). A greater diameter pipe with a larger moment of inertia will have lower bending stresses in the pipe if the external loading condition is the same and, therefore, will have less possibility of circumferential failure. A large wall thickness associated with a larger diameter pipe may not be important because chemical attack related breaks were only a small percentage of total breaks.

4. DISCUSSION

In the previous section, the failure conditions of AC water mains in the City of Regina were analyzed and the possible factors causing the failures were also discussed. Pipe age, size, climate and soil conditions were cited as possible factors which may influence the AC pipe conditions and cause them to break. These factors, along with other possible factors identified during the repair records review and field observations at repairs performed in the summer and fall of 2004, are discussed in this section.

4.1. Climate

Climate appears to be one of the most important factors contributing to the observed AC water main failure patterns. Two peaks in the historic data plot (Figure 2) are all related to off-normal climate conditions in 2001 and 2003, respectively. The higher number of breaks in 2003 corresponds to a hot summer with a long dry period. Abnormal weather was also observed in 2001, with a record rainfall in July followed by extremely low rainfall in August and September. The cyclic pattern of the monthly pipe breakage, as illustrated in Figure 3, may also be attributed to the seasonal cyclic pattern of climate changes in this region.

The summer season in Regina usually sees high temperatures and relatively low precipitation, especially in August and September. During these dry months, soil moisture is depleted due to evapotranspiration. A reduction in moisture content will result in shrinkage of the cohesive clay soils that are predominant within the Regina region and cause loading of the buried pipes. Additionally, the drying of the clay may reduce

the attenuation of imposed traffic and other loads, leading to higher loads transmitted to the pipes. The relative effect of these factors in contributing to the high incidences of breaks in summer, especially those in 2001 and 2003, requires further study.

Figure 3 also shows that a second peak in pipe break number occurs during the coldest period of the year for both of the abnormal years. This phenomenon has been observed by many researchers, including Rajani and Zhan (1996) and Selvadurai and Shinde (1993). It has been attributed to increased earth loads on the buried pipes due to freezing and expansion of the water in the ground. The process involves not only the water near the freezing front (0°C isotherm), but also the moisture around the front through migration towards the freezing front (Shah and Razaqpur 1993). A loss in moisture, as discussed previously, will further worsen the environment of water mains by causing soil movement around the pipes. In addition, a decrease in temperatures external to the pipe during the winter season will cause an increase in pipe tensile stress (Zhan and Rajani 1997). The very cold temperatures in the winter season of 2001 and 2003 may have contributed to the second peak of breaks that occurred in these two years.

4.2. Soil

The clay soil in the Regina region is a Montmorillonite type clay and consequently has high rates of volumetric shrinkage and expansion due to changes in moisture content. The change in soil volume will result in soil movement, which, in turn, induces additional stress on buried pipes. The soil movement may cause these stresses through different mechanisms, such as non-uniform bedding support and differential settlement. Since non-uniform soil bedding support or differential soil settlement is typically related to axial bending or beam action, it is expected that bending-related failures will be significant, especially during the period when greater soil moisture change occurs. The high incidence of circumferential failures (Table 1) and the large proportion of failures on small diameter mains (Table 2) are consistent with such external loading imposing bending stresses on the pipes.

Besides climate (temperature and precipitation), other factors may also cause change in moisture content, including water uptake by vegetation (e.g., roots of large trees), pipe leakage and other activities, such as pipe repairs.

4.3. Corrosion

In general, the water transported inside the pipes and the external soil and ground water conditions can influence the condition of asbestos cement pipes. The total breaks due to corrosion (Hole-in-main and Pinhole, as presented in Table 1), represent only 1 percent of the total number of failures, indicating that corrosion is not an important factor in AC water main failure in Regina. The non-corrosive environment was confirmed by exhumed AC water mains showing smooth internal surfaces even after 50 years in service.

4.4. Pipe age

The annual break curve of AC water mains (Figure 2) indicates that the system condition is deteriorating with time, especially in recent years. Since all the impacts induced by the physical, environmental and operational factors will accumulate with time, it is expected that more breaks will occur with increased pipe age. Therefore, the age of water mains is expected to be a overall factor affecting pipe breakage. However, the actual mechanisms behind the age effect have not been separately evaluated and these factors require further study.

4.5. Other factors

Other factors may include construction specifications and practices, operating pressures, manufacturing processes, traffic, etc. For example, the variable stresses due to traffic loading may induce pipe breakage by fatigue action. The increased breaks in August and September may also be due to the increased traffic volume in the summer season.

5. SUMMARY AND CONCLUSION

The historical failure data for asbestos cement water mains in the City of Regina were analyzed for the period from 1994 to 2003 to assess the condition and identify the factors that significantly influence the breakage of these water mains. The failure data suggest that the condition of the AC water mains in the City of Regina is deteriorating, with the number of failures increasing annually at an exponential rate during the 10-year period. Years 2001 and 2003 have recorded the two highest water main break numbers in history, due to particularly abnormal climate conditions in these two years. Most of the breaks occurred during the dry summer months and the cold winter months. Circumferential breakage was the predominant failure mode.

Uneven spatial and temporal patterns of AC water main breaks in the city were also observed. Pipe breakage was concentrated in a few subdivisions such as the central, central-west, northwest and southern areas. Water quality was not found to be an important factor in terms of pipe corrosion.

The primary causes behind the AC water main break patterns are attributed to the properties of the Regina clay and the local climate. Regina clay has a very high swelling and shrinkage potential upon moisture change. The high expansive characteristics of Regina clay coupled with a reduction of soil moisture content in summer contributes to the high incidence of pipe breaks in summer seasons and the break peaks in the driest years. Frost load and temperature change may have contributed to the relatively small peaks in breakage noted during the winter months.

Pipe diameter, age and other construction specifications and practices are also important factors when the pipe failure patterns in Regina were analyzed. These factors may influence the pipe failure patterns themselves and the effect may become more severe by combining with particular soil and climate factors. Further study of the contributing factors identified in this study will lead to a better understanding of the failure mechanisms, which is essential for the performance prediction of these water mains and, therefore, the management of the city's AC water main assets.

6. ACKNOWLEDGMENTS

The authors acknowledge the help provided by Mr. Shawn Koroluk and Mr. Brian Scherle of the City of Regina Engineering and Works Department during the data collection. The data collection and analysis by engineering student assistants, Mr. Williams Gibbons, Mr. Paul Ekberg and Ms. Alexis MacDonald is also appreciated.

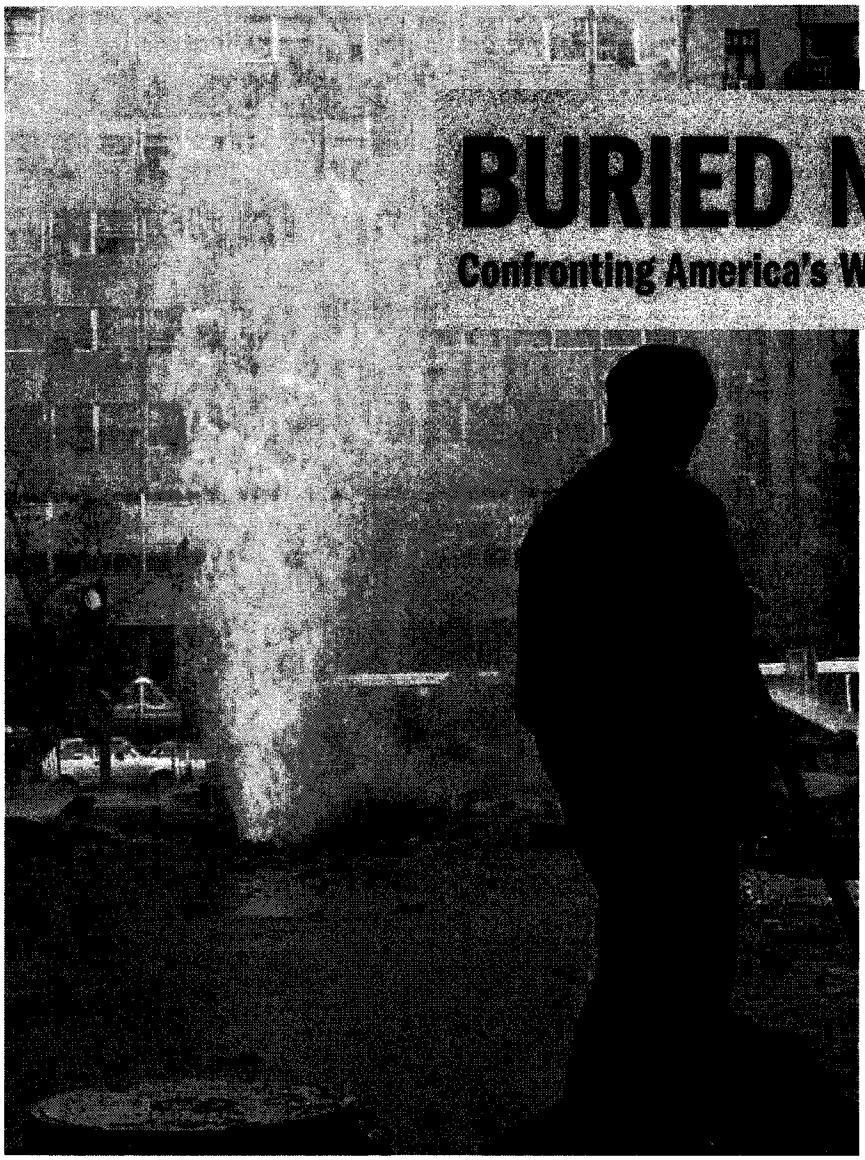
7. REFERENCES

1. Bahmanyar, G.H. and Edil, T.B. 1983. Cold Weather Effects on Underground Pipeline Failures, *Proceedings of the Conference on Pipelines in Adverse Environments II*, San Diego, CA, USA, 2:579-593.
2. Guan, X. 1995. *Condition and Replacement of Regina's Water Distribution System*, M.Sc. Theses, University of Regina, Regina, SK, Canada.
3. Jarvis, B. 1998. *Asbestos-Cement Pipe Corrosion – Interim Report*, Customer Services Division, Water Corporation, Western Australia, Australia.
4. Kettler, A.J. and Goulter, I.C. 1985. An Analysis of Pipe Breakage in Urban Water Distribution Network, *Canadian Journal of Civil Engineering*, 12:286-293.
5. Mavin, K. 1996. *Predicting the Failure Performance of Individual Water Mains*, Research Report No. 114, Urban Water Research Association of Australia, Australia.
6. Mordak, J. and Wheeler, J. 1988. *Deterioration of Asbestos Cement Water Mains, Final Report to the Department of the Environment*, Water Research Center, Wiltshire, UK.
7. Nebesar, B. 1983. *Asbestos/Cement Pipe Corrosion: Part 2 – Review of Recent Work on the Causes of Pipe Degradation and on Possible Improvements*, CANMET Report 83-17E, Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, Ottawa, Canada.

8. NRC 2002. *Deterioration and Inspection of Water Distribution Systems – Best Practice*, National Research Council of Canada, Ottawa, Canada.
9. Rajani, B.B. and Kleiner, Y. 2001. Comprehensive Review of Structural Deterioration of Water Mains: Physically Based Models, *Urban Water*, 3:151-164.
10. Rajani, B.B. and Zhan, C. 1996. On the Estimation of Frost Loads, *Canadian Geotechnical Journal*, 33:629-641.
11. Selvadurai, A.P.S. and Shinde, S.B. 1993. Frost Heave Induced Mechanics of Buried Pipelines, *Journal of Geotechnical Engineering*, 119:1929-1951.
12. Shah, K.R. and Razaqpur, A.G. 1993. A Two-Dimensional Frost-Heave Model for Buried Pipelines, *International Journal for Numerical Methods in Engineering*, 36:2545-2566.
13. Zhan, C. and Rajani, B.B. 1997. Estimation of Frost Load in a Trench: Theory and Experiment, *Canadian Geotechnical Journal*, 34:568-579.

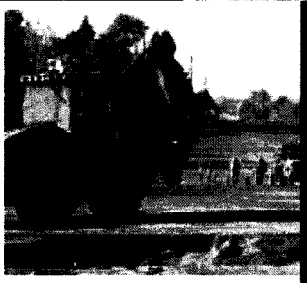
Western Group Rate Case

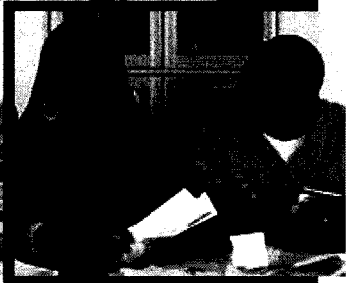
Exhibit FKS-16



BURIED NO LONGER:

Confronting America's Water Infrastructure Challenge





American Water Works Association

The Authoritative Resource on Safe Water®

Acknowledgments

This report was developed by the American Water Works Association under the direction of its Water Utility Council, through Stratus Consulting in Boulder, Colorado. Significant portions of the analyses described in this report were initiated or developed by John Cromwell, who unfortunately passed away before this project was completed. John was a true visionary, a wonderful friend and colleague, and an ardent believer in promoting sound management of water system infrastructure. We hope this report does proper service to John's intent, integrity and passion. Special recognition is also due to Bob Raucher, who completed the work with great attention to detail, patience and outstanding professionalism.

Haydn Reynolds is the developer of the Nessie Model and managed all the empirical investigations in this report. His continued engagement in the development of this report has been exemplary, as has been his willingness to address the many questions involved in the transition of the final report preparation from John Cromwell to Bob Raucher and others at Stratus Consulting. Finally, but not least, a number of AWWA utility members did significant work on this project, including Dave Rager (who chairs the Water Utility Council), Mike Hooker (who was WUC chair when the report was initiated), Aurel Arndt (who chairs the advisory work group on this project), and Joe Bella, John Sullivan, Richard Talley, Robert Walters, and Dave Weihrauch, all of whom made significant contributions as members of the advisory work group.

Project Funding

Funding for this project was provided by the Water Industry Technical Action fund (WITAF). WITAF is funded through AWWA organizational member dues. It supports activities, information, and analysis to advance sound and effective drinking water legislation, regulation and policy.

Introduction. A new kind of challenge is emerging in the United States, one that for many years was largely buried in our national consciousness. Now it can be buried no longer. Much of our drinking water infrastructure, the more than one million miles of pipes beneath our streets, is nearing the end of its useful life and approaching the age at which it needs to be replaced. Moreover, our shifting population brings significant growth to some areas of the country, requiring larger pipe networks to provide water service.

As documented in this report, restoring existing water systems as they reach the end of their useful lives and expanding them to serve a growing population will cost at least $1 trillion over the next 25 years, if we are to maintain current levels of water service. Delaying the investment can result in degrading water service, increasing water service disruptions, and increasing expenditures for emergency repairs. Ultimately we will have to face the need to "catch up" with past deferred investments, and the more we delay the harder the job will be when the day of reckoning comes.

In the years ahead, all of us who pay for water service will absorb the cost of this investment, primarily through higher water bills. The amounts will vary depending on community size and geographic region, but in some communities these infrastructure costs alone could triple the size of a typical family's water bills. Other communities will need to collect significant "impact" or development fees to meet the needs of a growing population. Numerous communities will need to invest for replacement **and** raise funds to accommodate growth at the same time. Investments that may be required to meet new standards for drinking water quality will add even more to the bill.

Although the challenge to our water infrastructure has been less visible than other infrastructure concerns, it's no less important. Our water treatment and delivery systems provide public health protection, fire protection, economic prosperity and the high quality of life we enjoy. Yet most Americans pay less than $3.75 for every 1,000 gallons of safe water delivered to their taps.

This report demonstrates that as a nation, we need to bring the conversation about water infrastructure above ground. Deferring needed investments today will only result in greater expenses tomorrow and pass on a greater burden to our children and grandchildren. It's time to confront America's water infrastructure challenge.

The Era of Infrastructure Replacement. More than a decade ago the American Water Works Association (AWWA) announced that a new era was dawning: the replacement era, in which our nation would need to begin rebuilding the water and wastewater systems bequeathed to us by earlier generations. Our seminal report–*Dawn of the Replacement Era*–demonstrated that significant investments will be required in coming decades if we are to maintain the water and wastewater systems that are so essential to our way of life.

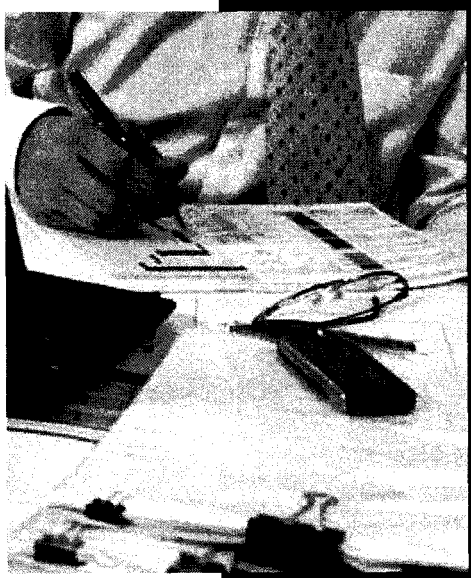
The *Dawn* report examined 20 water systems, using a relatively new technique to build what came to be called a "Nessie Curve" for each system. The Nessie Curve, so called because the graph follows an outline that someone likened to a silhouette of the Loch Ness Monster, revealed that each of the 20 water systems faced unprecedented needs to rebuild its underground water infrastructure—its pipe network. For each system, the future investment was an "echo" of the demographic history of the community, reflecting succeeding generations of pipe that were laid down as the community grew over many years. Most of those generations of pipe were shown to be coming to an end of their useful service lives in a relatively compressed period. Like the pipes themselves, the need for this massive investment was mostly buried and out of sight. But it threatens our future if we don't elevate it and begin to take action now.

The present report was undertaken to extend the *Dawn* report beyond those 20 original cities and encompass the entire United States. The results are startling. They confirm what every water utility professional knows: we face the need for massive reinvestment in our water infrastructure over the coming decades. The pipe networks that were largely built and paid for by earlier generations—and passed down to us as an inheritance—last a long time, but they are not immortal. The nation's drinking water infrastructure—especially the underground pipes that deliver safe water to America's homes and businesses—is aging and in need of significant reinvestment. Like many of the roads, bridges, and other public assets on which the country relies, most of our buried drinking water infrastructure was built 50 or more years ago, in the post-World War II era of rapid demographic change and economic growth. In some older urban areas, many water mains have been in the ground for a century or longer.

Given its age, it comes as no surprise that a large proportion of US water infrastructure is approaching, or has already reached, the end of its useful life. The need to rebuild these pipe networks must come on top of other water investment needs, such as the need to replace water treatment plants and storage tanks, and investments needed to comply with standards for drinking water quality. They also come on top of wastewater and stormwater investment needs which—judging from the US Environmental Protection Agency's (USEPA) most recent "gap analysis"—are likely to be as large as drinking water needs over the coming decades. Moreover, both water and wastewater infrastructure needs come on top of the other vital community infrastructures, such as streets, schools, etc.

Prudent planning for infrastructure renewal requires credible, analysis-based estimates of where, when, and how much pipe replacement or expansion for growth is required. This report summarizes a comprehensive and robust national-level analysis of the cost, timing, and location of the investments necessary to renew water mains over the coming decades. It also examines the additional pipe investments we can anticipate to meet projected population growth, regional population shifts, and service area growth through 2050.

This analysis is based on the insight that there will be "demographic echoes" in which waves of reinvestment are driven by a combination of the original patterns of pipe investment, the pipe materials used, and local operating environments. The report examines the reinvestment demands implied by these factors, along with population trends, in order to estimate needs for pipe replacement and concurrent investment demands to accommodate population growth.



Although this report does not substitute for a careful and detailed analysis at the utility level as a means of informing local decisions, it constitutes the most thorough and comprehensive analysis ever undertaken of the nation's drinking water infrastructure renewal needs. The keys to our analysis include the following:

1. Understanding the original timing of water system development in the United States.
2. Understanding the various materials from which pipes were made, and where and when the pipes of each material were likely to have been installed in various sizes.
3. Understanding the life expectancy of the various types and sizes of pipe ("pipe cohorts") in actual operating environments.
4. Understanding the replacement costs for each type and size of pipe.
5. Developing a probability distribution for the "wear-out" of each pipe cohort.

Methodology

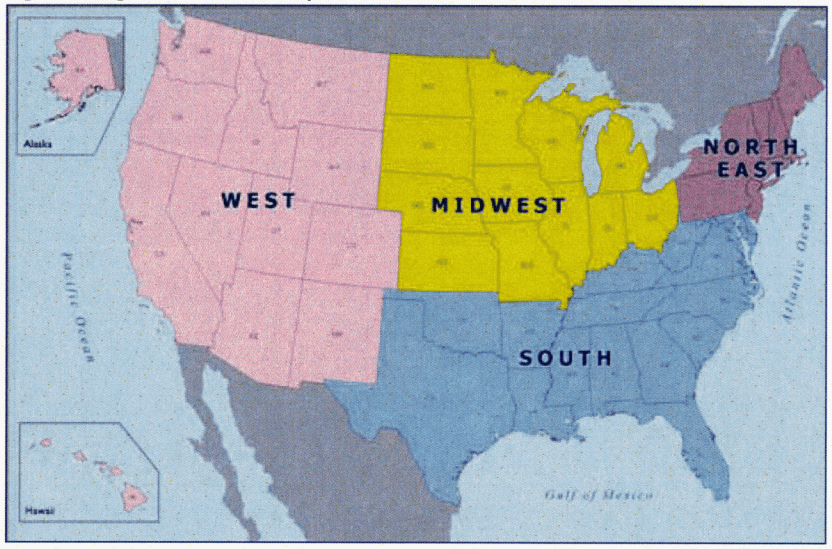
For this report, we differentiated across four water system size categories*:

- Very small systems (serving fewer than 3,300 people, representing 84.5% of community water systems).
- Small systems (3,300 to 9,999 served, representing 8.5% of community water systems).
- Medium-size systems (10,000 to 49,999 served, representing over 5.5% of systems). And,
- Large systems (serving more than 50,000 people, representing 1.5% of community water systems).

** Note that the water system size categories used in this analysis are not identical to the size categories USEPA uses for regulatory purposes. Note also that although data were analyzed based on these four size categories, some of the graphs that accompany this report combine medium-size and small systems. This is done for simplicity in the visual presentation, when the particular dynamics being represented are closely similar for medium-size and small systems.*

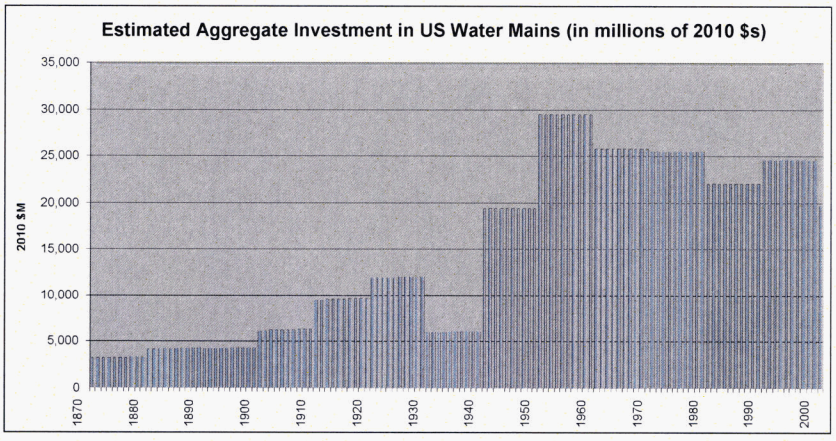
Next, we divided the country into four regions (Northeast, Midwest, South, and West), as shown in Figure 1. These regions are not equal in population, but they roughly share certain similarities, including their population dynamics and the

Figure 1: Regions Used in This Report



historical patterns of pipe installation driven by those dynamics. Data published by USEPA, the water industry, and the US Census Bureau were tapped to obtain a solid basis for regional pipe installation profiles by system size and pipe diameter. The US Census Bureau has produced a number of retrospective studies of the changes in urban and rural circumstances between 1900 and 2000 that proved especially useful in this analysis. The report also used the AWWA Water/Stats database, the USEPA Community Water Supply Survey, and data from the 2002 Public Works Infrastructure Survey (PWIS) as essential inputs in the analysis.

Figure 2: Historic Investment Profile for All US Water Systems, 1850-2000



In addition, we conducted a limited survey of professionals in the field concerning pipe replacement issues and other relevant "professional knowledge." The national aggregate for the original investment in all types and sizes of pipes is shown in Figure 2, while Figure 3 shows the aggregate current replacement value of water pipes by pipe material and utility size, totaling over $2.1 trillion.

Figure 3: Aggregate Replacement Value of Water Pipes by Pipe Material and Utility Size (millions 2010 $s)

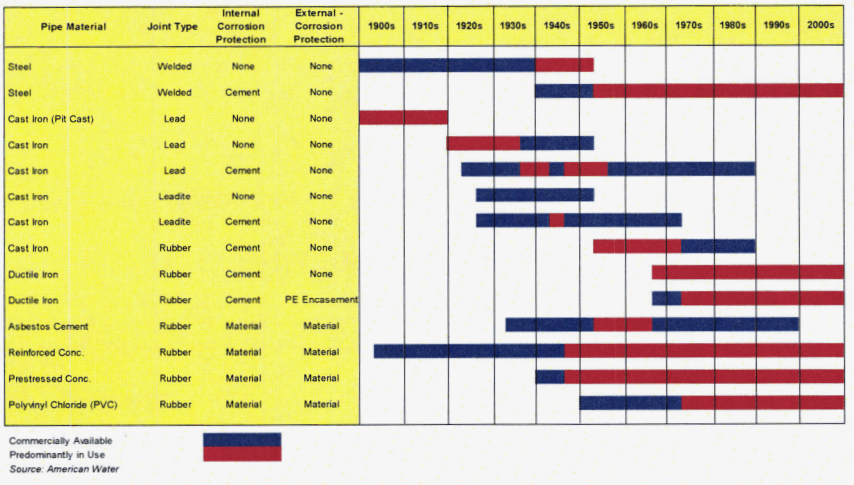
Region	CI	CICL	DI	AC	PV	Steel	PCCP	TOTAL
Northeast Large	48,958	8,995	5,050	2,308	1,875	335	0	67,522
Northeast Medium & Small	66,357	61,755	28,777	26,007	16,084	5,533	6,899	211,411
Northeast Very Small	14,491	15,992	10,661	7,281	7,937	329	462	57,152
Midwest Large	37,413	9,151	3,077	2,504	1,098	784	512	54,539
Midwest Medium & Small	74,654	92,106	51,577	37,248	30,506	8,682	11,152	305,925
Midwest Very Small	37,597	28,943	25,464	12,428	19,720	601	828	125,581
Southeast Large	30,425	28,980	29,569	21,229	14,936	9,337	7,227	141,703
South Medium & Small	54,772	98,608	140,079	103,659	102,804	21,394	17,160	538,475
South Very Small	43,183	24,998	49,791	34,529	47,823	1,461	1,244	203,028
West Large	15,448	16,055	28,949	14,774	14,723	7,443	6,215	103,607
West Medium & Small	15,775	50,145	70,355	50,541	48,885	12,276	9,806	257,782
West Very Small	16,344	11,199	17,910	13,166	17,245	545	453	76,862
Total	455,416	446,927	461,258	325,674	323,637	68,719	61,957	2,143,589

CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Finally, we used historical data on the production and use of seven major types of pipe with 14 total variations (Figure 4) to estimate what kinds of pipe were installed in water systems in particular years. This was validated by field checking with a sample of water utilities as well as checking against the original Nessie analysis. Together these steps resulted in the development of 16 separate inventories (four regions with four utility sizes in each region), with seven types of pipe in each inventory, *thus providing the most comprehensive picture of the nation's water pipe inventory ever assembled.* Note that in some of the report's graphs, "long-" and "short-lived" versions of certain pipe materials are combined, for purposes of visual simplicity in the presentation.

In order to consider growth, it was also necessary to examine population trends across rural, suburban, and urban settings over the past century. US Census Bureau

Figure 4: Historic Production and Use of Water Pipe by Material



projections of demographic trends allowed the development of infrastructure need profiles for growth through 2050 in each of the regions and utility size categories (for the latter purpose, city size was used as a proxy for utility size).

The study generally assumes that utilities continue efforts to manage the number of main breaks that occur per mile of pipe rather than absorb increases in pipe failures. That is, the study assumes utilities will strive to maintain current levels of service rather than allow increasing water service outages. We assume that each utility's objective is to make these investments at the optimal time for maintaining current service levels and to avoid replacing pipes while the repairs are still cost-effective. Ideally, pipe replacement occurs at the end of a pipe's "useful life"; that is, the point in time when replacement or rehabilitation becomes less expensive in going forward than the costs of numerous unscheduled breaks and associated emergency repairs.

With this data in hand and using the assumptions above, we projected the "typical" useful service life of the pipes in our inventory using the "Nessie Model"™. The model embodies pipe failure probability distributions based on many utilities' current operating experiences, coupled with insights from extensive research and professional experiences with typical pipe conditions at different ages and sizes, according to pipe material. The analysis used seven different types of pipe in three diameters and addressed pipe inventories dating back to 1870. Estimated typical service lives of pipes are

Figure 5: Average Estimated Service Lives by Pipe Materials (average years of service)

Derived Current Service Lives (Years)	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.
SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.

Figure 6: Aggregate Needs for Investment in Water Mains Through 2035 and 2050, by Region

2011-2035 Totals			
(2010 $M)	**Replacement**	**Growth**	**Total**
Northeast	$92,218	$16,525	$108,744
Midwest	$146,997	$25,222	$172,219
South	$204,357	$302,782	$507,139
West	$82,866	$153,756	$236,622
Total	**$526,438**	**$498,285**	**$1,024,724**

2011-2050 Totals			
(2010 $M)	**Replacement**	**Growth**	**Total**
Northeast	$155,101	$23,200	$178,301
Midwest	$242,487	$36,755	$279,242
South	$394,219	$492,493	$886,712
West	$159,476	$249,794	$409,270
Total	**$951,283**	**$802,242**	**$1,753,525**

reflected in Figure 5. Note that the *actual* lives of pipes may be quite different in a given utility. Because pipe life depends on many important local variables as well as upon utility practices, predicting the actual life expectancy of any given pipe is outside the scope of this study. Many utilities will have pipes that last much longer than these values suggest while others will have pipes that begin to fail sooner. However, these values have been validated as national "averages" by comparing them to actual field experience in a number of utilities throughout the country. The model also includes estimates of the indicative costs to replace each size category of pipe, as well as the cost to repair the projected number of pipe breaks over time according to pipe size.

The analysis of pipe replacement needs is compiled in the Nessie Model by combining the demographically based pipe inventories with the projected effective service lifetimes for each pipe type. This yields an estimate of how much pipe of each size in each region must be replaced in each of the coming 40 years. Factoring in the typical cost to replace these pipes, we derive an estimate of the total investment cost for each future year. The model then derives a series of graphs (the Nessie curves) that depict the amount of spending required in each future year to replace each of the different pipe types by utility size and region. Aggregating this information, we derived the dollar value of total drinking water infrastructure replacement needs over the coming 25 and 40 years for each utility size category per region, and for the United States.

Key Findings

1. The Needs Are Large. *Investment needs for buried drinking water infrastructure total more than $1 trillion nationwide over the next 25 years*, assuming pipes are replaced at the end of their service lives and systems are expanded to serve growing populations. Delaying this investment could mean either increasing rates of pipe breakage and deteriorating water service, or suboptimal use of utility funds, such as paying more to repair broken pipes than the long-term cost of replacing them. Nationally, the need is close to evenly divided between replacement due to wear-out and needs generated by demographic changes (growth and migration).

Over the coming 40-year period, *through 2050, these needs exceed $1.7 trillion.* Replacement needs account for about 54% of the national total, with about 46% attributable to population growth and migration over that period.

Figure 6 (previous page) shows aggregate needs for investment in water mains through 2050, due to wear-out and population growth.

2. Household Water Bills Will Go Up. Important caveats are necessary here, because there are many ways that the increased investment in water infrastructure can be allocated among customers. Variables include rate structures, how the investment is financed, and other important local factors. But the level of investment required to replace worn-out pipes and maintain current levels of water service *in the most affected communities could in some cases triple household water bills.* This projection assumes the costs are spread evenly across the population in a "pay-as-you-go" approach (See "The Costs Keep Coming" below). Figures 7 and 8 illustrate the increasing cost of water that can be expected by households for replacement, and for replacement plus growth, respectively. The utility categories shown in these figures are presented to depict a range of household cost impacts, from the least-to-the-most affected utilities.

Figure 7: Costs per Household for Water Main Replacement by Utility Size and Region

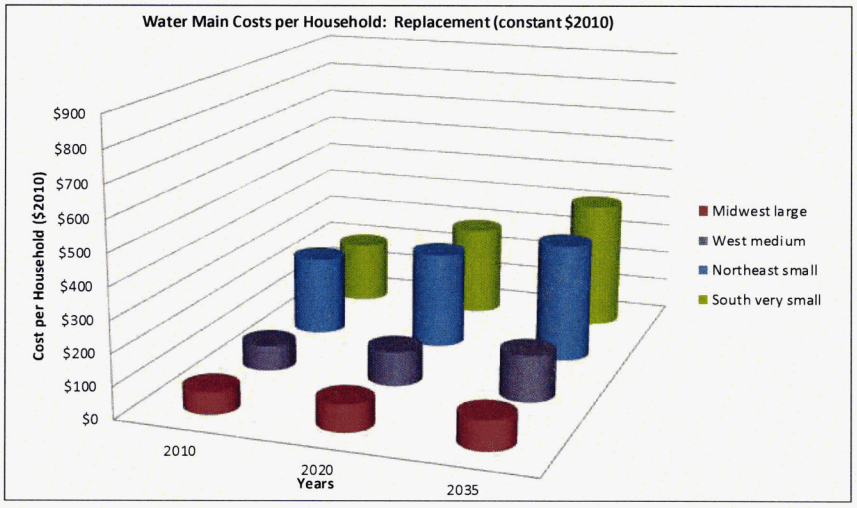
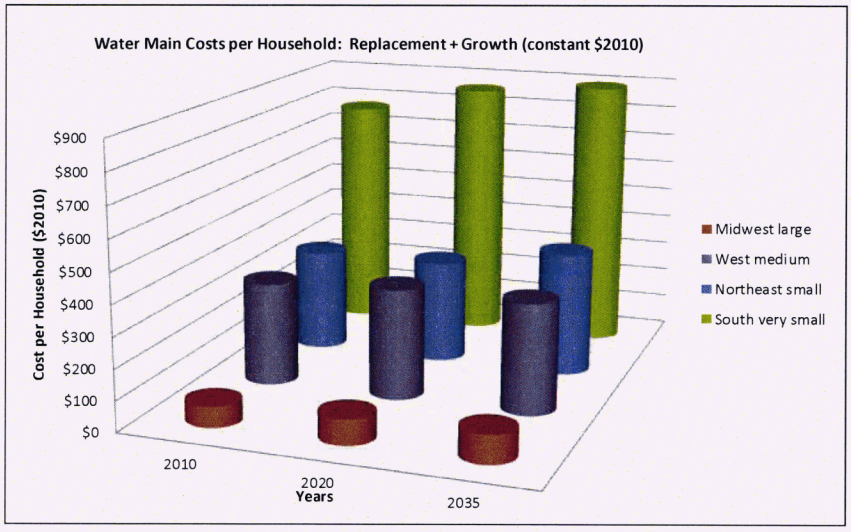


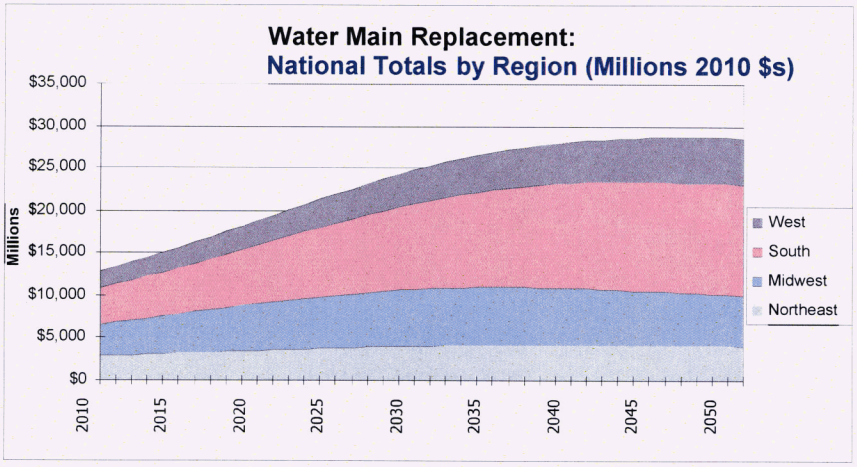
Figure 8: Costs per Household for Water Main Replacement Plus Growth



With respect to the cost of growth, other caveats are important. Many communities expect growth to pay or help pay for itself through developer fees, impact fees, or similar charges. In such communities, established residents will not be required to shoulder the cost of population growth to the extent that these fees recover those costs. *But regardless of how the costs of replacement and growth are allocated among builders, newcomers, or established residents, the total cost that must be borne by the community will still rise.*

3. There Are Important Regional Differences. The growing national need affects different regions in different ways. In general, the South and the West will face the steepest investment challenges, with total needs accounting for considerably more than half the national total (see Figures 6 and 9). This is largely attributable to the fact that the population of these regions is growing rapidly. In contrast, in the Northeast and Midwest, growth is a relatively small component of the projected need. However, the population shifts away from these regions complicate the infrastructure challenge, as there are fewer remaining local customers across whom to spread the cost of renewing their infrastructure.

Figure 9: Water Main Replacement Costs per Region

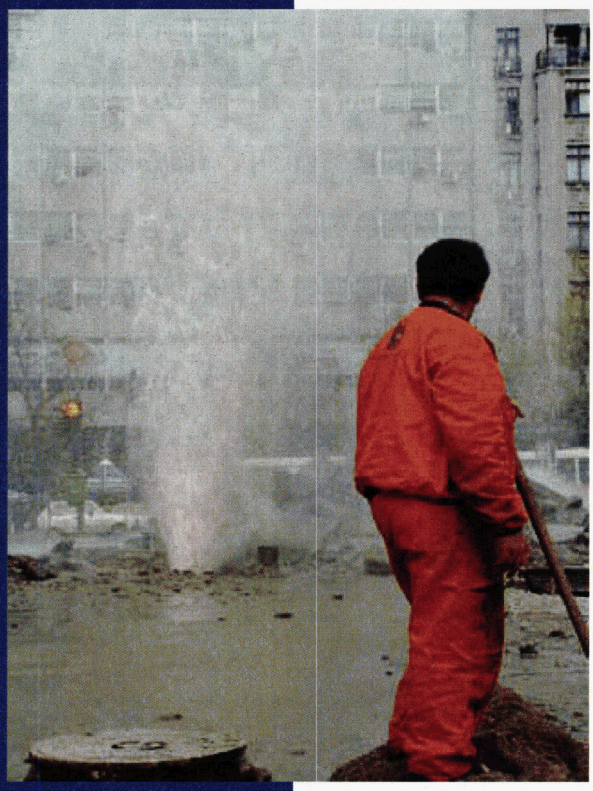


This regional perspective reveals the inherent difficulty of managing infrastructure supply and demand. Although water pipes are fixed in place and long-lasting, the population that drives the demand for these assets is very mobile and dynamic. People move out of one community, leaving behind a pipe network of fixed size but with fewer customers to support it. They move into a new community, requiring that the water system there be expanded to serve the new customers.

4. There Are Important Differences Based on System Size.

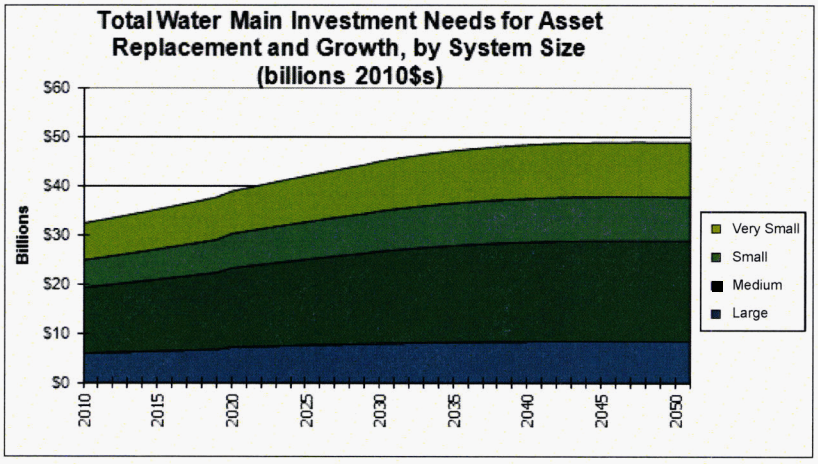
As with many other costs, *small communities may find a steeper challenge ahead on water infrastructure.* Small communities have fewer people, and those people are often more spread out, requiring more pipe "miles per customer" than larger systems. In the most affected small communities, the study suggests that a typical three-person household could see its drinking water bill increase by as much as $550 per year above current levels, simply to address infrastructure needs, depending as always on the caveats identified above.

In the largest water systems, costs can be spread over a large population base. Needed investments would be consistent with annual per household cost increases ranging from roughly $75 to more than $100 per year by the mid-2030s, assuming the expenses were spread across the population in the year they were incurred. Figure 10 illustrates the differing total costs of required investment by system size.



5. The Costs Keep Coming. The national-level investment we face will roughly double from about $13 billion a year in 2010 to almost $30 billion annually by the 2040s for replacement alone. If growth is included, needed investment must increase from a little over $30 billion today to nearly $50 billion over the same period. This level of investment must then be sustained for many years, if current levels of water service are to be maintained. *Many utilities will have to face these investment needs year after year, for at least several decades.* That is, by the time the last cohort of pipes analyzed in this study (predominantly the pipes laid between the late 1800s and 1960) has been replaced in, for example, 2050, it may soon thereafter be time to begin replacing the pipes laid after 1960, and so on. In that respect, these capital outlays are unlike those required to build a new treatment plant or storage tank, where the capital costs are incurred up front and aren't faced again for many years. Rather, infrastructure renewal investments are likely to be incurred each year over several decades. For that reason, *many utilities may choose to finance infrastructure replacement on a "pay-as-you-go" basis rather than through debt financing.*

Figure 10: Total Water Main Replacement and Growth Needs by System Size



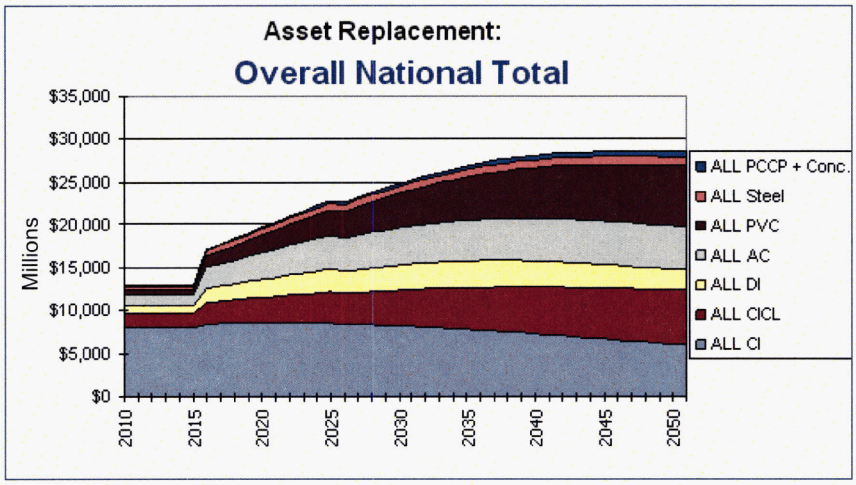
6. Postponing Investment Only Makes the Problem Worse.

Overlooking or postponing infrastructure renewal investments in the near term will only add to the scale of the challenge we face in the years to come. Postponing the investment steepens the slope of the investment curve that must ultimately be met, as shown in Figure 11 (next page). It also increases the odds of facing the high costs associated with water main breaks and other infrastructure failures. The good news is that *not all of the $1 trillion investment through 2035 must be made right now.* There is time to make suitable plans and implement policies that will help address the longer-term challenge. The bad news is that the required investment level is growing, as more pipes continue to age and reach the end of their effective service lives.

As daunting as the figures in this report are, the prospect of not making the necessary investment is even more chilling. Aging water mains are subject to more frequent breaks and other failures that can threaten public health and safety (such as compromising tap water quality and fire-fighting flows). Buried infrastructure failures also may impose significant damages (for example, through flooding and sinkholes), are costly to repair, disrupt businesses and residential communities, and waste precious water resources. These maladies weaken our economy and undermine our quality of life. As large as the cost of reinvestment may be, **not** undertaking it will be worse in the long run by almost any standard.

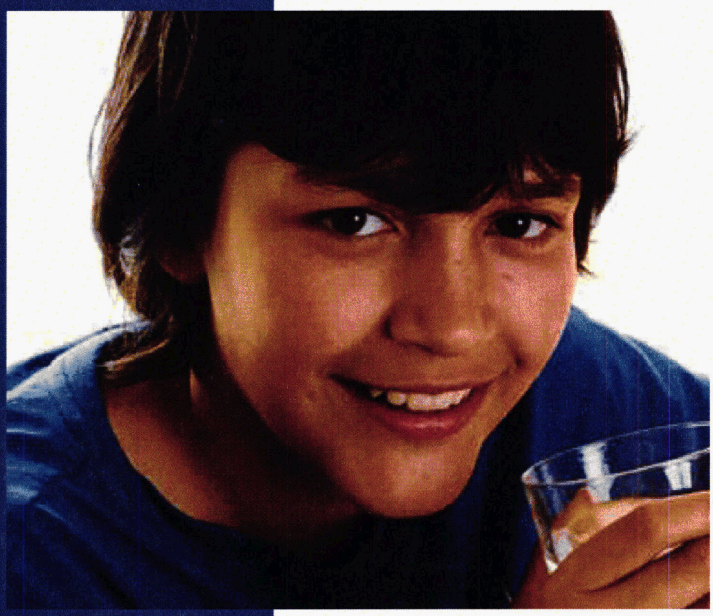
This suggests that a crucial responsibility for utility managers now and in the future is to develop the processes necessary to continually improve their understanding of the "replacement dynamics" of their own water systems. Those dynamics should be reflected in an Asset Management Plan (AMP) and, of course, in a long-term capital investment plan. The 2006 AWWA Report *Water Infrastructure at a Turning Point* includes a full discussion of this issue.

Figure 11: Effect of Deferring Investment Five Years with a Ten-Year Make-Up Period



Conclusion

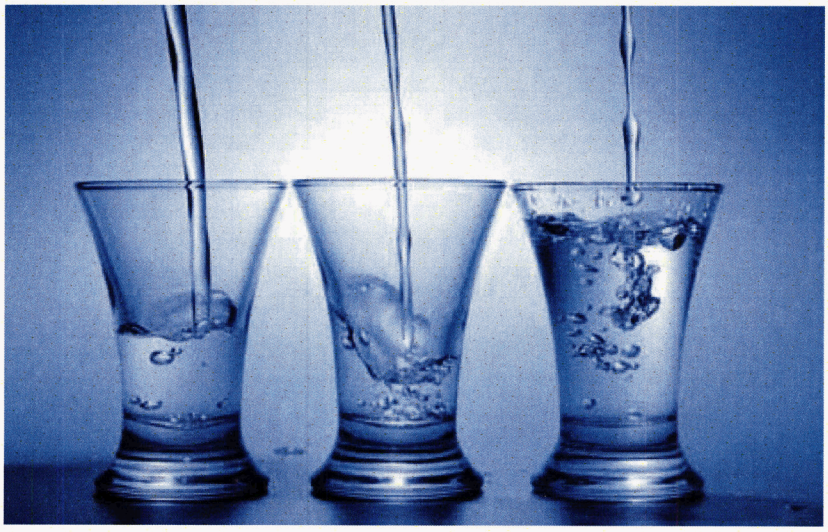
Because pipe assets last a long time, water systems that were built in the latter part of the 19th century and throughout much of the 20th century have, for the most part, never experienced the need for pipe replacement on a large scale. The dawn of the era in which these assets will need to be replaced puts a growing financial stress on communities that will continually increase for decades to come. It adds large and hitherto unknown expenses to the more apparent above-ground spending required to meet regulatory standards and address other pressing needs.



It is important to reemphasize that there are significant differences in the timing and magnitude of the challenges facing different regions of the country and different sizes of water systems. But the investments we describe in this report are real, they are large, and they are coming.

The United States is reaching a crossroads and faces a difficult choice. We can incur the haphazard and growing costs of living with aging and failing drinking water infrastructure. Or, we can carefully prioritize and undertake drinking water infrastructure renewal investments to ensure that our water utilities can continue to reliably and cost-effectively support the public health, safety, and economic vitality of our communities. AWWA undertook this report to provide the best, most accurate information available about the scale and timing of these needed investments.

It is clear the era AWWA predicted a decade ago—the replacement era—has arrived. The issue of aging water infrastructure, which was buried for years, can be buried no longer. Ultimately, the cost of the renewal we face must come from local utility customers, through higher water rates. However, the magnitude of the cost and the associated affordability and other adverse impacts on



communities—as well as the varying degrees of impact to be felt across regions and across urban and rural areas—suggest that there is a key role for states and the federal government as well. In particular, states and the federal government can help with a careful and cost-effective program that lowers the cost of necessary investments to our communities, such as the creation of a credit support program—for example, AWWA's proposed Water Infrastructure Finance and Innovation Authority (WIFIA).

Finally, in many cases, difficult choices may need to be made between competing needs if water bills are to be kept affordable. Water utilities are willing to ask their customers to invest more, but it's important this investment be in things that bring the greatest actual benefit to the community. Only in that spirit can we achieve the goal to which we all aspire, the reliable provision of safe and affordable water to all Americans.

Additional Information and Resources.

A full and robust infrastructure analysis is an indispensable tool for decision making by water and wastewater utilities. This report does not substitute for such detailed local analysis for purposes of designing an infrastructure asset management program for individual utilities.

Additional information is available from AWWA concerning asset management. Particular attention should be given to the WITAF reports *Dawn of the Replacement Era, Avoiding Rate Shock, Thinking Outside the Bill* and *Water Infrastructure at a Turning Point.* In addition, Manual M1, *Principles of Water Rates, Fees, and Charges,* and the AWWA Utility Management Standards may be helpful. For more information, visit the AWWA Bookstore at **www.awwa.org/store.**

A number of graphs and figures from this report are also available through the AWWA website at **www.awwa.org/infrastructure.** They include:

Estimated Distribution of Mains by Material
Northeast and Midwest
South and West

Proportion of 2010 Systems Built by Year
Northeast
Midwest
South
West

Investment for Replacement Plus Growth, by Region and Size of Utility

Northeast
Large
Medium
Small
Very Small

Midwest
Large
Medium
Small
Very Small

South
Large
Medium
Small
Very Small

West
Large
Medium
Small
Very Small

Household Cost of Needed Investment by Region and Size of Utility

Northeast
Large
Medium
Small
Very Small

Midwest
Large
Medium
Small
Very Small

South
Large
Medium
Small
Very Small

West
Large
Medium
Small
Very Small

www.awwa.org/infrastructure

Estimated Distribution of Mains by Material Over Time
Northeast & Midwest Regions

	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (SSL)	AC (LSL)	PVC	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	AC (LSL)	Steel	Conc & PCCP
	<6 inch diameter								6-10 inch diameter								>10 inch diameter						
1870	100%								100%								100%						
1880	100%								100%								100%						
1890	100%								100%								100%						
1900	100%								100%								100%						
1910	100%								100%								100%						
1920	100%								100%								100%						
1930	50%	30%	20%						50%	30%	20%						50%	30%	20%				
1940	20%	60%	20%						20%	60%	20%						20%	40%	20%			20%	
1950		60%				20%	20%			60%				20%	20%			40%			10%	20%	30%
1960		50%			10%	20%	20%			50%			10%	20%	20%			35%		5%	10%	20%	30%
1970		20%			40%			40%		20%			40%			40%				50%		20%	30%
1980				25%	30%			45%				25%	35%			40%				60%		15%	25%
1990				50%	5%			45%				50%	5%			45%				60%		15%	25%
2000				55%				45%				55%				45%				60%		15%	25%
2010				55%				45%				55%				45%				60%		15%	25%
2020				55%				45%				55%				45%				60%		15%	25%
2030				55%				45%				55%				45%				60%		15%	25%

Steel and PCCP pipe not in widespread use in sizes under 10 inches.

CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The regions are combined because they share similar dynmaics for this distribution.

Note:
"LSL" indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.

"SSL" indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices etc.

Estimated Distribution of Mains by Material Over Time
South & West Regions

	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	AC (LSL)	Steel	Conc & PCCP
	<6 inch diameter								6-10 inch diameter								>10 inch diameter						
1870	100%								100%								100%						
1880	100%								100%								100%						
1890	100%								100%								100%						
1900	100%								100%								100%						
1910	100%								100%								100%						
1920	100%								100%								100%						
1930	50%	30%	20%						50%	30%	20%						50%	30%	20%				
1940		70%	30%							70%	30%							50%	30%			20%	
1950		25%				40%	35%			25%				40%	35%			40%			15%	25%	20%
1960		25%		2%	3%	40%	30%			25%		2%	3%	40%	30%			40%		5%	10%	25%	20%
1970		10%		10%	10%	40%		30%		10%		10%	10%	40%		30%				45%	10%	25%	20%
1980				25%	25%			50%				30%	30%			40%				60%		20%	20%
1990				45%	5%			50%				50%	5%			45%				60%		20%	20%
2000				50%				50%				50%				50%				60%		20%	20%
2010				50%				50%				50%				50%				60%		20%	20%
2020				50%				50%				50%				50%				60%		20%	20%
2030				50%				50%				50%				50%				60%		20%	20%

Steel and PCCP pipe not in widespread use in sizes under 10 inches.

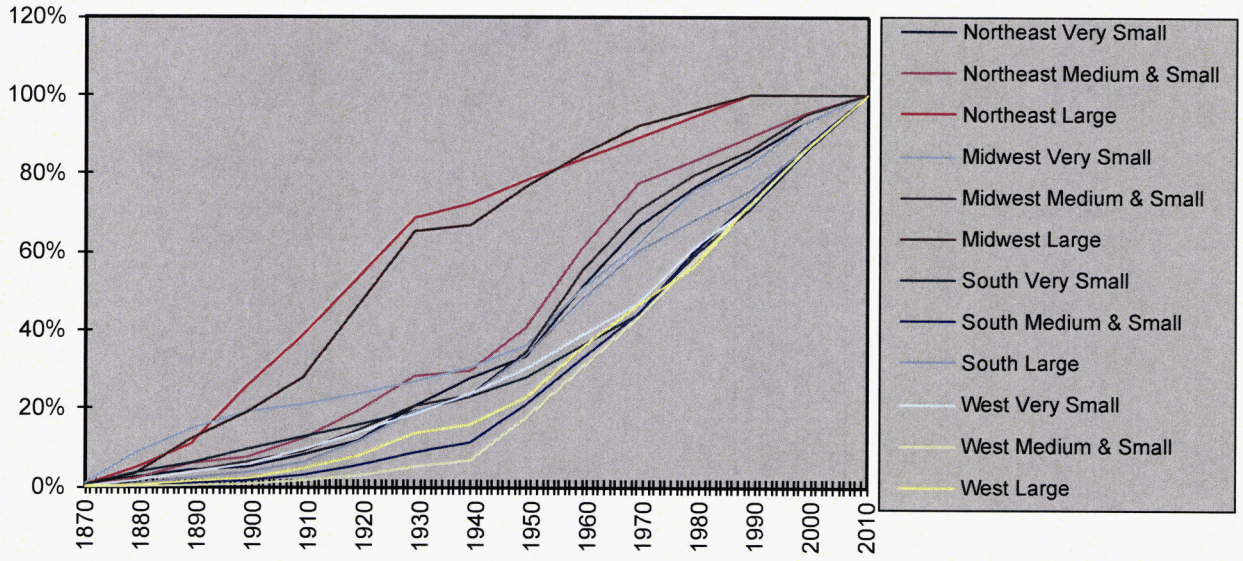
CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The regions are combined because they share similar dynmaics for this distribution.

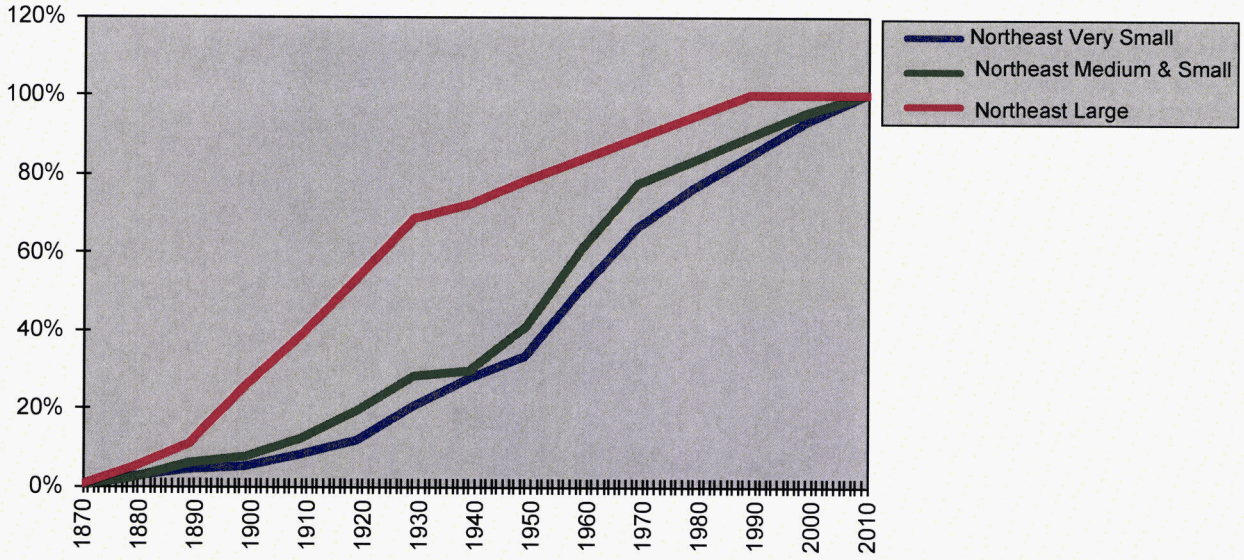
Note:
"LSL" indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.

"SSL" indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices etc.

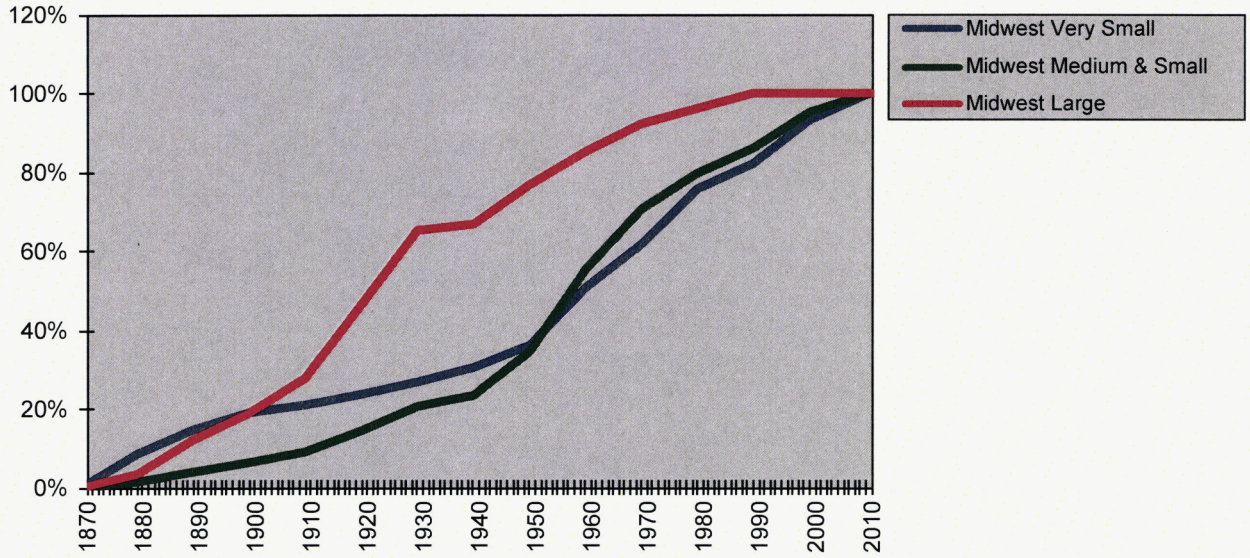
Proportion of Current System Built by Decade: All Regions



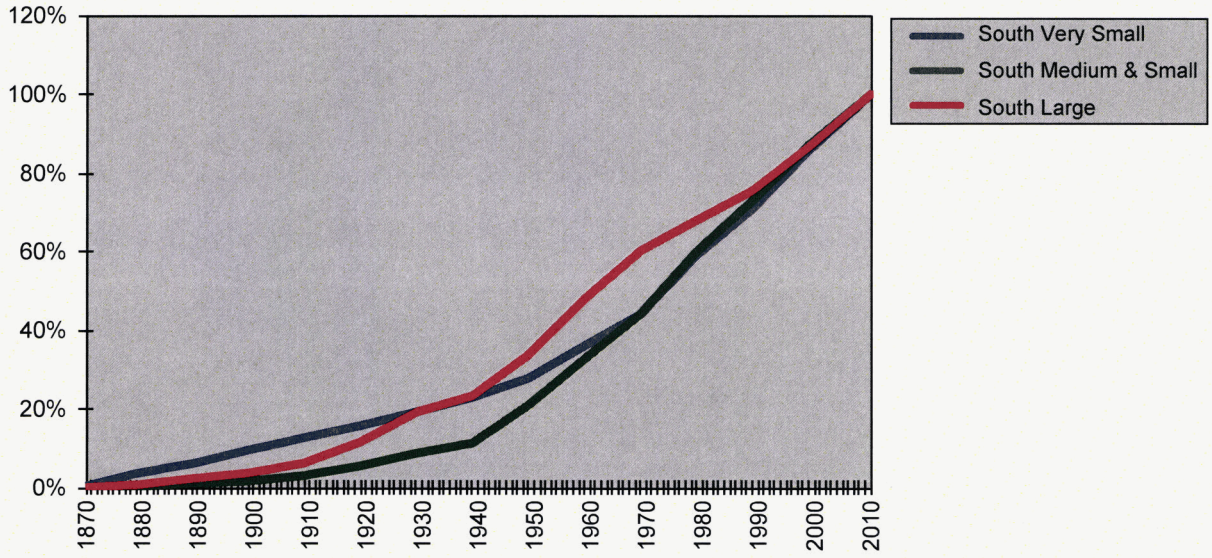
Proportion of Current System Built by Decade: Northeast



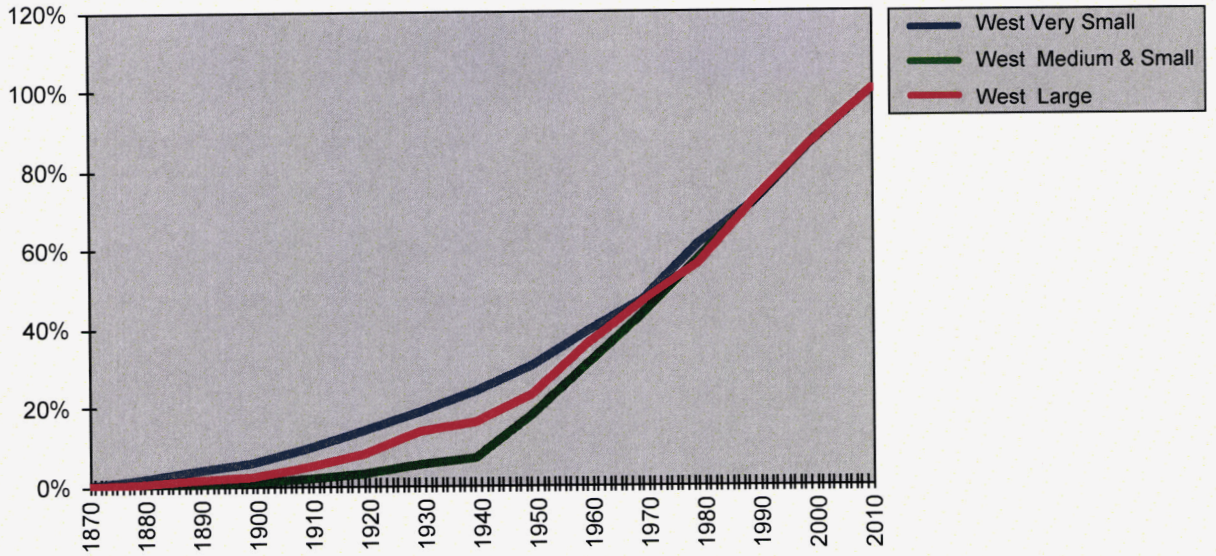
Proportion of Current System Built by Decade: Midwest



Proportion of Current System Built by Decade: South

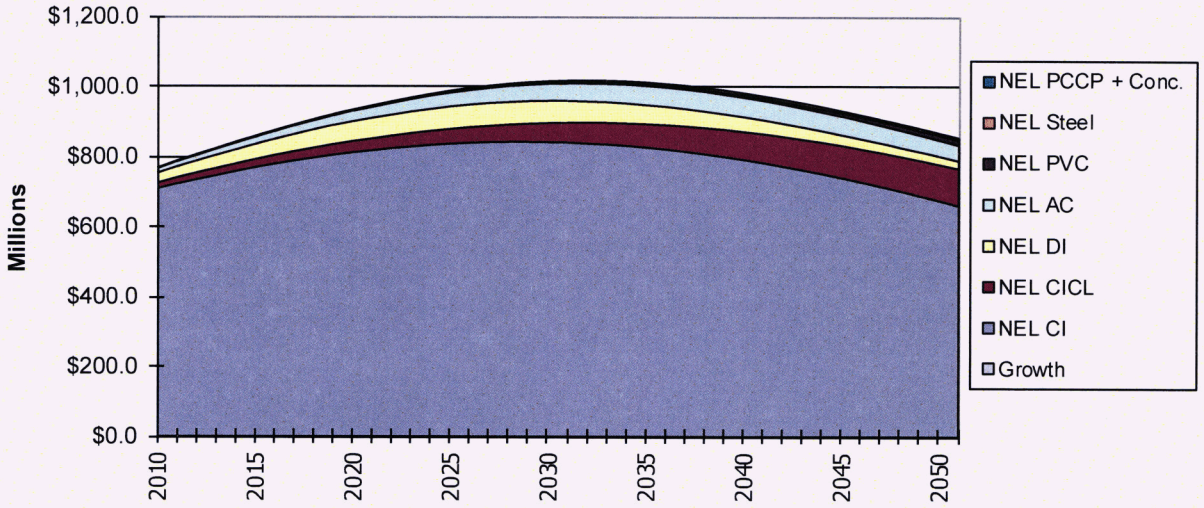


Proportion of Current System Built by Decade: South



Investment for Replacement & Growth

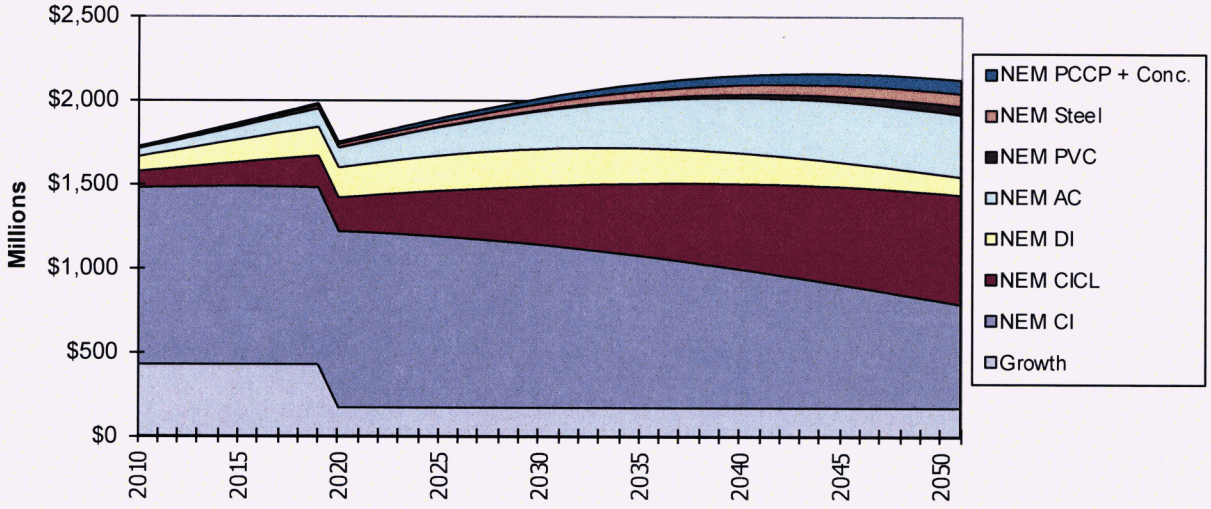
Northeast Large



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

Northeast Medium

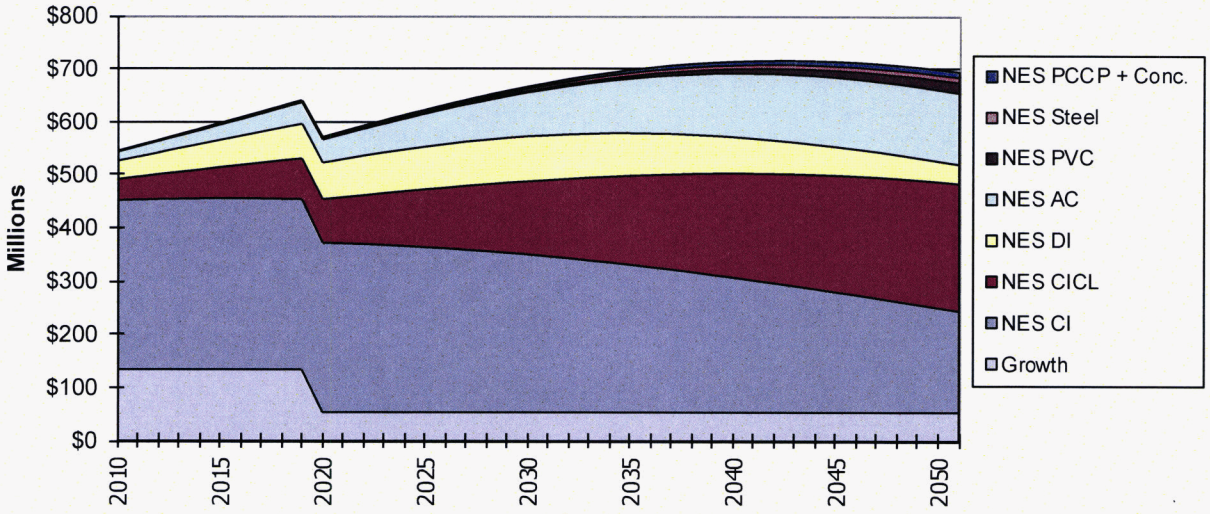


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

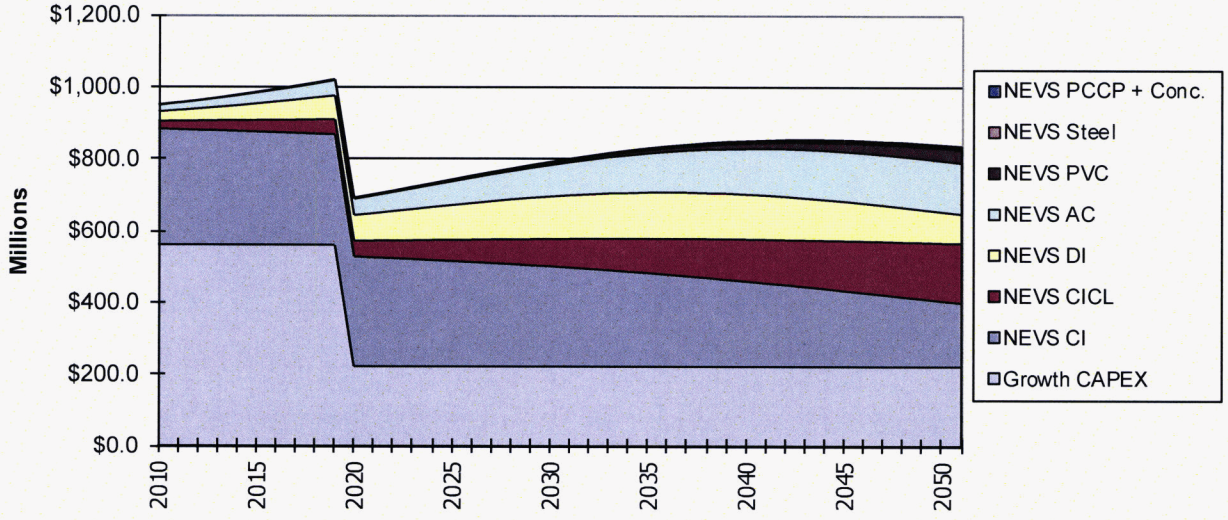
Northeast Small



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

Northeast Very Small

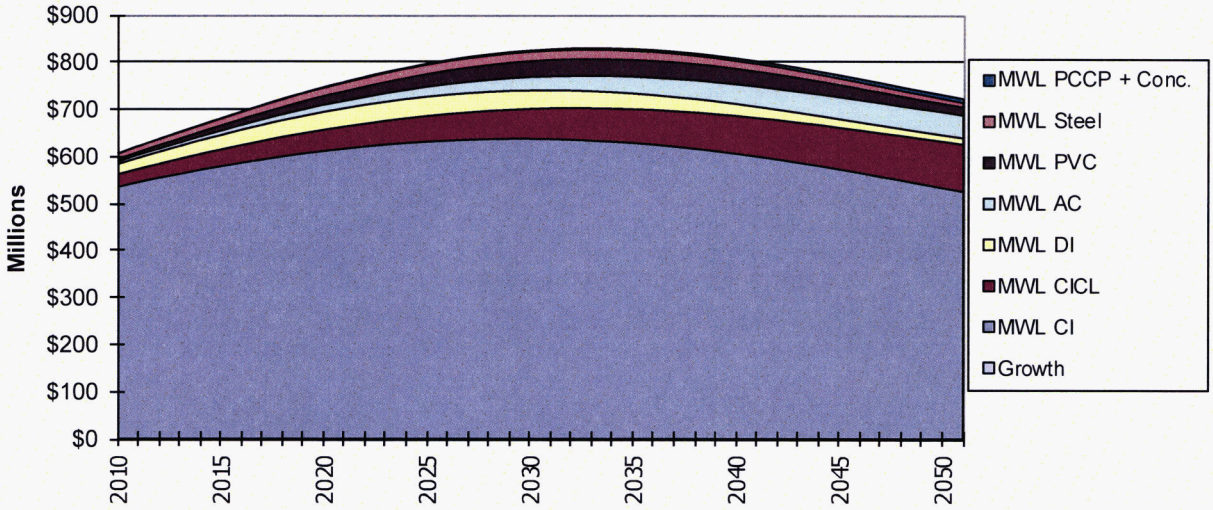


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

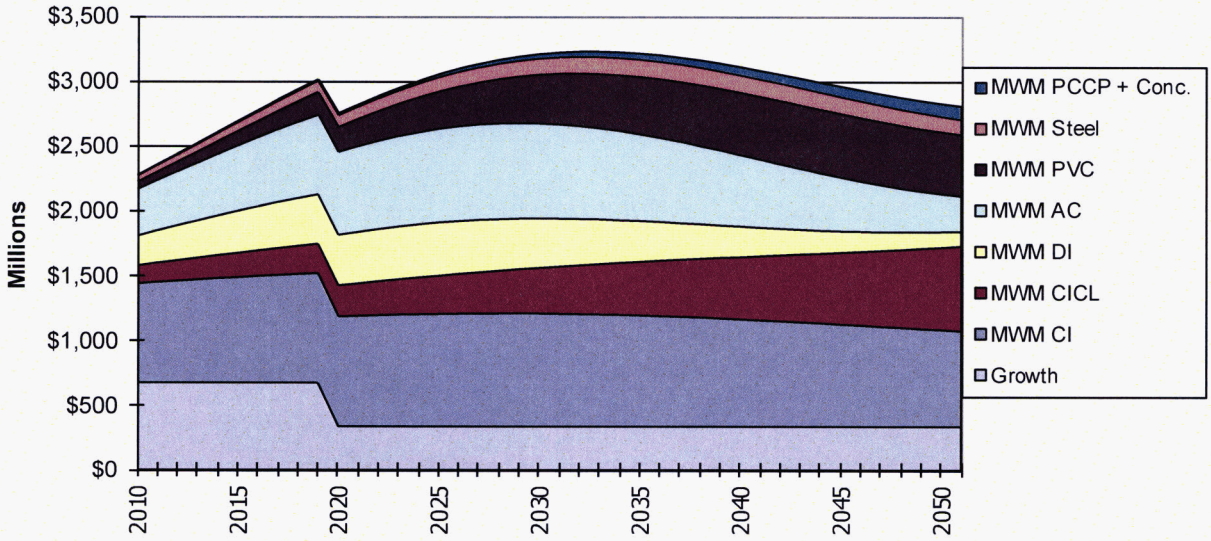
Midwest Large



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

Midwest Medium

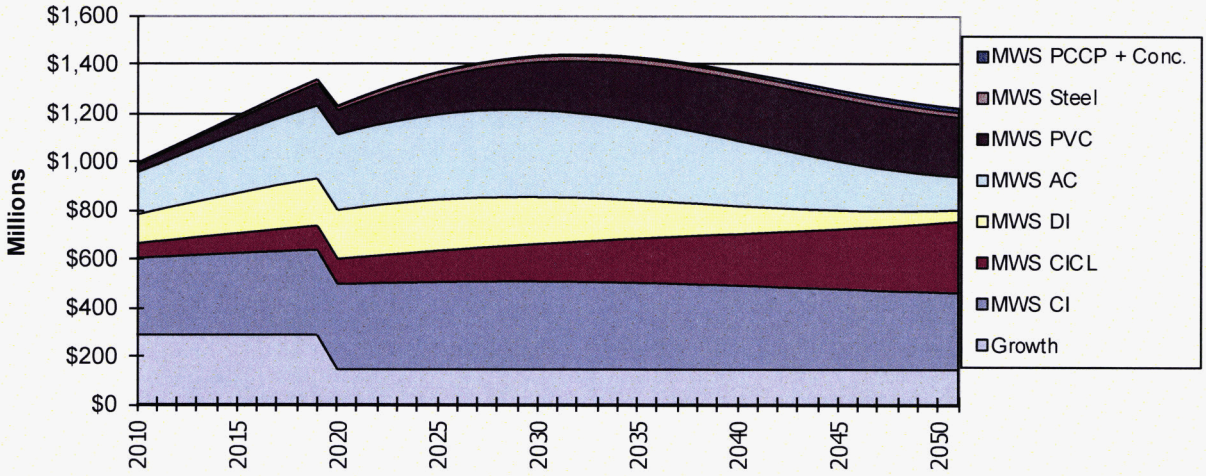


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

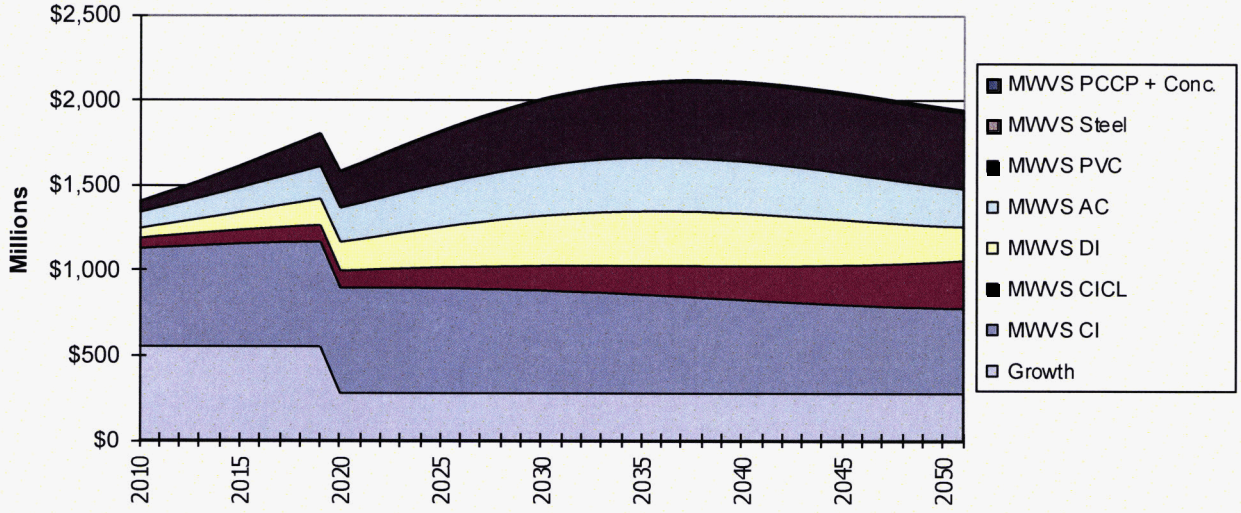
Midwest Small



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

Midwest Very Small

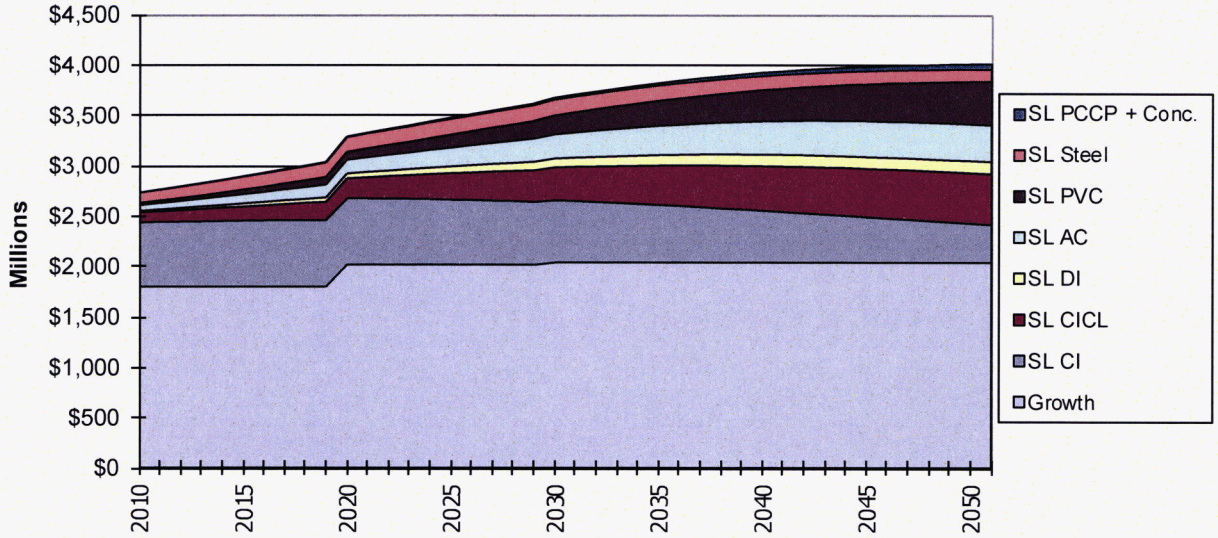


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

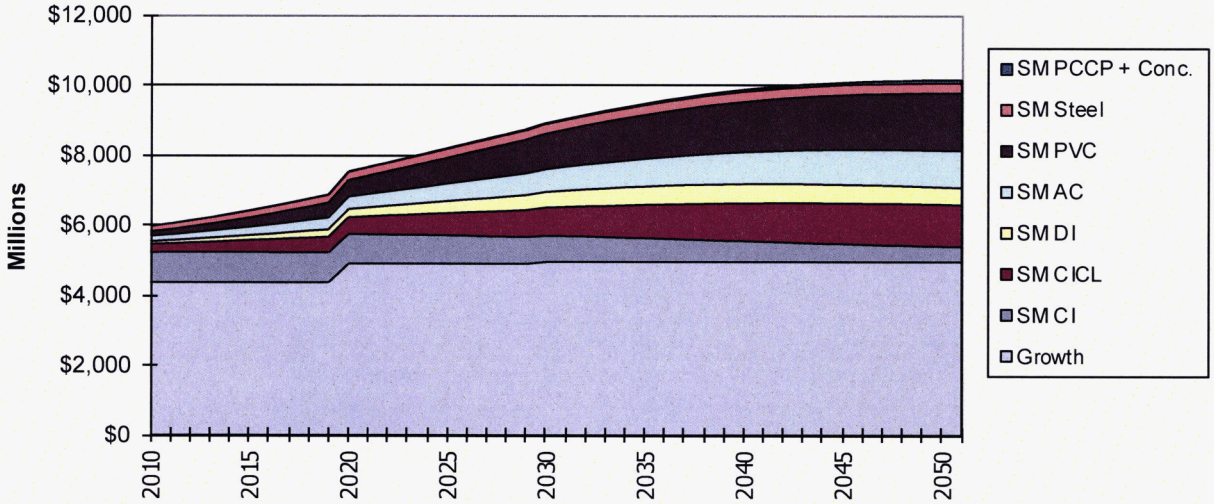
South Large



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

South Medium

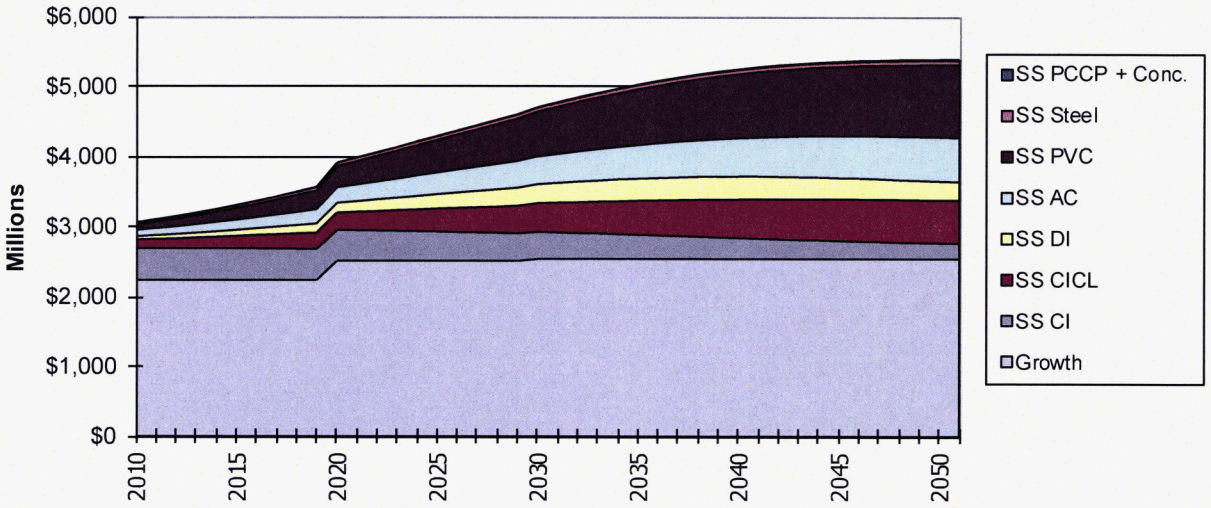


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

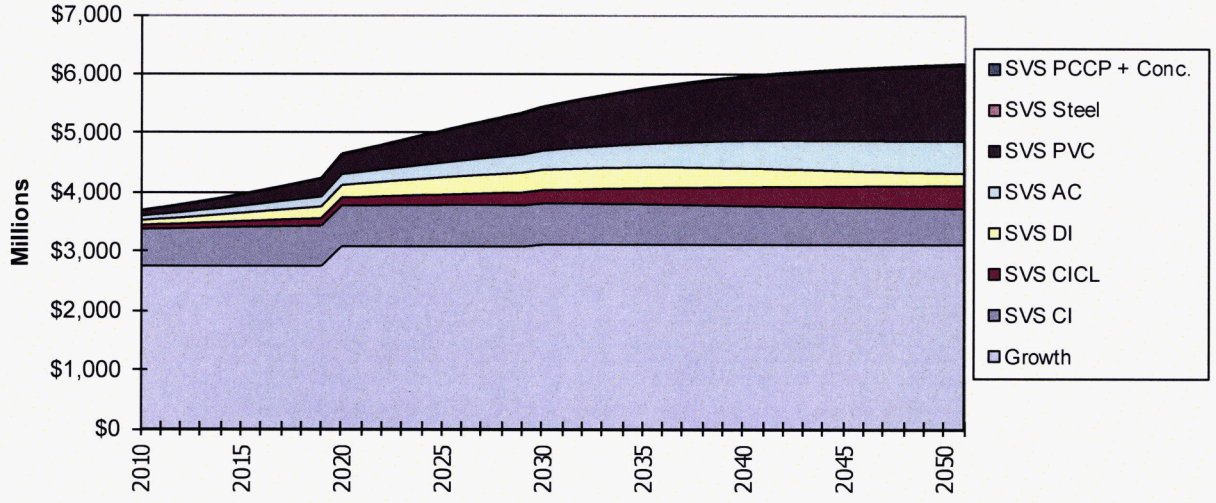
South Small



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

South Very Small

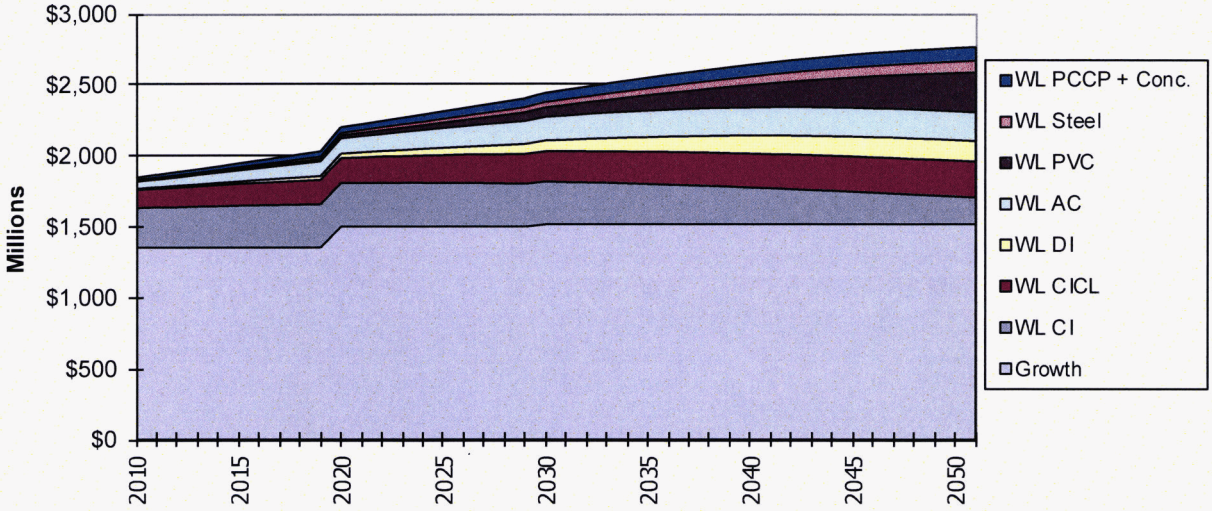


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

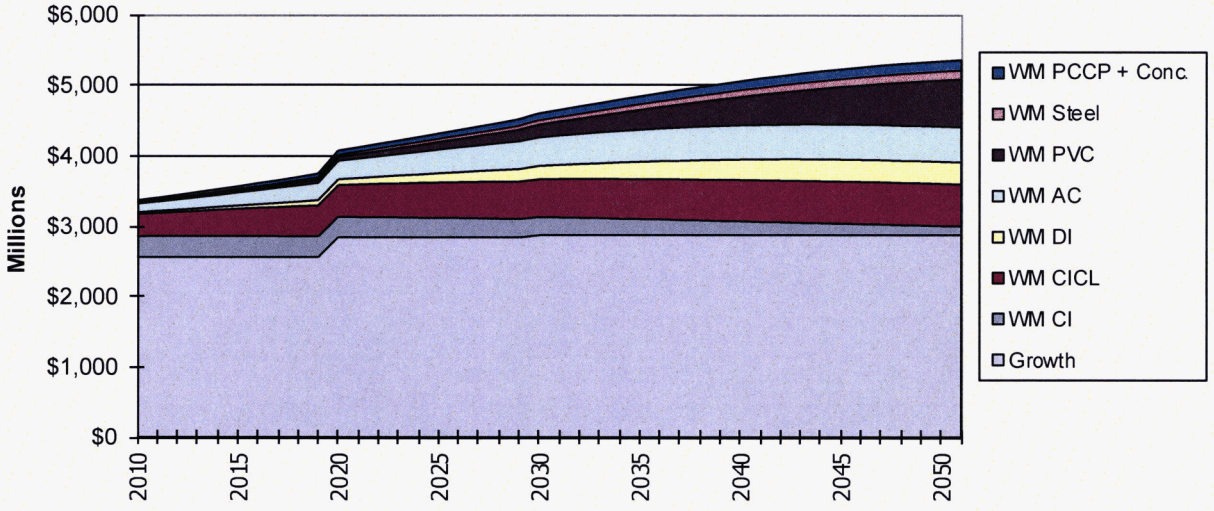
West Large



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

West Medium

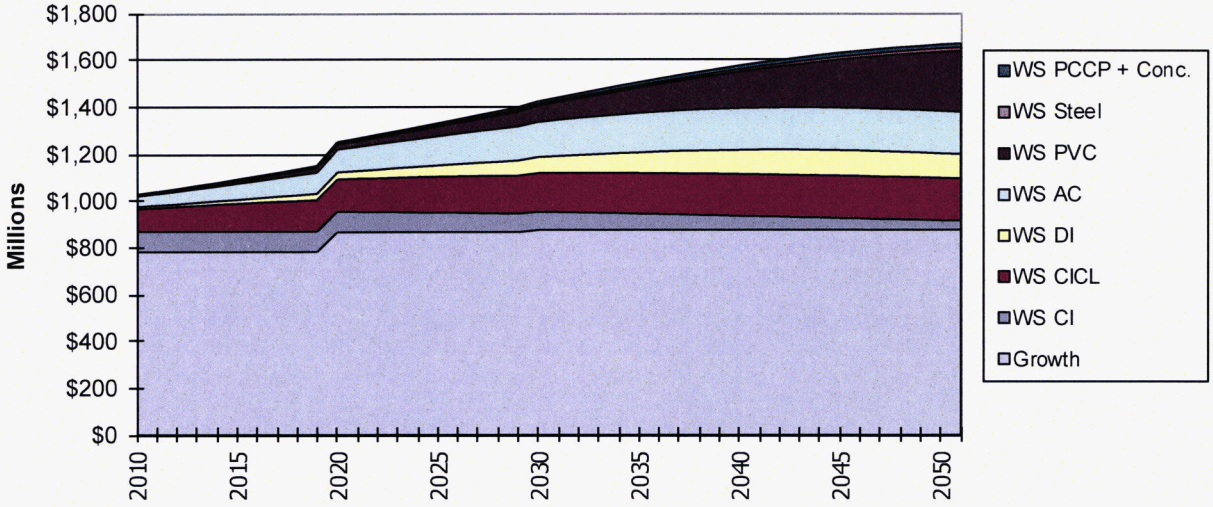


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Investment for Replacement & Growth

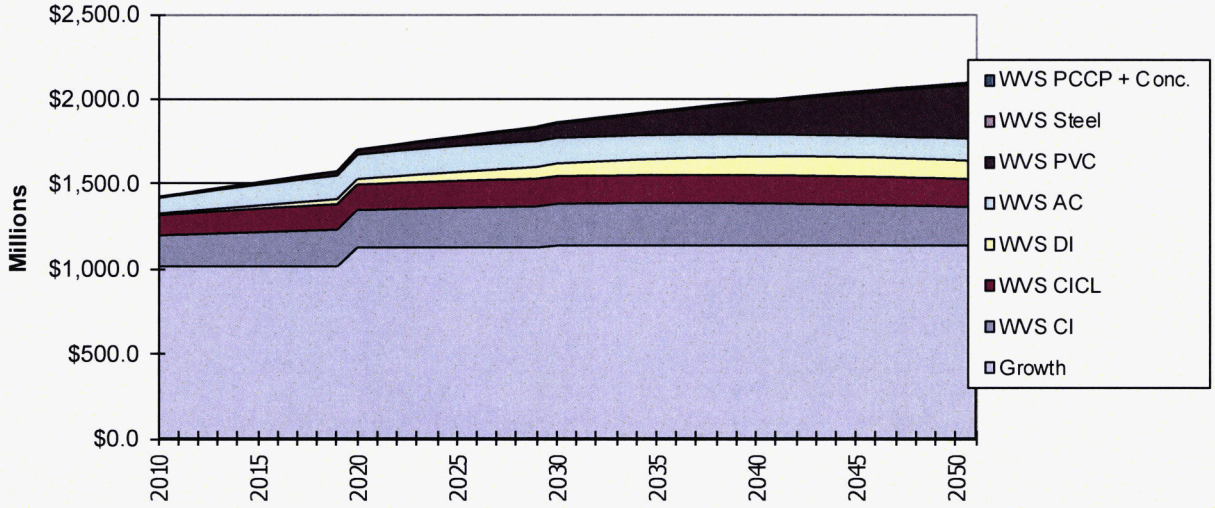
West Small



CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

Investment for Replacement & Growth

West Very Small

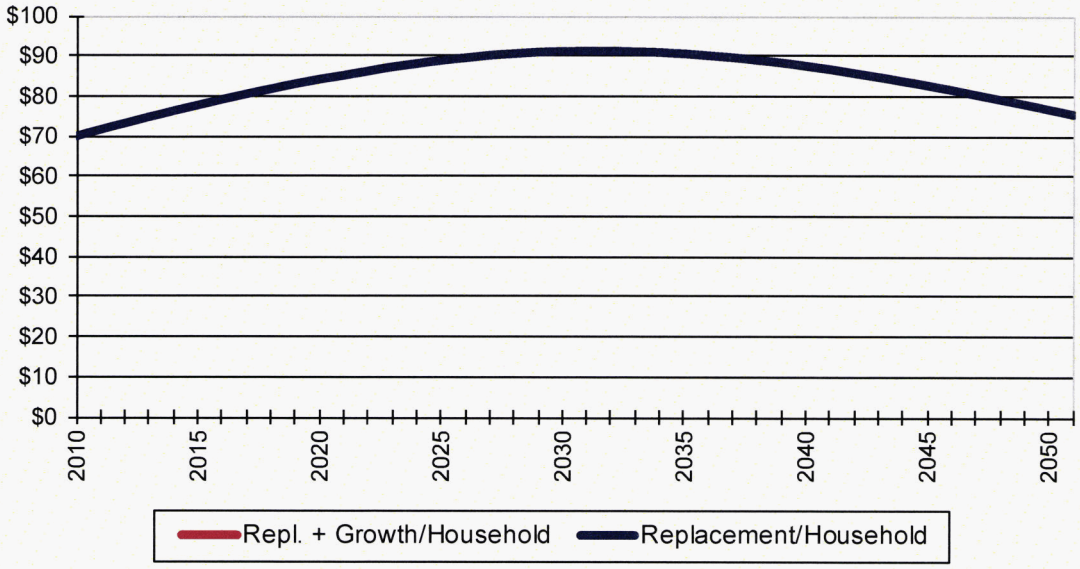


CI: cast iron; CICL: cast iron cement lined; DI: ductile iron; AC: asbestos cement; PV: polyvinyl chloride; PCCP: prestressed concrete cylinder pipe

The charts show needs for replacement of particular types of pipe and for growth (see the keys below and to the right of the chart). An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next.

Household Cost of Needed Investment for Replacement Plus Growth*

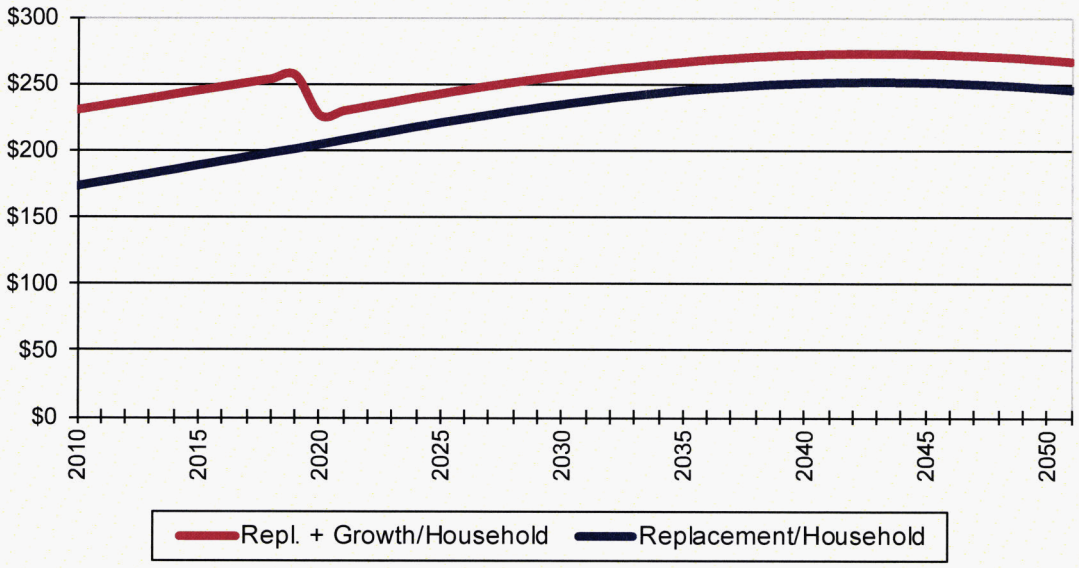
Northeast Large



*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

Household Cost of Needed Investment for Replacement Plus Growth*

Northeast Medium

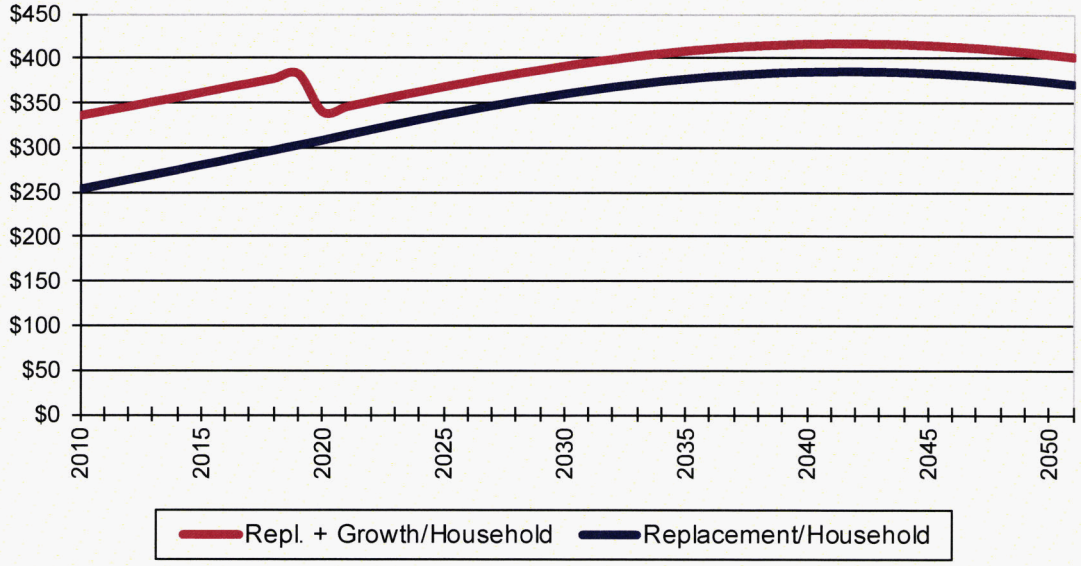


*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

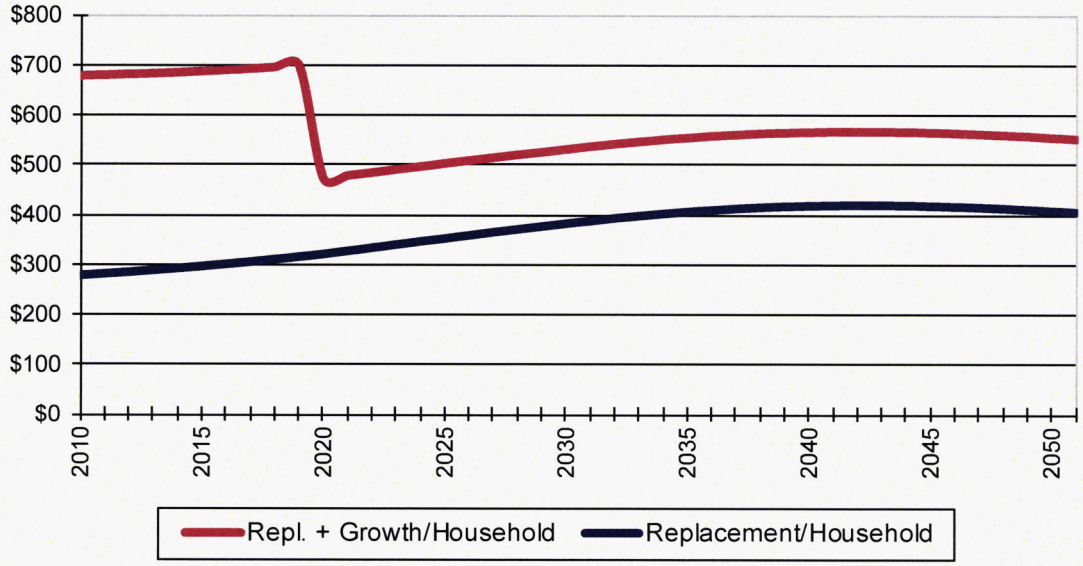
Northeast Small



**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

Household Cost of Needed Investment for Replacement Plus Growth*

Northeast Very Small

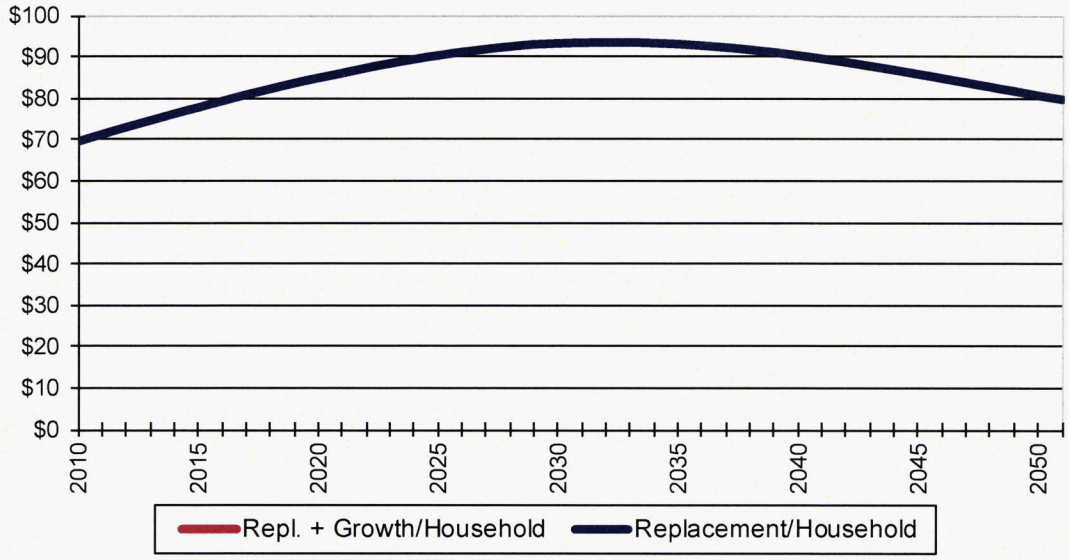


**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

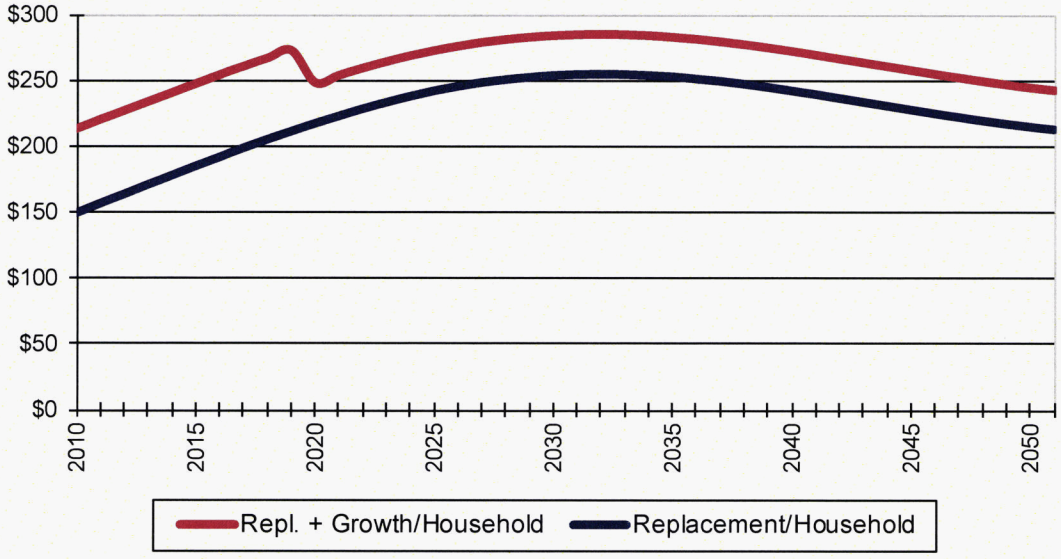
Midwest Large



*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

Household Cost of Needed Investment for Replacement Plus Growth*

Midwest Medium

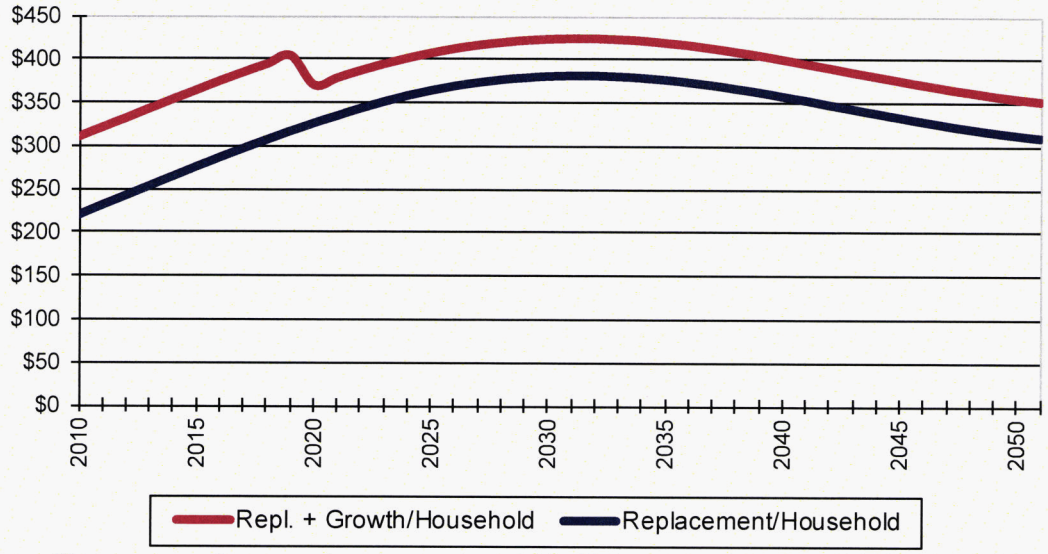


*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

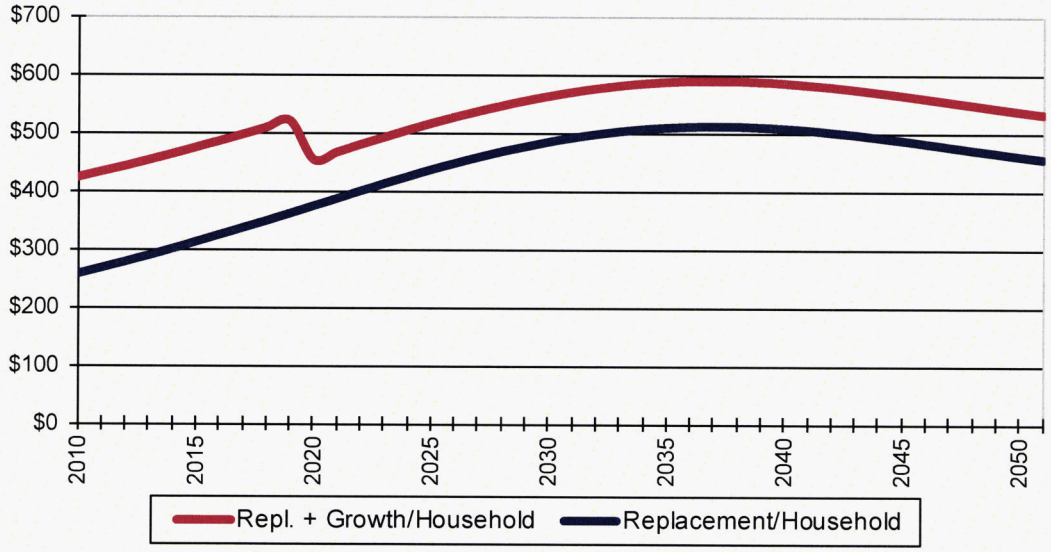
Midwest Small



*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

Household Cost of Needed Investment for Replacement Plus Growth*

Midwest Very Small

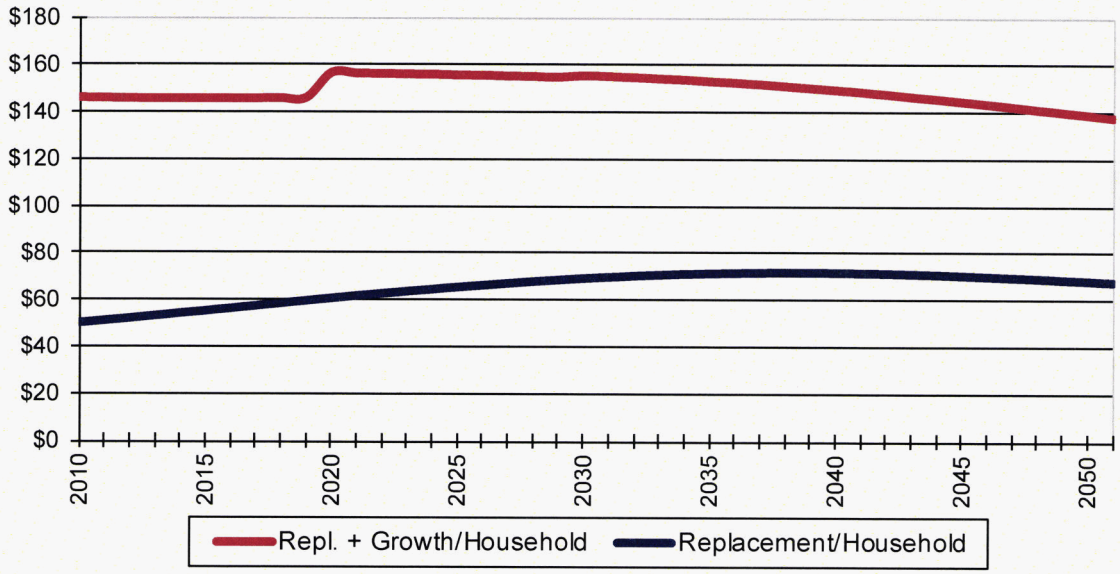


*This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

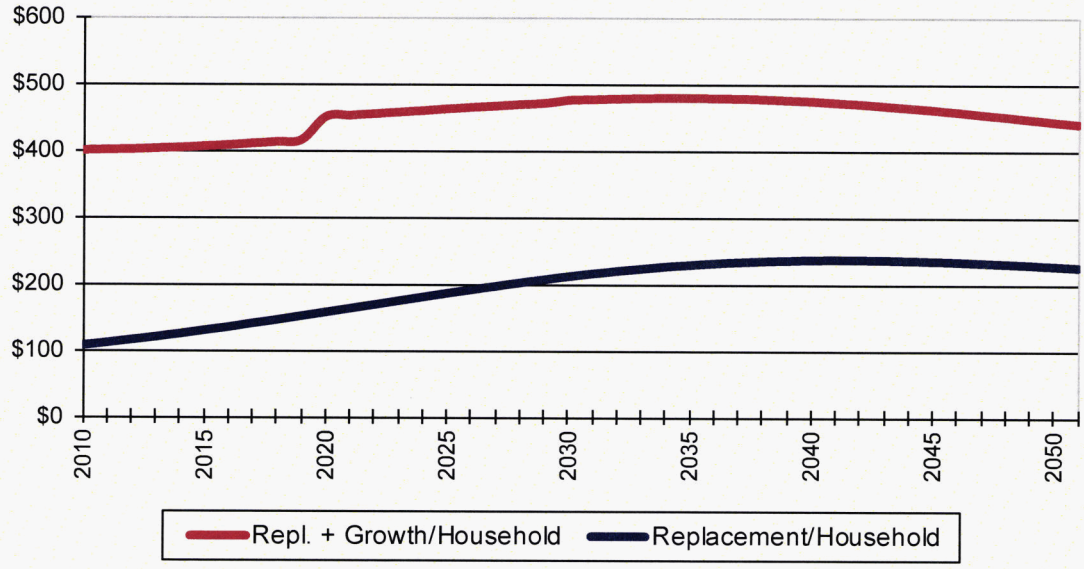
South Large



This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

Household Cost of Needed Investment for Replacement Plus Growth*

South Medium

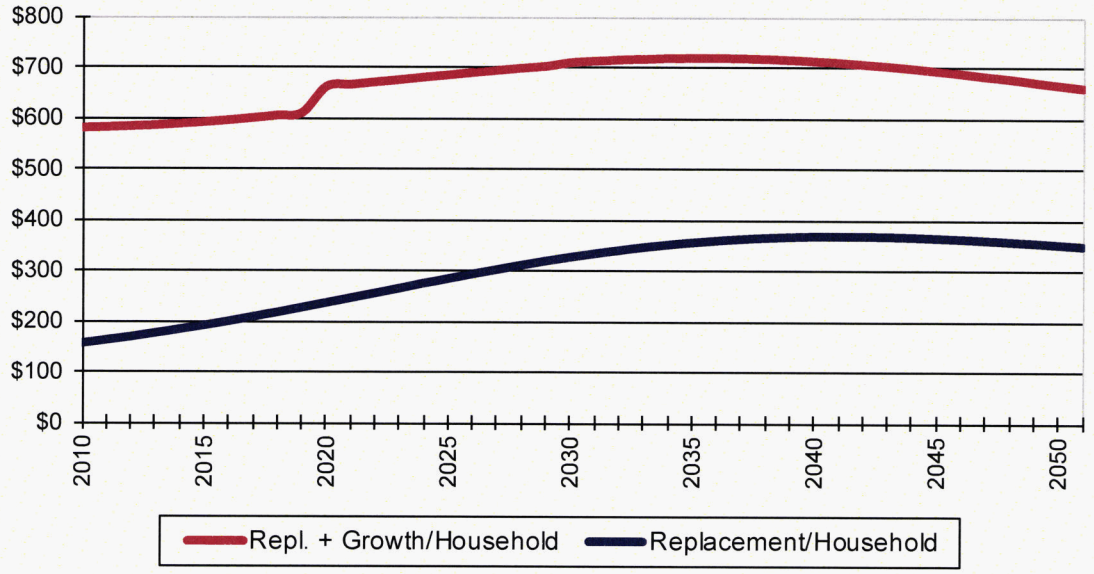


This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

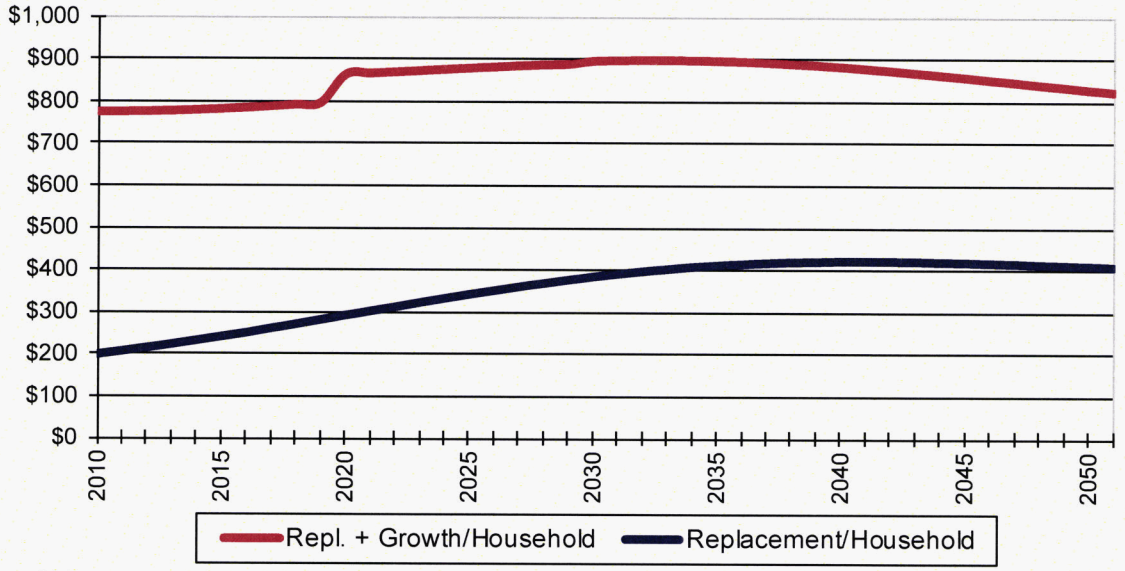
South Small



This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

Household Cost of Needed Investment for Replacement Plus Growth*

South Very Small

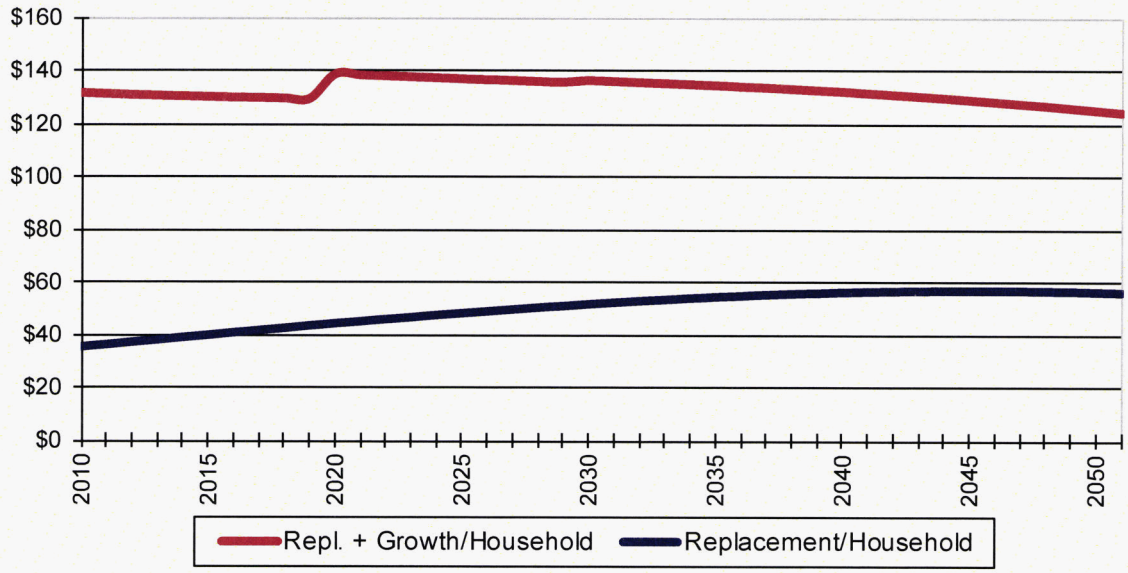


This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

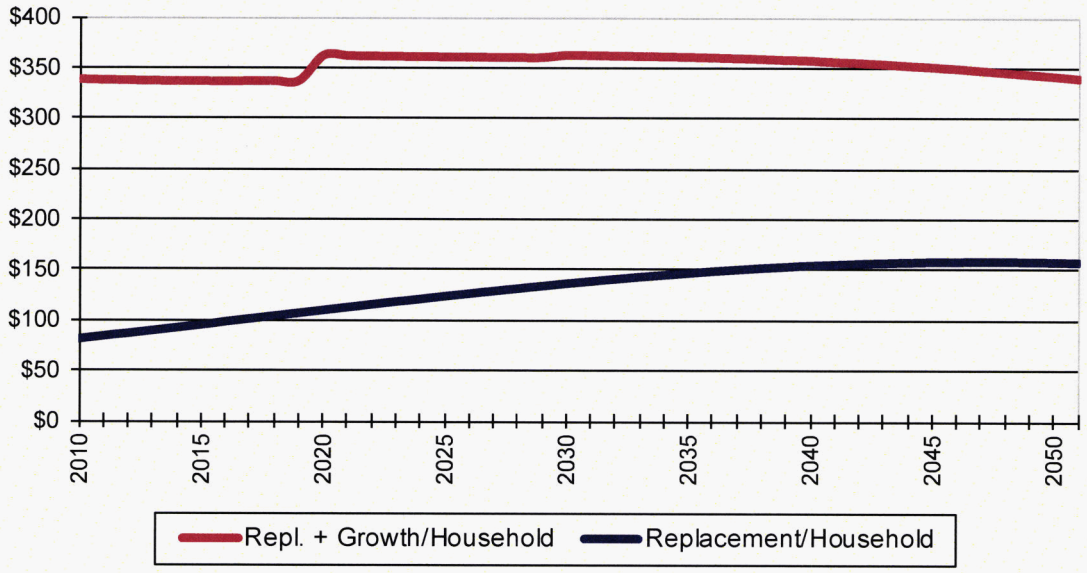
West Large



**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

Household Cost of Needed Investment for Replacement Plus Growth*

West Medium

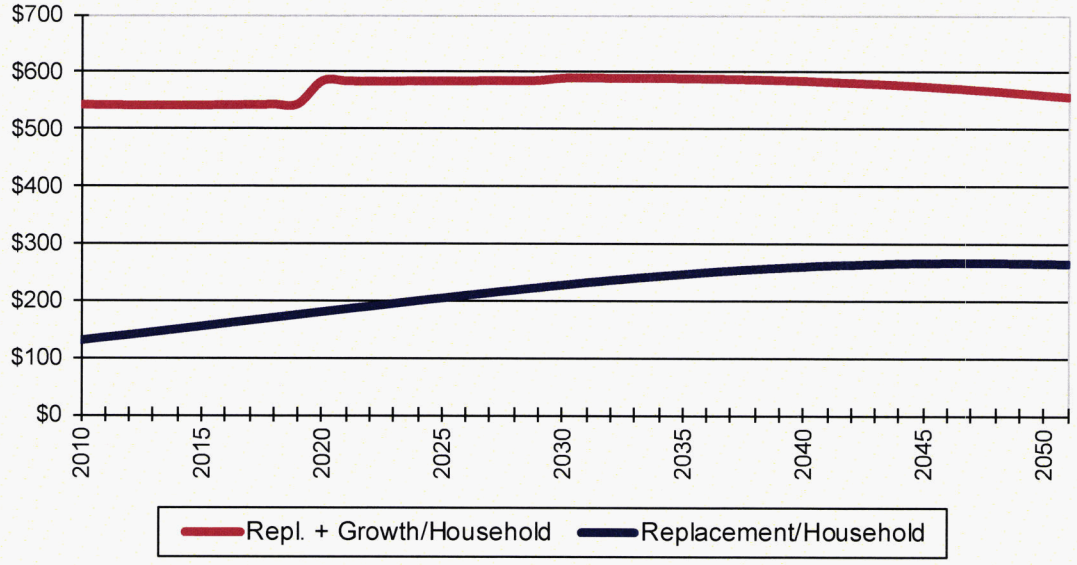


**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

Household Cost of Needed Investment for Replacement Plus Growth*

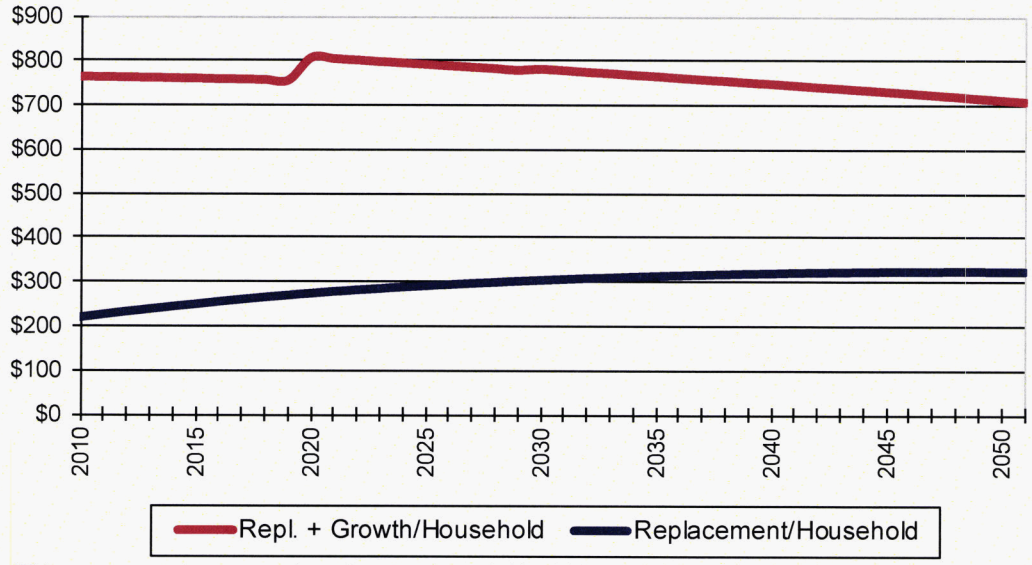
West Small



**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

Household Cost of Needed Investment for Replacement Plus Growth*

West Very Small



**This assumes costs are spread evenly across households of 2.6 persons each, based on data from the US Census.*

The charts show per household costs for replacement, and for replacement plus growth. The model assumes costs are spread evenly over households averaging 2.6 persons per household in accordance with US Census data. An artifact of the model and US Census data result in an apparent upward or downward "spike" in growth-related needs between certain decades. In reality, the apparent sudden shift in growth-related needs will be spread more evenly over the years bridging each decade to the next."

FKS-17

Western Group Rate Case

Exhibit FKS-17

WESTERN GROUP TANK COATING AND INSPECTION SCHEDULE

SITE NAME	YEAR BUILT	MATERIAL	TANK CAPACITY	DIAMETER (Feet)	HEIGHT (Feet)	EXTERIOR COATING (Every 7 years) Next Coating Years		INTERIOR COATING (Every 14 years) Next Coating Year	Cost to Coat Tank Exterior	Cost to Coat Tank Interior
PINAL VALLEY SERVICE AREA										
Tierra Grande Tank No. 2	Unk	Steel	10,000	10	20	2022	2029	2022	$3,011	$4,765
Coolidge Airport	1951	Steel	15,000	12	17	2018	2025	2025	$3,568	$6,021
Well No. 27	1952	Steel	16,000	13	18	2017	2024	2024	$3,743	$6,290
Stanfield Tank No. 3	Unk	Steel	20,000	11	24	2021	2028	2028	$3,959	$6,196
Well No. 29 Settling Tank	2008	Bolted	31,000	19	16	2017	2024	2024	$5,417	$10,067
North Park Tank No. 2	1963	Steel	35,000	13	30	2018	2025	2018	$6,122	$9,567
Well No. 28 Settling Tank	2008	Bolted	35,000	19	18	2017	2024	2024	$5,940	$10,765
Well Nos. 9 and 10 - Dearation Tank	1986	Steel	35,500	12	42	2016	2023	2016	$7,644	$11,388
Henness Road Settling Tank	2007	Bolted	70,000	25	20	2017	2024	2024	$9,319	$17,620
Coolidge Elevated Tank	1929	Steel	100,000	26	25	2022	2029	2029	$11,623	$21,116
Stanfield Tank No. 2	1976	Steel	100,000	27	24	2017	2024	2024	$11,785	$21,773
Scott Drive Tank No. 1	1984	Steel	110,000	19	52	2022	2029	2029	$15,267	$23,357
Well Nos. 9 and 10 Storage Tank	1985	Steel	116,000	50	8	2016	2023	2016	$14,655	$40,321
Cottonwood Lane Settling Tank	2007	Bolted	190,000	33	30	2017	2024	2024	$17,916	$32,941
Tierra Grande Tank No. 3	1987	Steel	250,000	43	24	2016	2023	2016	$21,246	$43,698
Valley Farms	2009	Steel	250,000	50	18	2016	2023	2023	$21,723	$49,746
Well No. 7 Tank No. 3	1950	Steel	500,000	48	37	2017	2024	2024	$33,402	$63,688
North Park Tank No. 1	1985	Steel	650,000	60	30	2017	2024	2024	$38,407	$81,134
Cottonwood Lane	1961	Steel	920,000	74	28	2022	2029	2029	$49,006	$110,860
Well No. 7 Tank No. 2	1978	Steel	1,000,000	69	36	2021	2028	2021	$52,256	$109,251
Henness Road	2006	Steel	1,100,000	90	24	2016	2023	2023	$59,696	$146,926
Burgess Peak	1969	Steel	2,000,000	93	40	2020	2027	2020	$83,503	$183,232
Scott Drive Tank No. 2	1987	Steel	5,000,000	128	52	2018	2025	2018	$153,080	$340,296
Casa Grande Mtn	1978	Steel	5,000,000	147	40	2019	2026	2019	$160,919	$394,181
WHITE TANK										
Monte Vista Settling Tank	2008	Bolted	21,000	16	16	2017	2024	2024	$4,371	$7,825
Monte Vista Tank No. 1	1967	Steel	50,000	19	24	2016	2023	2016	$7,746	$13,329
Monte Vista Tank No. 2	1972	Steel	100,000	28	24	2016	2023	2016	$12,323	$22,947
Blue Horizon Settling Tank	2008	Bolted	106,000	35	15	2018	2025	2025	$11,585	$25,629
Beautiful Az Estates Tank No. 1	1982	Steel	500,000	49	36	2022	2029	2029	$33,298	$64,087
Beautiful Az Estates Tank No. 2	2002	Steel	1,000,000	65	38	2016	2023	2016	$50,129	$101,958
Blue Horizon Tank No. 1	2007	Steel	1,000,000	104	16	2017	2024	2024	$62,462	$173,189
AJO										
Ajo Town Tank No. 2	1956	Steel	250,000	42	24	2016	2023	2016	$20,601	$42,131
Ajo Town Tank No. 1	1981	Steel	500,000	60	24	2019	2026	2019	$33,318	$74,348

Interior Coating Costs = $6.00/sq. ft.
Exterior Coating Costs = $4.50/sq. ft.

WESTERN GROUP TANK COATING AND INSPECTION SCHEDULE

SITE NAME	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	14-Year Costs	Annualized Costs
PINAL VALLEY SERVICE AREA																
Tierra Grande Tank No. 2							$7,776							$3,011		
Coolidge Airport			$3,568							$9,589						
Well No. 27		$3,743							$10,033							
Stanfield Tank No. 3						$3,959							$10,155			
Well No. 29 Settling Tank		$5,417							$15,484							
North Park Tank No. 2			$15,689							$6,122						
Well No. 28 Settling Tank		$5,940							$16,704							
Well Nos. 9 and 10 - Dearation Tank	$19,032							$7,644								
Henness Road Settling Tank		$9,319							$26,939							
Coolidge Elevated Tank							$11,623							$32,739		
Stanfield Tank No. 2		$11,785							$33,559							
Scott Drive Tank No. 1							$15,267							$38,624		
Well Nos. 9 and 10 Storage Tank	$54,976							$17,916								
Cottonwood Lane Settling Tank		$2,017							$50,857							
Tierra Grande Tank No. 3	$64,944							$21,246								
Valley Farms	$21,723							$71,469								
Well No. 7 Tank No. 3		$33,402							$97,090							
North Park Tank No. 1		$38,407							$119,541							
Cottonwood Lane							$49,006							$159,866		
Well No. 7 Tank No. 2						$161,507							$52,256			
Henness Road	$59,696							$206,622								
Burgess Peak					$183,232							$83,503				
Scott Drive Tank No. 2			$493,376							$153,080						
Casa Grande Mtn				$555,101							$160,919					
	$220,371	**$110,030**	**$512,633**	**$555,101**	**$183,232**	$165,466	$83,672	**$324,897**	**$370,207**	**$168,791**	**$160,919**	**$83,503**	**$62,412**	**$234,240**	**$3,235,473**	**$231,105**
WHITE TANK																
Monte Vista Settling Tank		$4,371							$12,196							
Monte Vista Tank No. 1	$7,746							$21,075								
Monte Vista Tank No. 2	$12,323							$35,270								
Blue Horizon Settling Tank			$11,585							$37,213						
Beautiful Az Estates Tank No. 1							$33,298							$97,385		
Beautiful Az Estates Tank No. 2	$50,129							$152,087								
Blue Horizon Tank No. 1		$62,462							$235,651							
	$70,198	**$66,833**	**$11,585**	**$0**	**$0**	**$0**	$33,298	$208,432	$247,847	**$37,213**	**$0**	**$0**	**$0**	**$97,385**	**$772,790**	**$55,199**
AJO																
Ajo Town Tank No. 2	$62,731							$20,601								
Ajo Town Tank No. 1				$107,666							**$74,348**					
	$62,731	$0	**$0**	**$107,666**	**$0**	**$0**	**$0**	**$20,601**	**$0**	**$0**	$74,348	**$0**	**$0**	**$0**	**$265,346**	**$18,953**

Interior Coating Costs = $6.00/sq. ft.
Exterior Coating Costs = $4.50/sq. ft.

Western Group Rate Case

Exhibit FKS-18

Nitrates and Nitrites

TEACH Chemical Summary

U.S. EPA, Toxicity and Exposure Assessment for Children's Health

This TEACH Chemical Summary is a compilation of information derived primarily from U.S. EPA and ATSDR resources, and the TEACH Database. The TEACH Database contains summaries of research studies pertaining to developmental exposure and/or health effects for each chemical or chemical group. TEACH does not perform any evaluation of the validity or quality of these research studies. Research studies that are specific for adults are not included in the TEACH Database, and typically are not described in the TEACH Chemical Summary.

I. INTRODUCTION

Nitrates and nitrites are chemicals used in fertilizers, in rodenticides (to kill rodents), and as food preservatives (1-5). Nitrates and nitrites come in various forms, but when dried are typically a white or crystalline powder. Nitrate (NO_3^-) and nitrite (NO_2^-) are also naturally-occurring compounds that are a metabolic product of microbial digestion of wastes containing nitrogen, for example, animal feces or nitrogen-based fertilizers (2, 4). Sodium and potassium nitrates are used as fumigants in canisters, which are placed underground in rodent dens and holes, and then ignited to explode and release gases that kill the rodents (1, 3). Sodium nitrite is a food additive that is used as a preservative (4, 5).

Likely exposure pathways for children include ingesting contaminated drinking water, most commonly of concern for private wells (4); and foods containing preservatives, particularly cured meats such as hot dogs and lunch meats (4-7). Nitrates have also been detected in fruits and vegetables (6, 8-10).

Exposure to nitrates and nitrites at levels above health-based risk values (see Section VI in this Chemical Summary) has been reported to have adverse health effects on infants and children. The health effect of most concern to the U.S. EPA for children is the "blue baby syndrome" (methemoglobinemia) seen most often in infants exposed to nitrate from drinking water used to make formula (11). Infants of ages 0-3 months are at highest risk for blue baby syndrome because their normal intestinal flora contribute to the generation of methemoglobin; older children and adults can experience this syndrome, but at higher concentrations of nitrates (2, 4). The blue baby syndrome is named for the blue coloration of the skin of babies who have high nitrate concentrations in their blood. The nitrate binds to hemoglobin (the compound which carries oxygen in blood to tissues in the body), and results in chemically-altered hemoglobin (methemoglobin) that impairs oxygen delivery to tissues, resulting in the blue color of the skin (4, 12). The blue coloration can be seen in the lips, nose, and ears in early stages of blue baby syndrome, and extend to peripheral tissues in more severe cases. Reduced oxygenation of the tissues can have numerous adverse implications for the child, the most severe of which are coma and death (4).

Exposure to higher levels of nitrates or nitrites has been associated with increased incidence of cancer in adults, and possible increased incidence of brain tumors, leukemia, and nasopharyngeal (nose and throat) tumors in children in some studies (8, 9, 11, 13-19) but not others (20-29). The U.S. EPA concluded that there was conflicting evidence in the literature as to whether exposures to nitrate or nitrites are associated with cancer in adults and in children (1, 2).

II. EXPOSURE MEDIA AND POTENTIAL FOR CHILDREN'S EXPOSURE[1]

Exposure Media	Relative Potential for Children's Exposure[2,3]	Basis[4]
Diet	Higher	Use of nitrate fertilizer on crops can result in higher concentrations in some foods. Nitrites and, less often, nitrates are used as preservatives in foods such as cured meats, for example, bacon and salami. Nitrates have been found in vegetables and some baby foods that contain vegetables.
Groundwater	Medium	Nitrates and nitrites in fertilizers readily migrate from fertilized soil to groundwater.
Drinking Water	Medium	For many situations, the potential for children's exposure from drinking water is medium to low. The potential can be higher when private wells become contaminated with nitrates from feed lot and agricultural runoff, and contaminated groundwater. Some geographic areas are at higher risk of drinking water contamination of private wells with nitrates.
Sediment	Lower	Nitrates and nitrites are highly water soluble and therefore less likely to partition to sediment.
Soil	Lower	Nitrates and nitrites are not retained in soil and quickly partition to any water phase.
Ambient Air	Lower	Nitrates and nitrites are not volatile and are not generally released into the air. Registered users of fumigant canisters containing nitrates for killing of rodents follow strict use protocols that limit exposure to fumes from its use.
Indoor Air	Lower	Nitrates and nitrites are not usually released in indoor air. Use of nitrite or nitrate inhalants from commercial products in the home may be a concern for adolescents.

[1] For more information about child-specific exposure factors, please refer to the Child-Specific Exposure Factors Handbook (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55145).

[2] The Relative Potential for Children's Exposure category reflects a judgment by TEACH Workgroup, U.S. EPA, that incorporates potential exposure pathways, frequency of exposure, level of exposure, and current state of knowledge. Site-specific conditions may vary and influence the relative potential for exposure. For more information on how these determinations were made, go to http://www.epa.gov/teach/teachprotocols_chemsumm.html.

[3] Childhood represents a lifestage rather than a subpopulation, the distinction being that a subpopulation refers to a portion of the population, whereas a lifestage is inclusive of the entire population.

[4] Information described in this column was derived from several resources (e.g., 1-5) including studies listed in the TEACH Database (http://www.epa.gov/teach).

III. TOXICITY SUMMARY[5, 6]

Reduced oxygenation of hemoglobin (methemoglobinemia) has been reported after exposure to nitrate- and nitrite-contaminated drinking water; also called the "blue baby syndrome" because of the cyanotic (oxygen-deficient) symptoms that result from the reduced oxygenation of the blood (2, 4). Infants less than 4 months old are the most sensitive population for methemoglobinemia following exposure to nitrates and nitrites, but it does occur in older age groups (12, 13, 30-33). Severe methemoglobinemia can lead to coma or death (2, 4).

Other health effects following fetal exposure to elevated levels of nitrates in drinking water included intrauterine growth retardation (34), increased incidence of Sudden Infant Death Syndrome (SIDS) (35), cardiac defects (36), and increased risk of nervous system defects (37-40).

The U.S. EPA concluded that there was conflicting evidence in the literature as to whether exposures to nitrate or nitrites are associated with cancer in adults and in children (1, 2). The types of cancers studied included non-Hodgkin's lymphoma as well as stomach and gastric cancers in adults (11); and brain tumors, leukemia, and nasopharyngeal cancers in children (13-18, 20-25, 28, 29). Maternal (during pregnancy) or child consumption of nitrite-containing meats may be associated with increased incidence of brain tumors in children (for more details, see Human Exposures and Effects section) (13, 15-17).

A few studies have reported other health effects that are possibly associated with nitrate exposure in children, including increased incidence of childhood diabetes (41), recurrent diarrhea (42), and recurrent respiratory tract infections (43). Other reported effects of chronic exposure reported in adults include frequent urination and spleen hemorrhaging (bleeding) (2, 4). Acute high dose ingestion exposure to nitrates can cause abdominal pain, muscle weakness, blood in stools and urine, fainting, and death (4).

Carcinogenicity Weight-of-Evidence Classification[7]: There is no weight-of-evidence classification in the U.S. EPA IRIS file available at this time for either nitrates (http://www.epa.gov/iris/subst/0076.htm) or nitrites (http://www.epa.gov/iris/subst/0078.htm). The World Health Organization International Agency for Research on Cancer (IARC) ranked nitrates and nitrites high on the priority list for upcoming review of possible carcinogenicity of ingested nitrates and nitrites (http://monographs.iarc.fr/ENG/Meetings/prioritylist.pdf).

[5] Please refer to research article summaries listed in the TEACH Database for details about study design considerations (e.g., dose, sample size, exposure measurements).

[6] This toxicity summary is likely to include information from workplace or other studies of mature (adult) humans or experimental animals if child-specific information is lacking for the chemical of interest. Summaries of articles focusing solely on adults are not listed in the TEACH Database because the TEACH Database contains summaries of articles pertaining to developing organisms.

[7] For recent information pertaining to carcinogen risk assessment during development, consult "Guidelines for Carcinogen Risk Assessment and Supplemental Guidance on Risks from Early Life Exposure" at *http://www.epa.gov/cancerguidelines*.

IV. EXPOSURE AND TOXICITY STUDIES FROM THE TEACH DATABASE

This section provides a brief description of human and animal studies listed in the TEACH Database. These descriptions generally include the overall conclusion in each study without evaluation or assessment of scientific merit by TEACH. For more details about doses and exposure levels, query the TEACH Database. Any consideration of adverse events should include an understanding of the relative exposure on a body weight basis. In many cases, exposure levels in animal studies are greater than exposure levels normally encountered by humans.

A. *HUMAN EXPOSURE AND EFFECTS*

- Nitrate contamination of drinking water is of special concern in agricultural areas (4, 12, 30, 44, 45). Nitrate-contaminated drinking water often arises as a result of fertilizers applied to crops, which are converted to nitrate in the soil and then seep into groundwater and into private residential wells. Of particular concern is proximity of animal feed lots to some groundwater sources of drinking water, which may lead to groundwater contamination with nitrates from run-off from these feed lots (3, 6, 11, 12).
- Nitrates have been measured in foods, and have been detected in vegetables and preserved meats (6-8, 10, 13, 46, 47), and baby foods (9, 48, 49). Nitrate and nitrite intakes for children in Estonia were estimated from measures of nitrate and nitrite concentrations in meat products (50) and in vegetables (10).
- Nitrates have been detected in breast milk, and concentrations increased with increasing consumption of nitrates by the mother (51). Nitrates have also been measured in blood and stools of children (46).
- Nitrite exposure of teens from use of nitrite inhalants (e.g., "poppers" also called amyl nitrate, gasoline, shoe polish, halothane, whippets, and spray paints) has been reported in a survey of teens (52) (See Considerations for Decision Making).
- Measurement of methemoglobin concentrations in blood has been used as a biomarker of effect for infants and children (43). Some studies found an association between concentrations of methemoglobin in blood and nitrate exposure (33, 53), but other studies did not (45, 54).
- Health effects that were significantly associated with nitrate or nitrite exposure during pregnancy include increased incidence of intrauterine growth retardation (34), cardiac defects (36), central nervous system defects (37-40), Sudden Infant Death Syndrome (SIDS) (35), and miscarriage (55).
- The most sensitive health effect endpoint for nitrate exposure is methemoglobinemia in infants, also called "blue baby syndrome". When humans metabolize nitrate, an alternative form of hemoglobin, called methemoglobin, is formed and is detectable in blood. Infants with blue baby syndrome turn blue because their red blood cells, which contain methemoglobin, have a decreased ability to carry oxygen. Blue baby syndrome has been reported following exposure of infants to nitrate-contaminated drinking water (12, 30-33). Infants of ages 0-3 months are at higher risk for blue baby syndrome because their normal intestinal flora contribute to the generation of methemoglobin; older children and adults can experience this syndrome, but at higher concentrations of nitrates (2, 4).

- The U.S. EPA concluded that there was conflicting evidence in the literature as to whether exposures to nitrate or nitrites are associated with cancer in adults and in children (1, 2). Exposures to nitrates or nitrites during pregnancy, and possible associations with incidence of cancer in children, have been studied. Two studies reported that increased risk of brain tumors in children was significantly associated with increased maternal consumption of increasing amounts of cured meats (containing nitrates and nitrites) during pregnancy (13, 17).
- Possible associations between childhood nitrate exposure and cancer have been investigated. Children living in areas with higher nitrate levels in drinking water had higher levels of some forms of chromosomal damage than control children living in areas with lower nitrate levels (56). In some studies, increased incidence of childhood brain cancer (13, 15-18) and nasopharyngeal cancer (21) correlated with childhood nitrate exposure in the diet or drinking water, though other studies found no such correlations for some of the same cancers (20-27). An association between nitrate exposure and incidence of childhood leukemias was found in one study (57) but not in two others (28, 29). Living in areas with high nitrate levels in drinking water during childhood was associated with a higher incidence of testicular cancer (58) or urothelial cancer (a specific cancer of the urogenital tract) (23).
- Effects on other systems in humans have been associated with childhood exposure to nitrates or nitrites (41-43, 59-62). Exposure of children to nitrates or nitrites was associated with increased incidence of childhood diabetes in one study (41), but not others (59-61). Single studies have reported associations between children's exposure to nitrates or nitrites, and recurrent respiratory tract infections (43), increased risk for thyroid disorders during adulthood (59), or recurrent diarrhea (42).

B. EXPERIMENTAL ANIMAL EXPOSURE AND EFFECTS

- Several experimental animal studies of health effects following prenatal exposure to nitrates or nitrites have been reported (all studies summarized here involved exposure via maternal ingestion). Results of studies of teratogenic effects in offspring following maternal exposure to nitrates or nitrites during pregnancy were equivocal. For example, adverse effects were observed in offspring following prenatal exposure, including delays in brain development in the hippocampal region (63), decreased fetal weight gain (64, 65), increased fetal mortality (64), and delayed acquisition of certain behaviors (66). However in other studies, prenatal exposure resulted in no observable teratogenic effects following prenatal exposure to nitrate (67, 68) or nitrite (67, 69).
- Effects of prenatal exposure of mice to nitrites on the hematopoietic (blood cell formation) system revealed increased liver hematopoiesis in fetuses in one study (70). The liver is a major organ for blood cell development in fetuses. In another study, increased levels of methemoglobin were observed in pregnant mothers but not their fetuses following prenatal exposure to nitrite (71).

- Prenatal exposure to mixtures of sodium nitrite with other chemicals may have different effects than each chemical alone. For example, sodium nitrite administered together with ethylurea induced malformations in fetuses, including eye, brain, kidney, and skeletal defects; such malformations were not induced by administration of either chemical alone in this study (72). Increased incidence of brain tumors was observed in hamster offspring following concurrent maternal exposure to nitrite and ethylurea during pregnancy (73, 74). Nitrite and ethylurea are thought to chemically react in the gastrointestinal tract to form the potent carcinogen, ethylnitrosourea (73). Female offspring had a higher incidence of tumors than male offspring (74).

V. CONSIDERATIONS FOR DECISION-MAKERS

This section contains information that may be useful to risk assessors, parents, caregivers, physicians, and other decision-makers who are interested in reducing the exposure and adverse health effects in children for this particular chemical. Information in this section focuses on ways to reduce exposure, assess possible exposure, and, for some chemicals, administer treatment.

- The most likely exposure pathways for children are ingestion of contaminated drinking water and ingestion of food containing preservatives, such as cured meats and hot dogs (2, 4, 5).
- General consumer information on preservatives in food is available from the U.S. FDA (75, 76).
- Some nitrites in household products have been used as inhalants by adolescents and adults to enhance sexual performance, and are commonly called "poppers" (77). Compounds include amyl, butyl, isobutyl, and cyclohexyl nitrites, and are often sold in small brown bottles and labeled as "video head cleaner," "room odorizer," "leather cleaner," or "liquid aroma" (77).
- The U.S. EPA Oral Reference Dose (RfD) and the Maximum Contaminant Level (MCL) for drinking water (see Toxicity Reference Values in this document) are set to prevent methemoglobinemia in infants, the most sensitive health endpoint in children (78).
- The MCL is 1 mg/L for nitrites and 10 mg/L for nitrates in drinking water. As a potential health effect, the U.S. EPA states that, "Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die" (78). The U.S. EPA makes the same statement for nitrite in water (78).
- Caregivers may consider an alternate water supply, e.g. bottled water, where nitrate-contaminated ground water may be impacting drinking water.
- The U.S. EPA regulates public water systems, and does not have the authority to regulate private drinking water wells that serve fewer than 25 people (79). Some states may have rules to protect users of these wells. The U.S. EPA urges owners of private wells to have their well water tested annually and more often if someone in the household is pregnant or nursing. The U.S. EPA urges owners to test their well water for nitrate concentrations and several other contaminants (80).
- Nitrates are not filtered out of drinking water using filtration devices that utilize only carbon or activated carbon filtration. Nitrates can be filtered from drinking water using ion exchange, reverse osmosis, or electrolysis methods (81).

- A Nitrate/Nitrite Toxicity Case Study in Environmental Medicine is available from the U.S. Agency for Toxic Substances and Diseases Registry (ATSDR), which provides clinical information for physicians on the diagnosis and treatment of nitrate and nitrite toxicity. Details of a case study of a 2 month-old infant with blue baby syndrome is included (4).
- Consult the "Child-Specific Exposure Factors Handbook," EPA-600-P-00-002B, for factors to assess children's drinking water consumption rates (82). An updated External Draft of the 2006 version of this handbook is available (83).

VI. TOXICITY REFERENCE VALUES

Oral/Ingestion

U.S. EPA Reference Dose (RfD) for Chronic Oral Exposure:

Nitrate, 1.6 mg/kg-day, based on the critical effect of early clinical signs of methemoglobinemia in infants (excess of 10%) 0-3 months of age exposed to nitrate in infant formula (http://www.epa.gov/iris/subst/0076.htm, I.A.I.) (11). Last agency verification date 8/22/90.

Nitrite, 1E-1 (or 0.1) mg/kg-day, based on methemoglobinemia in infants chronically exposed to nitrite in drinking water (http://www.epa.gov/iris/subst/0078.htm, I.A.I.) (84). Last agency verification date 2/26/86.

U.S. EPA Drinking Water Advisories (4 kg child):

Nitrate, 1 day=10 mg/kg and 10 day=10 mg/kg;

Nitrite, 1 day=1 mg/kg and 10 day=1 mg/kg (http://www.epa.gov/ost/drinking/standards/dwstandards.pdf, p. 9) (85). Last revised Winter, 2006.

U.S. EPA Maximum Contaminant Level (MCL) for Drinking Water:

Nitrate, 10 mg/L; nitrite, 1 mg/L.

Both are based on potential health effects of shortness of breath and blue baby syndrome in infants (http://www.epa.gov/safewater/mcl.html#mcls) (86). Last revised 7/02.

U.S. EPA Maximum Contaminant Level Goal (MCLG):

Nitrate, 10 mg/L; nitrite, 1 mg/L.

Both are based on potential health effects of shortness of breath and blue baby syndrome in infants (http://www.epa.gov/safewater/mcl.html#mcls) (86). Last revised 7/02.

VII. U.S. FEDERAL REGULATORY INFORMATION

- The reference value, U.S. EPA Drinking Water Advisory for a 4 kg Child, for both nitrate and nitrite were recently revised. The 1-day and 10-day values for nitrate are both 10 mg/kg, and for nitrite are both 1 mg/kg (see Toxicity Reference Values).
- The U.S. EPA regulates drinking water for public water systems and drinking water wells that serve at least 25 people (79); information is available for owners of private wells (80).
- Nitrite and nitrate are listed as number 216 and 219 respectively out of 275 chemicals on the 2005 Priority List of Hazardous Substances for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) section 104 (i), as amended by the Superfund Amendments and Reauthorization Act (SARA). This is a list in the order of priority of concern of substances most commonly found at sites listed on the National Priorities list (NPL); there are currently 275 substances on this list (87).
- The U.S. EPA requires reporting of quantities of certain chemicals that exceed a defined reportable quantity, and that quantity varies for different chemicals. Under the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313 "Toxic Chemicals," quantities of nitrate compounds (water soluble) or sodium nitrite greater than 25,000 pounds manufactured or processed, or greater than 10,000 pounds otherwise used, is required; under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), reporting releases of sodium nitrite of any quantity exceeding 100 pounds is required (88).

VIII. BACKGROUND ON CHEMICAL

A. CAS Number: Nitrate 14797-55-8; **Nitrite** 14797-65-0.

B. Physicochemical Properties: Nearly all nitrate and nitrite salts are soluble in water, and occur as a whitish powder when not dissolved in water (5). Go to the National Library of Medicine ChemID Web site (*http://chem.sis.nlm.nih.gov/chemidplus*) and search for nitrate or nitrite.

C. Production: Fertilizers comprise the majority of environmental releases of inorganic sources of nitrates (5). Total U.S. reported releases of nitrate compounds totaled over 291 million pounds in 2005 (89).

D. Uses: Primary sources of organic nitrates in the environment include human sewage and livestock manure (5). Sources of inorganic nitrates in the environment include potassium nitrate and ammonium nitrate, which may leach to ground water and contaminate private residential drinking water wells (3, 5). Potassium nitrates are mainly used as fertilizers and may also be used in heat transfer salts, glass and ceramics, rodenticides, and in matches and fireworks (2). Ammonium nitrates are mostly used as fertilizers, but also in explosives and blasting agents (2).

E. Environmental Fate: Nitrates are very mobile in soil and have a high potential to migrate to ground water due to high solubility in water and weak retention by soil (3, 5). Nitrates and nitrites do not volatilize and therefore are likely to remain in water until consumed by plants or other organisms (3). Ammonium nitrate is taken up by bacteria, and nitrate degradation is fastest under anaerobic conditions (5). Nitrite is easily oxidized to nitrate, and nitrate is the more predominant compound of the two detected in groundwater (4).

Additional information on nitrates and nitrites is available in the TEACH Database and at the following Web sites:

www.epa.gov/iris/subst/0076.htm
www.epa.gov/iris/subst/0078.htm
www.epa.gov/safewater/dwh/c-ioc/nitrates.html

REFERENCES

1. U.S. Environmental Protection Agency. 1991. "Reregistration Eligibility Decision: Inorganic Nitrate/Nitrite (Sodium and Potassium Nitrates)." http://www.epa.gov/oppsrrd1/REDs/old_reds/4052red.pdf.
2. U.S. Environmental Protection Agency Ground Water and Drinking Water. 2006. "Consumer Factsheet on: Nitrates/Nitrites." http://www.epa.gov/safewater/dwh/c-ioc/nitrates.html.
3. U.S. Environmental Protection Agency Pesticides and Toxic Substances. 1991. "R.E.D. Facts: Inorganic Nitrates/Nitrite (Sodium and Potassium Nitrates)." http://www.epa.gov/oppsrrd1/REDs/factsheets/4052fact.pdf.
4. U.S. Agency for Toxic Substances and Diseases Registry. 2001. "Case Studies in Environmental Medicine: Nitrate/Nitrite Toxicity." http://www.atsdr.cdc.gov/HEC/CSEM/nitrate/docs/nitrate_nitrite.pdf.
5. World Health Organization. 2006. "International Program on Chemical Safety, Environmental Health Criteria 5: Nitrates, Nitrites, and N-Nitroso Compounds." http://www.inchem.org/documents/pims/chemical/pimg016.htm.
6. Laitinen, S., et al. 1993. "Calculated dietary intakes of nitrate and nitrite by young Finns." Food Addit.Contam 10(4):469-477.
7. Reinik, M., et al. 2005. "Nitrites, nitrates and N-nitrosoamines in Estonian cured meat products: intake by Estonian children and adolescents." Food Addit.Contam 22(11):1098-1105.
8. Sanchez-Echaniz, J., et al. 2001. "Methemoglobinemia and consumption of vegetables in infants." Pediatrics 107(5):1024-1028.
9. Dusdieker, L.B., et al. 1994. "Nitrate in baby foods. Adding to the nitrate mosaic." Arch.Pediatr.Adolesc.Med. 148(5):490-494.
10. Tamme, T., et al. 2006. "Nitrates and nitrites in vegetables and vegetable-based products and their intakes by the Estonian population." Food Addit.Contam 23(4):355-361.
11. U.S. Environmental Protection Agency. 1991. "Integrated Risk Information System (IRIS): Nitrate." http://www.epa.gov/iris/subst/0076.htm.
12. Knobeloch, L., et al. 2000. "Blue babies and nitrate-contaminated well water." Environ.Health Perspect. 108(7):675-678.
13. Preston-Martin, S., et al. 1996. "Maternal consumption of cured meats and vitamins in relation to pediatric brain tumors." Cancer Epidemiol.Biomarkers Prev. 5(8):599-605.
14. Ward, M.H., et al. 2000. "Dietary exposure to nitrite and nitrosamines and risk of nasopharyngeal carcinoma in Taiwan." Int.J.Cancer 86(5):603-609.
15. Pogoda, J.M., and S. Preston-Martin. 2001. "Maternal cured meat consumption during pregnancy and risk of paediatric brain tumour in offspring: potentially harmful levels of intake." Public Health Nutr. 4(2):183-189.
16. Sarasua, S., and D.A. Savitz. 1994. "Cured and broiled meat consumption in relation to childhood cancer: Denver, Colorado (United States)." Cancer Causes Control 5(2):141-148.
17. McCredie, M., et al. 1994. "Antenatal risk factors for malignant brain tumours in New South Wales children." Int.J.Cancer 56(1):6-10.
18. Preston-Martin, S., et al. 1982. "N-Nitroso compounds and childhood brain tumors: a case-control study." Cancer Res. 42(12):5240-5245.
19. Volkmer, B.G., et al. 2005. "Influence of nitrate levels in drinking water on urological malignancies: a community-based cohort study." BJU.Int 95(7):972-976.

20. Bunin, G.R., et al. 1994. "Maternal diet and risk of astrocytic glioma in children: a report from the Childrens Cancer Group (United States and Canada)." Cancer Causes Control 5(2):177-187.
21. Bunin, G.R., et al. 1993. "Relation between maternal diet and subsequent primitive neuroectodermal brain tumors in young children." N.Engl.J.Med. 19;329(8):536-541.
22. Mueller, B.A., et al. 2001. "Residential water source and the risk of childhood brain tumors." Environ.Health Perspect. 109(6):551-556.
23. Lubin, F., et al. 2000. "The role of nutritional habits during gestation and child life in pediatric brain tumor etiology." Int.J.Cancer 86(1):139-143.
24. Howe, G.R., et al. 1989. "An exploratory case-control study of brain tumors in children." Cancer Res. 49(15):4349-4352.
25. Kuijten, R.R., et al. 1990. "Gestational and familial risk factors for childhood astrocytoma: results of a case-control study." Cancer Res. 50(9):2608-2612.
26. Kean-Cowdin, R., et al. 2003. "Maternal prenatal exposure to nitrosatable drugs and childhood brain tumours." Int.J.Epidemiol. 32(2):211-217.
27. Mueller, B.A., et al. 2004. "Household water source and the risk of childhood brain tumours: results of the SEARCH International Brain Tumor Study." Int.J.Epidemiol. 33(6):1209-1216.
28. Infante-Rivard, C., et al. 2001. "Drinking water contaminants and childhood leukemia." Epidemiology 12(1):13-19.
29. Law, G., et al. 1999. "Non-Hodgkin's lymphoma and nitrate in drinking water: a study in Yorkshire, United Kingdom." J.Epidemiol.Community Health 53(6):383-384.
30. Knobeloch, L., and M. Proctor. 2001. "Eight blue babies." WMJ. 100(8):43-47.
31. Savino, F., et al. 2006. "Methemoglobinemia caused by the ingestion of courgette soup given in order to resolve constipation in two formula-fed infants." Ann Nutr.Metab 50(4):368-371.
32. Jones, J.H., et al. 1973. "Grandmother's poisoned well: report of a case of methemoglobinemia in an infant in Oklahoma." J.Okla.State Med.Assoc. 66(2):60-66.
33. MMWR. 1997. "Methemoglobinemia Attributable to Nitrite Contamination of Potable Water Through Boiler Fluid Additives - New Jersey, 1992-1996." Morbidity and Mortality Weekly Report March 7, 1997.
34. Bukowski, J., et al. 2001. "Agricultural contamination of groundwater as a possible risk factor for growth restriction or prematurity." J.Occup.Environ.Med. 43(4):377-383.
35. George, M., et al. 2001. "Incidence and geographical distribution of sudden infant death syndrome in relation to content of nitrate in drinking water and groundwater levels." Eur.J.Clin.Invest 31(12):1083-1094.
36. Cedergren, M.I., et al. 2002. "Chlorination byproducts and nitrate in drinking water and risk for congenital cardiac defects." Environ.Res. 89(2):124-130.
37. Arbuckle, T.E., et al. 1988. "Water nitrates and CNS birth defects: a population-based case-control study." Arch.Environ.Health 43(2):162-167.
38. Dorsch, M.M., et al. 1984. "Congenital malformations and maternal drinking water supply in rural South Australia: a case-control study." Am.J.Epidemiol. 119(4):473-486.
39. Croen, L.A., et al. 2001. "Maternal exposure to nitrate from drinking water and diet and risk for neural tube defects." Am.J.Epidemiol. 153(4):325-331.
40. Brender, J.D., et al. 2004. "Dietary nitrites and nitrates, nitrosatable drugs, and neural tube defects." Epidemiology 15(3):330-336.
41. Virtanen, S.M., et al. 1994. "Nitrate and nitrite intake and the risk for type 1 diabetes in Finnish children. Childhood Diabetes in Finland Study Group." Diabet.Med. 11(7):656-662.

42. Gupta, S.K., et al. 2001. "Recurrent diarrhea in children living in areas with high levels of nitrate in drinking water." Arch.Environ.Health 56(4):369-373.
43. Gupta, S.K., et al. 2000. "Recurrent acute respiratory tract infections in areas with high nitrate concentrations in drinking water." Environ.Health Perspect. 108(4):363-366.
44. Gelberg, K.H., et al. 1999. "Nitrate levels in drinking water in rural New York State." Environ.Res. 80(1):34-40.
45. Craun, G.F., et al. 1981. "Methaemoglobin levels in young children consuming high nitrate well water in the United States." Int.J.Epidemiol. 10(4):309-317.
46. Zeman, C.L., et al. 2002. "Exposure methodology and findings for dietary nitrate exposures in children of Transylvania, Romania." J.Expo.Anal.Environ.Epidemiol. 12(1):54-63.
47. Tosun, I., and N.S. Ustun. 2004. "Nitrate content of lettuce grown in the greenhouse." Bull.Environ.Contam Toxicol. 72(1):109-113.
48. McMullen, S.E., et al. 2005. "Ion chromatographic determination of nitrate and nitrite in vegetable and fruit baby foods." J AOAC Int 88(6):1793-1796.
49. Casanova, J.A., et al. 2006. "Use of Griess reagent containing vanadium(III) for post-column derivatization and simultaneous determination of nitrite and nitrate in baby food." J AOAC Int 89(2):447-451.
50. Reinik, M., et al. 2005. "Nitrites, nitrates and N-nitrosoamines in Estonian cured meat products: intake by Estonian children and adolescents." Food Addit.Contam 22(11):1098-1105.
51. Dusdieker, L.B., et al. 1996. "Does increased nitrate ingestion elevate nitrate levels in human milk?" Arch.Pediatr.Adolesc.Med. 150(3):311-314.
52. Wu, L.T., et al. 2005. "Use of nitrite inhalants ("poppers") among American youth." J Adolesc.Health 37(1):52-60.
53. Gupta, S.K., et al. 1999. "Adaptation of cytochrome-b5 reductase activity and methaemoglobinaemia in areas with a high nitrate concentration in drinking-water." Bull.World Health Organ 77(9):749-753.
54. Shearer, L.A., et al. 1972. "Methemoglobin levels in infants in an area with high nitrate water supply." Am.J.Public Health 62(9):1174-1180.
55. MMWR. 1996. "Spontaneous Abortions Possibly Related to Ingestion of Nitrate-Contaminated Well Water - LaGrange County, Indiana, 1991-94." Morbidity and Mortality Weekly Report 45(26):July 5, 1996.
56. Tsezou, A., et al. 1996. "High nitrate content in drinking water: cytogenetic effects in exposed children." Arch.Environ.Health 51(6):458-461.
57. Thorpe, N., and A. Shirmohammadi. 2005. "Herbicides and nitrates in groundwater of Maryland and childhood cancers: a geographic information systems approach." J Environ Sci Health C.Environ Carcinog.Ecotoxicol.Rev. 23(2):261-278.
58. Moller, H. 1997. "Work in agriculture, childhood residence, nitrate exposure, and testicular cancer risk: a case-control study in Denmark." Cancer Epidemiol.Biomarkers Prev. 6(2):141-144.
59. van Maanen, J.M., et al. 2000. "Does the risk of childhood diabetes mellitus require revision of the guideline values for nitrate in drinking water?" Environ.Health Perspect. 108(5):457-461.
60. Moltchanova, E., et al. 2004. "Zinc and nitrate in the ground water and the incidence of Type 1 diabetes in Finland." Diabet.Med. 21(3):256-261.
61. Schober, E., et al. 2003. "Small area variation in childhood diabetes mellitus in Austria: links to population density, 1989 to 1999." J.Clin.Epidemiol. 56(3):269-273.
62. Tajtakova, M., et al. 2006. "Increased thyroid volume and frequency of thyroid disorders signs in schoolchildren from nitrate polluted area." Chemosphere 62(4):559-564.

63. Nyakas, C., et al. 1994. "Postnatal development of hippocampal and neocortical cholinergic and serotonergic innervation in rat: effects of nitrite-induced prenatal hypoxia and nimodipine treatment." Neuroscience 59(3):541-559.
64. Roth, A.C., et al. 1987. "Evaluation of the developmental toxicity of sodium nitrite in Long-Evans rats." Fundam.Appl.Toxicol. 9(4):668-677.
65. Inoue, T., et al. 2004. "Increases in serum nitrite and nitrate of a few-fold adversely affect the outcome of pregnancy in rats." J.Pharmacol.Sci. 95(2):228-233.
66. Vorhees, C.V., et al. 1984. "Developmental toxicity and psychotoxicity of sodium nitrite in rats." Food Chem.Toxicol. 22(1):1-6.
67. Fan, A.M., and V.E. Steinberg. 1996. "Health implications of nitrate and nitrite in drinking water: an update on methemoglobinemia occurrence and reproductive and developmental toxicity." Regul.Toxicol.Pharmacol. 23(1 Pt 1):35-43.
68. Heindel, J.J., et al. 1994. "Assessment of the reproductive and developmental toxicity of pesticide/fertilizer mixtures based on confirmed pesticide contamination in California and Iowa groundwater." Fundam.Appl.Toxicol. 22(4):605-621.
69. Shimada, T. 1989. "Lack of teratogenic and mutagenic effects of nitrite on mouse fetuses." Arch.Environ.Health 44(1):59-63.
70. Globus, M., and D. Samuel. 1978. "Effect of maternally administered sodium nitrite on hepatic erythropoiesis in fetal CD-1 mice." Teratology 18(3):367-378.
71. Gruener, N., et al. 1973. "Methemoglobinemia induced by transplacental passage of nitrites in rats." Bull.Environ.Contam Toxicol. 9(1):44-48.
72. Dreosti, I.E., et al. 1983. "Teratogenic effect of extended administration of N-nitrosoethylurea and ethylurea/nitrite in rats." Res.Commun.Chem.Pathol.Pharmacol. 41(2):265-281.
73. Rustia, M. 1975. "Inhibitory effect of sodium ascorbate on ethylurea and sodium nitrite carcinogensis and negative findings in progeny after intestinal inoculation of precursors into pregnant hamsters." J.Natl.Cancer Inst. 55(6):1389-1394.
74. Rustia, M., and J. Schenken. 1976. "Transplacental effects of ethylnitrosourea precursors ethylurea and sodium nitrite in hamsters." Cancer Res.Clin.Oncol. 85(3):201-207.
75. U.S. Food and Drug Administration. 1998. "A Fresh Look at Food Preservatives." http://www.cfsan.fda.gov/~dms/fdpreser.html.
76. U.S. Department of Agriculture: Food Safety and Inspection Service. 2001. "Fact Sheets: Food Labeling - Additives in Meat and Poultry Products." http://www.fsis.usda.gov/Fact_Sheets/Additives_in_Meat_&_Poultry_Products/index.asp.
77. National Institute on Drug Research. 2006. "NIDA Community Drug Alert Bulletin - Inhalants." http://www.drugabuse.gov/InhalantsAlert/index.html.
78. U.S. Environmental Protection Agency. 2002. "List of Contaminants and Their MCLs." http://www.epa.gov/safewater/mcl.html#mcls.
79. U.S. Environmental Protection Agency. 2006. "Public Drinking Water Systems Programs." http://www.epa.gov/safewater/pws/index.html.
80. U.S. Environmental Protection Agency. 2006. "Private Drinking Water Wells." http://www.epa.gov/safewater/privatewells/index2.html.
81. U.S. Environmental Protection Agency. 2005. "Health Water Series: Filtration Facts." http://www.epa.gov/safewater/faq/pdfs/fs_healthseries_filtration.pdf.
82. U.S. Environmental Protection Agency. 2002. "Child-Specific Exposure Factors Handbook." http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55145.

83. U.S. Environmental Protection Agency. 2006. "Child-Specific Exposure Factors Handbook 2006 (External Review Draft)." http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=56747.
84. U.S. Environmental Protection Agency. 2007. "Integrated Risk Information System (IRIS): Nitrite." http://www.epa.gov/iris/subst/0078.htm.
85. U.S. Environmental Protection Agency. 2006. "2006 Edition of the Drinking Water Standards and Health Advisories." http://www.epa.gov/waterscience/criteria/drinking/dwstandards.pdf.
86. U.S. Environmental Protection Agency. 2006. "Drinking Water Contaminants." http://www.epa.gov/safewater/contaminants/index.html.
87. U.S. Environmental Protection Agency. 2005. "Priority List of Hazardous Substances for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 104(i)." http://www.atsdr.cdc.gov/cercla/.
88. U.S. Environmental Protection Agency. 2001. "Lists of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act." http://www.epa.gov/ceppo/pubs/title3.pdf.
89. U.S. Environmental Protection Agency. 2006. "TRI Explorer: Providing Access to EPA's Toxic Release Inventory Data." http://www.epa.gov/triexplorer/.

Western Group Rate Case

Exhibit FKS-19

Probability of Nitrate Contamination of Recently Recharged Groundwaters in the Conterminous United States

BERNARD T. NOLAN,*,† KERIE J. HITT,† AND BARBARA C. RUDDY‡

U.S. Geological Survey, 413 National Center, Reston, Virginia 20192, and U.S. Geological Survey, Denver Federal Center, Mail Stop 415, Box 25046, Lakewood, Colorado 80225

A new logistic regression (LR) model was used to predict the probability of nitrate contamination exceeding 4 mg/L in predominantly shallow, recently recharged groundwaters of the United States. The new model contains variables representing (1) N fertilizer loading ($p < 0.001$), (2) percent cropland–pasture ($p < 0.001$), (3) natural log of human population density ($p < 0.001$), (4) percent well-drained soils ($p < 0.001$), (5) depth to the seasonally high water table ($p < 0.001$), and (6) presence or absence of unconsolidated sand and gravel aquifers ($p = 0.002$). Observed and average predicted probabilities associated with deciles of risk are well correlated ($r^2 = 0.875$), indicating that the LR model fits the data well. The likelihood of nitrate contamination is greater in areas with high N loading and well-drained surficial soils over unconsolidated sand and gravels. The LR model correctly predicted the status of nitrate contamination in 75% of wells in a validation data set. Considering all wells used in both calibration and validation, observed median nitrate concentration increased from 0.24 to 8.30 mg/L as the mapped probability of nitrate exceeding 4 mg/L increased from ≤0.17 to >0.83.

Introduction

Groundwater is an important national resource that provides drinking water for more than half of the people in the United States (*1*). Unfortunately, shallow groundwater (typically less than about 5 m in this study) is susceptible to contamination by chemicals derived from the land surface. Nitrate, from both natural and anthropogenic sources, is possibly the most widespread contaminant in groundwater (*2*). Because nitrate is both soluble and mobile, it is prone to leaching through soil with infiltrating water. Nitrate in watersheds is derived primarily from inorganic fertilizer, animal manure, and atmospheric deposition (*3*) and can persist in shallow groundwater for years. Natural sources of nitrate include organic N in plant matter and fixed ammonium in till and loess deposits (*4*, *5*).

Contamination of shallow groundwater is a public-health concern in areas where it is used for drinking. Even if the shallow groundwater in an area is not used for drinking, contaminants can migrate to deeper groundwater supplies. Shallow groundwater is more susceptible to nitrate contamination than deep groundwater, and privately owned domestic wells typically are shallower than public-supply wells and are not routinely monitored for water quality. Nine percent of domestic wells sampled by the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program during 1993–2000 had nitrate concentrations exceeding the U.S. Environmental Protection Agency's (USEPA's) maximum contaminant level (MCL) of 10 mg/L as N (*6*), compared with 2% of public-supply wells. These exceedances are based on 1710 domestic wells and 264 public-supply wells, irrespective of depth to groundwater.

Elevated concentrations of nitrate (greater than 2 mg/L) in drinking water have been associated with adverse health effects. Ingestion of nitrate by infants can cause low oxygen levels in the blood, a potentially fatal condition known as methemoglobinemia or "blue baby" disorder (*7*). For this reason, the USEPA established the MCL of 10 mg/L nitrate as N. Nitrate concentrations of 19–29 mg/L in rural, domestic wells in Indiana might have caused eight spontaneous abortions among four women during 1991–1994 (*8*). Nitrate in drinking water also might increase cancer risk through production of *N*-nitroso compounds in the body, which are highly carcinogenic (*9*). A study of cancer incidence in Iowa women 55–69 years old found that the risk of bladder cancer was 2.83 times higher and the risk of ovarian cancer was 1.84 times higher when nitrate concentration in municipal water supplies exceeded 2.46 mg/L. In another study, nitrate concentrations of 4 mg/L or more in water from community wells in Nebraska increased the risk of non-Hodgkin's lymphoma (*10*). Shallow groundwater unaffected by human activities commonly contains less than 2 mg/L of nitrate (*11*).

Determining where shallow groundwater is at risk of nitrate contamination can help managers decide where to allocate scarce resources for cleanup, monitoring, or implementation of alternative management practices. Logistic regression (LR) has been used extensively in epidemiological studies to predict risk and is becoming more commonplace in environmental applications. Logistic regression differs from classical, linear regression in that the modeled response is the probability of being in a category, rather than the observed quantity of a response variable (*12*)

$$p = \frac{e^{(b_o + \mathbf{bx})}}{1 + e^{(b_o + \mathbf{bx})}} \quad (1)$$

where b_o = constant and $\mathbf{bx}$ = vector of slope coefficients and explanatory variables.

Logistic regression is well-suited to analysis of nondetects because a threshold value is specified to define the response categories and has been successfully applied in prior studies on the risk of groundwater contamination (*13*–*22*). Readers may consult Hosmer and Lemeshow (*23*) and Kleinbaum (*24*) for a detailed discussion of logistic regression.

Logistic regression is an improvement over earlier aquifer vulnerability studies involving geographic information systems (GIS). Prior researchers (*25*) used GIS overlays to estimate the likelihood of nitrate contamination of shallow groundwater in the United States, with statistical verification of resulting risk groups. In ranking and overlay methods, the independent variables are weighted equally. In contrast,

* Corresponding author phone: (703) 648-4000; fax: (703) 648-6693; e-mail: btnolan@usgs.gov.
† U.S. Geological Survey, Reston, VA.
‡ U.S. Geological Survey, Denver, CO.

10.1021/es0113854 Not subject to U.S. copyright. Publ. 2002 Am. Chem.Soc.
Published on Web 04/09/2002

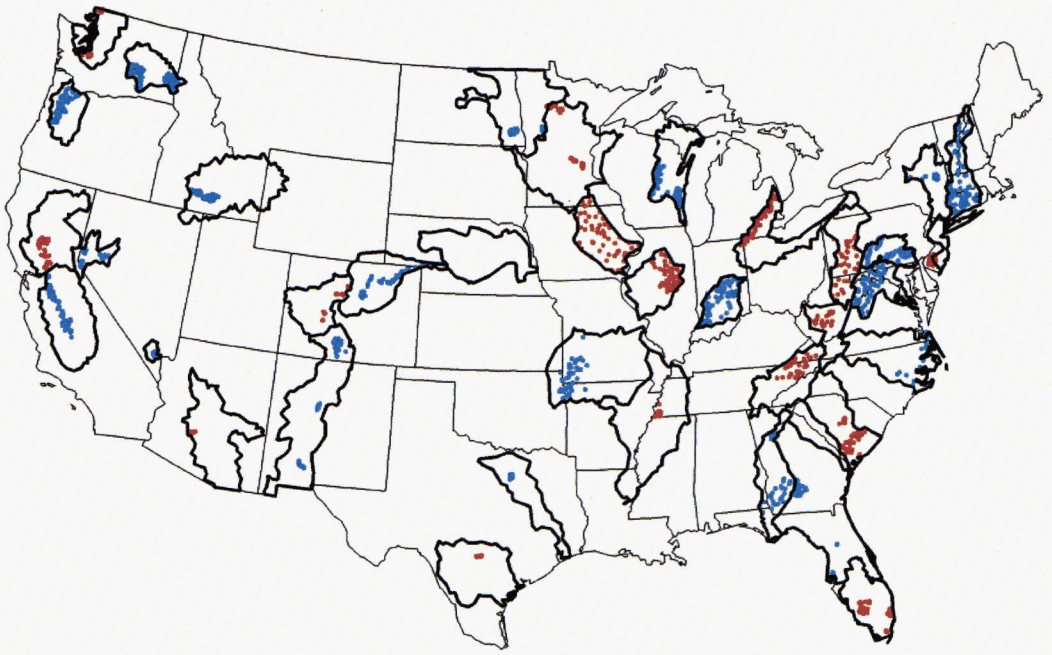


FIGURE 1. Locations of shallow wells comprising calibration and validation data sets used in logistic regression.

logistic regression assigns weights to independent variables by way of slope coefficients estimated using the observed data.

The current study is a follow-up to previous LR work that related variables representing N sources and aquifer susceptibility to elevated nitrate concentration in shallow groundwaters of the United States (*20*). The previous model was developed using data collected from 1230 wells by the first 20 NAWQA study units that began in 1991 and contained the following variables: (1) N fertilizer loading to the land surface, (2) percent cropland−pasture, (3) natural log of human population density, (4) percent well-drained soils, (5) depth to the seasonally high water table, and (6) presence or absence of a fracture zone within a surficial aquifer. All variables were highly significant at the 0.05 level, and the model fits the data well. A linear regression fit of observed and predicted probabilities of nitrate exceeding 4 mg/L yielded a coefficient of determination (r^2) value of 0.971.

The previous model was refined and used in the current study to predict the probability of nitrate contamination of predominantly shallow, recently recharged (within 10−20 years) groundwaters in unsampled areas of the nation. The previous model had been calibrated to groundwater nitrate data but was not validated with an independent data set. It was used to identify variables that significantly influence nitrate contamination of shallow groundwater but was not used in prediction. The new model was recalibrated with three updated variables that represent improved sources of data and validated using data collected by a different set of NAWQA study units that began in 1994. For example, land-use data in the new model represent the 1990s and are more current than the 1970s data used in the previous model.

A threshold of 4 mg/L nitrate was used to indicate anthropogenic effects relative to the 2 mg/L background level reported by Mueller and Helsel (*11*). Additionally, nitrate concentrations greater than 2 mg/L but less than the MCL of 10 mg/L have been associated with adverse health effects (*9, 10*). A modeling threshold based on the MCL of 10 mg/L was not used because it is considered too high to adequately protect drinking-water source areas. It is likely that groundwater in highly susceptible areas already has been contaminated, and groundwater with nitrate concentration greater than 10 mg/L is nearly impossible to remediate. In this paper, a groundwater nitrate concentration greater than 4 mg/L is designated an "event" and concentrations of 4 mg/L or less are designated "nonevents."

Methods

The calibration data set used in this study comprises 1280 wells that were sampled during 1992−1995 as part of land-use studies conducted by the first 20 NAWQA study units that began in 1991 (Figure 1). Springs and agricultural drains were excluded from analysis because of uncertainties in the source of water or contributing land-use area, and only one sample per well was used to preclude undue influence by wells that were sampled several times. Clustered wells were excluded to preclude over-representation of small areas. NAWQA land-use studies commonly have 20−30 wells and are designed to evaluate the quality of predominantly shallow, recently recharged groundwater beneath selected land uses in an aquifer of interest. The median depth to water for the calibration data set is 4.5 m. A few wells in the data set have depths to water approaching 200 m, but these are in fractured basalt in the Upper Snake River Basin. The fractured basalt aquifer is hydraulically connected to irrigation recharge and, therefore, is affected by overlying land use. The validation data set comprises 736 wells sampled during 1996−1999 as part of land-use studies conducted by 16 additional NAWQA study units that began in 1994 (Figure 1).

All wells were sampled according to procedures described by Koterba et al. (*26*). Nitrite-plus-nitrate was analyzed by the USGS National Water-Quality Laboratory based on procedures described in Fishman (*27*), and concentrations

are reported as elemental N. Nitrite-plus-nitrate concentration is referred to as "nitrate" in the current study because nitrite concentration in groundwaters sampled by NAWQA generally is negligible (*28*).

In the current study, we updated three variables in the previous LR model (*20*): N loading from inorganic fertilizer, percent cropland−pasture, and the presence or absence of rock fractures. Whereas the previous model had assumed an equal allocation of N fertilizer to agricultural and urban areas, the new model uses separate estimates of farm and nonfarm N loading from inorganic fertilizer. Farm and nonfarm N loadings were estimated by David L. Lorenz (USGS. Unpublished data, 2001) using data from the Association of American Plant Food Control (*29*). Estimated N loadings in counties subsequently were allocated by Landsat-derived National Land Cover Data (NLCD) (*30*) for 500-m radius circular areas around sampled wells. Farm fertilizer N was allocated equally to NLCD categories comprising orchards/vineyards, row crops, and small grains, and nonfarm fertilizer N was allocated equally to low-intensity residential and urban/recreational grasses. Assumption of equal N application rate to different crop types is reasonable because crops in a given area commonly are rotated. Although the fertilizer application rate varies from year to year, groundwater movement is slow and chemicals accumulate over several growing seasons. Effects of changing N loadings are integrated and averaged over time. Using a single farm application rate of N for a county is reasonable also because the range of crop types in a given county is fairly limited.

The following individual NLCD categories were aggregated for consistency with the combined cropland−pasture variable in the previous model (*20*): pasture/hay, row crops, small grains, and fallow land. The NLCD represent early to mid-1990s land use, which is consistent with the 1992−1995 nitrate data used to calibrate the LR model. Cropland−pasture data used in the previous model were compiled by Anderson et al. (*31*), but these data (1970s) are not current. The previous model used Anderson data updated with 1990 Census population data to reflect recent conversion of agricultural land to new residential land (*32*).

Nitrogen loads from animal manure and septic systems are not explicitly represented in the new LR model. A variable representing animal manure, based on animal population in counties, was tested with these data but found statistically insignificant in regression. Although manure contributes lesser amounts of N than inorganic fertilizer nationally, it is an important regional source. Confined feeding operations are not explicitly represented in the model because a current, national coverage of such operations is unavailable. The cropland−pasture variable in the new LR model, however, contains information on N sources such as animal manure and septic systems. Population density is a surrogate for nonagricultural sources of nitrogen in urban areas, such as septic tanks, sewer exfiltration, and domestic animals.

The previous model (*20*) included a variable for the presence or absence of rock fractures, which had been compiled locally by NAWQA study-unit personnel. Because these data are not present outside of the NAWQA land-use study areas, a geology variable of national scope was needed to facilitate prediction in unsampled areas of the nation. To determine the uppermost susceptible aquifer, a binary indicator variable representing the presence or absence of unconsolidated sand and gravel aquifers was substituted for the former variable in the new model. The data sources are (1) a 1/2 500 000-scale principal aquifers map in the National Atlas of the United States (*33*), and (2) a 1/1 000 000-scale map of glaciated sediments east of the Rocky Mountains (*34*). The principal aquifer map shows the surface outcrop or near-surface (shallow subcrop) locations of aquifers but excludes glaciated sediments and alluvial aquifers along major rivers. The glaciated geology map comprises coarse-grained and fine-grained stratified sediments, till, and other materials in quaternary sediments (including river alluvium) of glaciated regions. The glaciated geology map complements the principal aquifer map because glaciogenic and alluvial aquifers (not shown on the principal aquifers map) are important sources of water in the northern and midwestern United States. Wells in areas shown as unconsolidated sand and gravel aquifers on the principal aquifer map or as coarse-grained stratified sediment on the glaciated geology map were coded "1", and wells in all other areas were coded as "0" to create the binary indicator variable.

State Soil Geographic (STATSGO) data describing the infiltration characteristics of the upper 1.8 m of soil were used in conjunction with the principal aquifer and glaciated geology maps to describe the overall susceptibility of near-surface aquifers to surface-derived contaminants. This accounts for the possibility that overlying materials (e.g., loess) might have infiltration characteristics different from unconsolidated sand and gravel comprising a near-surface aquifer.

The remaining variables in the new LR model are the same as used previously (*20*): natural log of 1990 human population density (*35*), percent well-drained soils or hydrologic groups A and B from the STATSGO database (*36*), and STATSGO depth to the seasonally high water table. STATSGO data represent spatial patterns of soil properties on the landscape and cover the nation at the 1/250 000 scale. The STATSGO variables were compiled as weighted averages within land-use study areas because STATSGO attributes vary little within 500 m of sampled wells. Nitrogen fertilizer loading, percent cropland−pasture, and population density are more variable and were compiled as weighted averages within 500 m of wells.

Variables in the new LR model were checked for statistical significance using the Wald statistic, which is the ratio of the maximum likelihood estimate of the slope coefficient to its standard error (*23*). The Wald statistic p value indicates whether slope coefficients are significantly different from zero. Linear regression was used to evaluate goodness-of-fit by comparing observed and predicted probabilities associated with deciles of risk. Deciles of risk are obtained by ranking predicted probabilities from low to high and creating 10 groups or bins, each with $n/10$ observations. The r^2 value was computed for the observed and average predicted probabilities, with higher values indicating better fit. The Hosmer−Lemeshow (HL) goodness-of-fit test statistic was used to evaluate observed and expected probabilities in bins. Forty bins were used to increase the ability of the test to detect potential departures from model fit caused by a few individual observations in a bin. Higher HL p values indicate a better fit because the null hypothesis is that the model fits the data. Logistic regression modeling and related diagnostics used SAS and SYSTAT software (brand names in this paper do not constitute endorsement by the U.S. Geological Survey).

All of the variables in the new model were recompiled within 1-km grid cells to predict nitrate contamination risk at the national scale. Equation 1 was used with model inputs corresponding to over 7 million 1-km grid cells to calculate the probability for each that nitrate concentration in shallow groundwater exceeds 4 mg/L.

Results and Discussion

Recalibration of Multivariate Logistic Regression Model. Variables in the new LR model were checked for statistical significance using Wald statistic p values. The new model contains variables representing (1) N fertilizer loading ($p < 0.001$), (2) NLCD percent cropland−pasture ($p < 0.001$), (3) natural log of human population density ($p < 0.001$), (4) percent well-drained soils ($p < 0.001$), (5) depth to the

TABLE 1. Explanatory Variables in the New Logistic-Regression Model

variable	estimated coefficient	Wald *p* value
constant	−5.541	<0.001
1992 fertilizer N (kg/ha)	0.004	<0.001
NLCD cropland−pasture (%)	0.016	<0.001
ln (1990 population density), ln (people/km^2)	0.229	<0.001
well-drained soils (%)[a]	0.025	<0.001
depth to seasonally high water table (m)	1.088	<0.001
presence or absence of unconsolidated sand and gravel aquifers	0.424	0.002

[a] Sum of percentages of STATSGO soil hydrologic groups A and B in area.

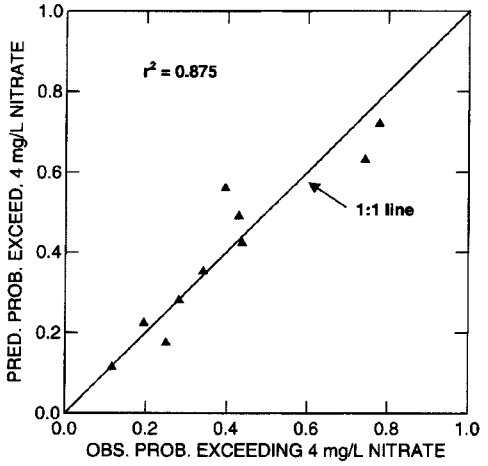


FIGURE 2. Relation between observed and average predicted probabilities of nitrate exceeding 4 mg/L in shallow groundwater, for deciles of risk associated with the new logistic regression model.

seasonally high water table ($p < 0.001$), and (6) presence or absence of unconsolidated sand and gravel aquifers ($p = 0.002$). The Wald p values indicate that all six variables are highly significant at the 0.05 level, and all slope coefficients are positive (Table 1).

Average predicted probabilities were compared with observed probabilities for deciles of risk to assess the fit of the new model. Each decile or bin yields an average predicted probability and an observed probability based on the number of observed values in the group that are greater than the threshold value. The observed and average predicted probabilities are well-correlated ($r^2 = 0.875$), indicating that the new LR model fits the data well (Figure 2). The HL p value is 0.224, indicating that the fit of the new model is acceptable (higher HL p values indicate better fit). These results generally agree with those obtained with the previous model (*20*).

The slope coefficients indicate that the probability of nitrate contamination of shallow groundwater increases with increasing N fertilizer loading, percent cropland−pasture, population density, percent well-drained soils, depth to the seasonally high water table, and with the presence of unconsolidated sand and gravel aquifers (Table 1). Relations between groundwater nitrate concentration and N fertilizer or agricultural land use are well-documented (*2, 13, 21, 37, 38*). Relations among percent population density, percent well-drained soils, and depth to the seasonally high water table are consistent with the previous model (*20*). The positive sign of the slope coefficient for seasonally high water-table depth is consistent with the findings of Burkart et al. (*17*), who observed a positive correlation between this STATSGO variable and nitrate concentration in shallow aquifers. Whereas very shallow depth to water indicates waterlogged conditions conducive to denitrification, increasing depth to water lessens denitrification potential and increases the likelihood that nitrate exceeds 4 mg/L. Deep wells, which might have yielded anoxic samples with low nitrate concentration, generally were not considered in this analysis of predominantly shallow groundwaters.

The likelihood of nitrate contamination increases with the presence of unconsolidated sand and gravel aquifers, which comprise coarse-grained deposits that facilitate leaching of water and chemicals to the water table. Other aquifer types from the principal aquifer map that were tested but found ineffective in LR include semiconsolidated sand aquifers, sandstone aquifers, sandstone and carbonate-rock aquifers, carbonate-rock aquifers, and basaltic and volcanic-rock aquifers. Unconsolidated sands and gravels commonly have high effective porosity compared with other types of sediments and rock. Consolidated rocks have less interconnected pore space available for fluid flow, so the degree of fracturing affects water and chemical movement. Some of the above rocks (e.g., carbonate rocks and fractured basalt) inherently are susceptible to contamination because of solution channels and fractures. The reason for the ineffectiveness of these aquifer variables in LR is unclear. However, the principal aquifer map represents rock subcrops as well as outcrops, which might be deeper than some sampled wells in the shallow groundwater data set and, therefore, unrelated to the water-quality measurement. Median well depth in the calibration data set is 11.5 m. Although the NAWQA program characterizes geologic formations in which sampled wells are completed, these data are unavailable outside of NAWQA study areas. The principal aquifer and glaciated geology maps were used to characterize geology outside of NAWQA study areas to enable LR predictions in unsampled areas of the nation.

Some of the variables in the LR model (e.g., N fertilizer and percent cropland−pasture; percent well-drained soils and the presence or absence of unconsolidated sand and gravel aquifers) are related and therefore raise multicollinearity concerns. These variables, however, are not strongly related. Nitrogen fertilizer represents applications in urban areas as well as agricultural areas. Percent cropland−pasture contains information on additional N sources besides inorganic fertilizer, such as manure, septic systems, and atmospheric deposition; and although cropland−pasture indicates where inorganic fertilizer likely is applied, it does not indicate the rate of actual application. The rate and timing of N fertilizer application depend on regional and local factors such as crop type, tillage practice, soil type, and climate. If multicollinearity were present, the p values corresponding to both N fertilizer and cropland−pasture would be very large (e.g., 0.7 or greater) because the model would be unable to select from among the competing variables. Rather, both p values are highly significant (<0.001) (Table 1). Similarly, the binary indicator variable for unconsolidated sand and gravel aquifers complements the 1/250 000 STATSGO data representing well-drained soils. Whereas STATSGO data represent the upper 1.8 m of surficial soils, the binary indicator variable represents the underlying sediments and rocks composing the principal aquifer. Both p values associated with these variables are highly significant at the 0.05 level (Table 1).

Groundwater Nitrate in Specific Areas Follows Predicted Probabilities. Equation 1 was used with model coefficients in Table 1 to predict the probability of nitrate exceeding 4 mg/L for 1-km grid cells, resulting in a national map of the likelihood of nitrate contamination of shallow groundwater

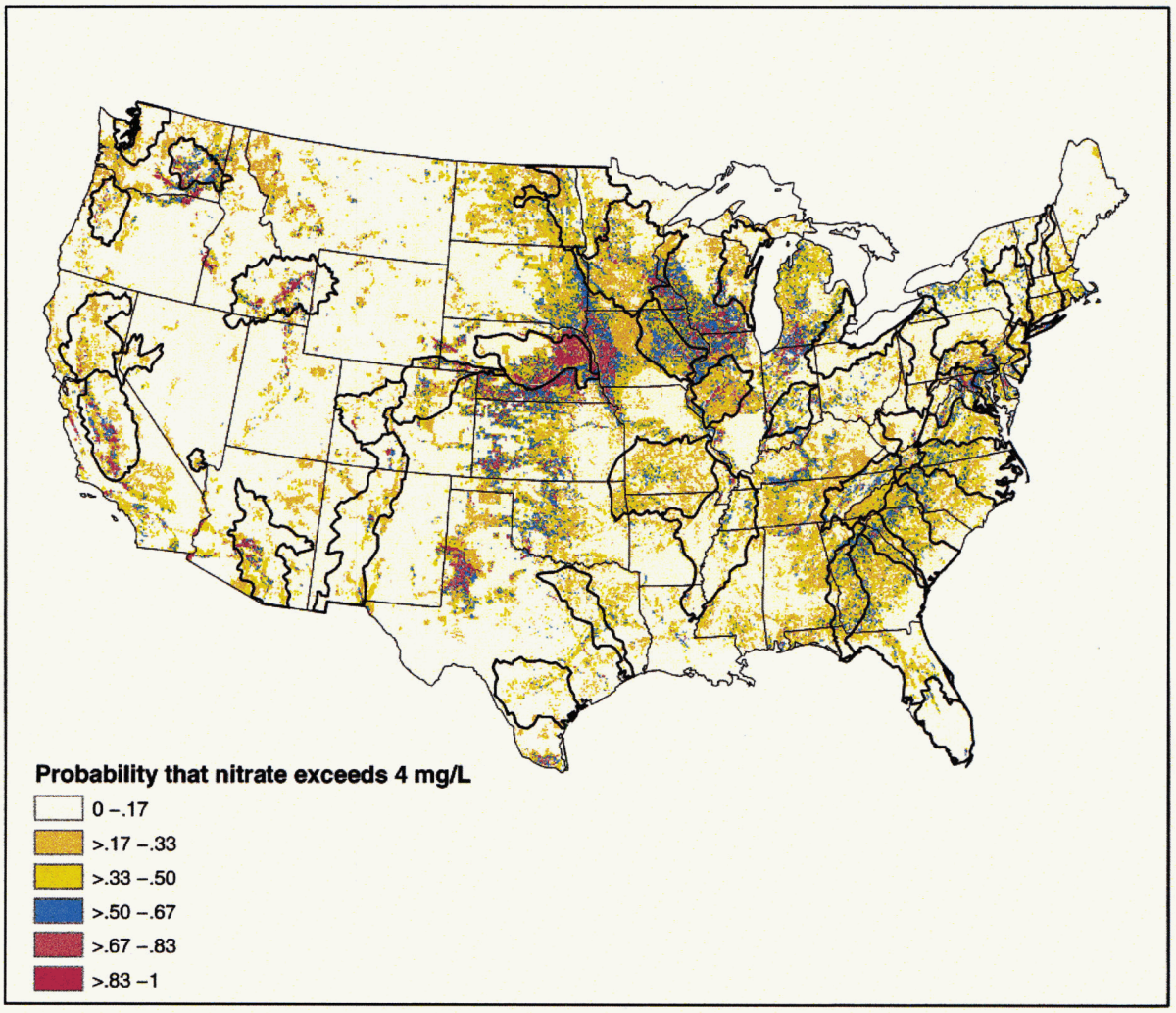


FIGURE 3. Probability that nitrate exceeds 4 mg/L in shallow groundwaters of the United States, based on the new logistic regression model.

(Figure 3). Mapped probabilities reflect regional patterns of N sources and aquifer-susceptibility characteristics. High probabilities are most extensive in the High Plains, which can have high N fertilizer loading and well-drained soils overlying unconsolidated, coarse-grained deposits.

In most NAWQA study units, the exceedance probability predicted with the LR model reasonably approximates the observed proportion of wells with nitrate exceeding 4 mg/L, indicating that the model adequately simulates regional N loading and aquifer susceptibility in these areas. The observed probability of nitrate exceedances is 0.031 for wells in land-use studies of the Albemarle–Pamlico Drainage Basin (ALBE) in northeastern North Carolina and southeastern Virginia. The median predicted probability in the area (based on probabilities predicted with eq 1 for each well in ALBE land-use studies) is 0.085. Denitrification resulting from large amounts of organic carbon in poorly drained sediments contributes to low nitrate concentration in shallow groundwater of the outer Coastal Plain in the region (*39*).

The observed probability of nitrate exceeding 4 mg/L is 0.333 in shallow groundwaters of the Las Vegas Valley area and Carson and Truckee River Basins in western Nevada, and the median predicted probability is 0.309. Nitrogen loading is comparatively low in the Carson Desert, where alfalfa is the major crop. Alfalfa, a legume that fixes atmospheric N, does not need additional fertilizer after the plants are established. However, excess application of residential fertilizers, septic systems, and leakage from sewer pipes can lead to nitrate contamination of groundwater in the Las Vegas area (*40*).

In contrast to this, the probability of nitrate contamination in shallow groundwaters of the Central Columbia Plateau (CCPT) in eastern Washington is high. The observed probability that nitrate exceeds 4 mg/L is 0.703 for wells in land-use studies of the area, and the median predicted probability is 0.641. Irrigation and high rates of fertilizer application are major contributors to the high nitrate concentration in groundwaters of the area (*41*). Almost all of the water in the Plateau supports irrigation in arid agricultural areas, greatly increasing the recharge of water and nitrate to shallow groundwater. Although irrigation was not explicitly considered in model calibration, fertilizer might be a useful surrogate for irrigation in the region because arid areas that are fertilized commonly are irrigated.

The model inaccurately predicts the probability of contamination in some locales, such as the Rio Grande Valley of southern Colorado and western New Mexico. The observed probability that nitrate exceeds 4 mg/L only is 0.270 for wells in land-use studies of the area, but the median predicted probability 0.539. Diagnostic tests were used to evaluate changes in the Pearson χ^2 statistic and estimated model coefficients resulting from poorly fitted, individual observa-

TABLE 2. Logistic Regression Classification Criteria for Calibration and Validation Data Sets

data set	classification criteria (%)			observed "events" (nitrate > 4 mg/L) (%)
	total correct responses	model sensitivity	model specificity	
1991 study units calibration data set (1280 observations)	67.6	50.9	78.5	39.6
1994 study units validation data set (736 observations)	75.0	12.4	96.0	25.1

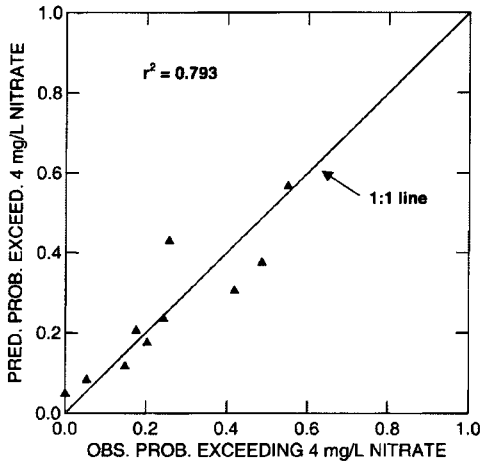


FIGURE 4. Relation between observed and average predicted probabilities of nitrate exceeding 4 mg/L in shallow groundwater, for deciles of risk associated with the validation data set.

tions in the calibration data set. Three of four observations that fit the LR model poorly and that have large effect (high leverage) on the values of the estimated parameters are in the San Luis Valley, which is in the northern (Colorado) portion of the Rio Grande Valley. The three wells are in areas with high estimated fertilizer loading (396–434 kg/ha) and high percent cropland–pasture (94.6–96.7%), yet observed nitrate concentration is <4 mg/L in all three cases (0.1–3.7 mg/L). Leaching of fertilizer is variable in the Rio Grande Valley and depends on additional factors such as the timing of fertilizer and irrigation and recharge rate to the aquifer (*42*).

In the Albuquerque area of the Rio Grande Valley, no samples had nitrate concentration greater than 4 mg/L. Relatively large dissolved organic carbon concentrations in shallow groundwaters of the area increase the potential for denitrification. High evapotranspiration in the southern part of the study area also might limit nitrate leaching. Annual potential evaporation may exceed 1000% of annual precipitation in the Rincon Valley area. A variable representing mean annual precipitation minus potential evapotranspiration was tested with the new logistic regression model to evaluate climate effects but did not significantly improve the model ($p = 0.19$). Mean annual precipitation was evaluated previously during LR model calibration (*20*) but was statistically insignificant.

Logistic Regression Model Validation. The new LR model was validated with an independent data set comprising 736 wells that were sampled during 1996–1999 (Figure 1). The probability of nitrate exceeding 4 mg/L was calculated for each well using model parameters in Table 1, and average predicted probabilities and observed probabilities were determined for deciles of risk to assess the fit of the model. The observed and average predicted probabilities are rea-

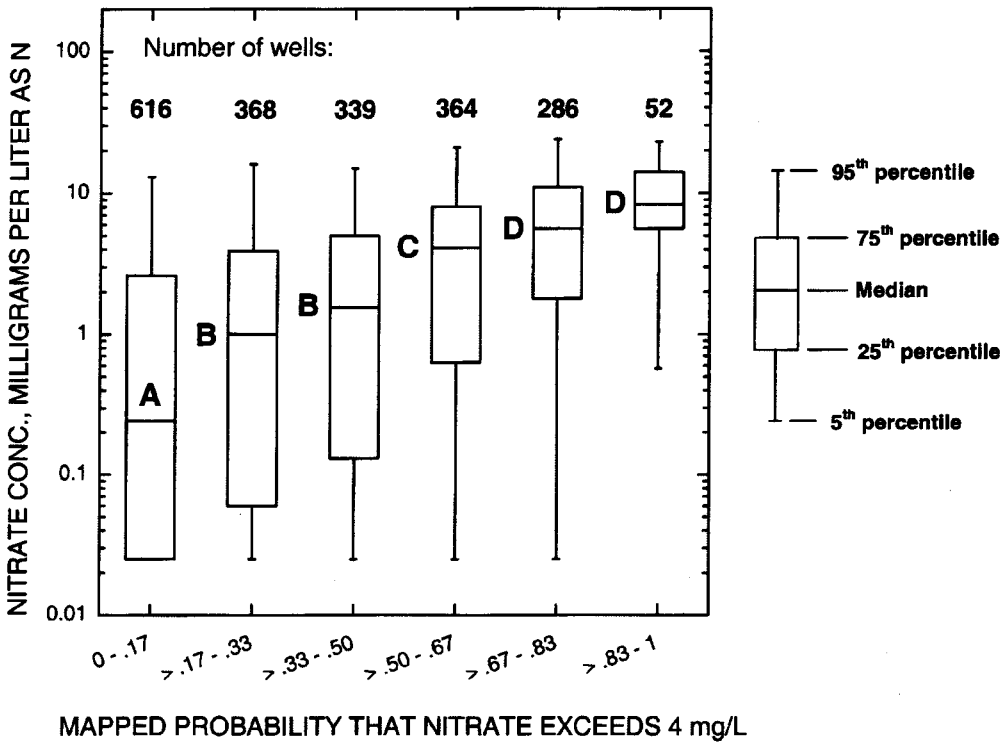


FIGURE 5. Relation between observed nitrate concentration in groundwater and mapped probability of nitrate concentration greater than 4 mg/L.

sonably well correlated ($r^2 = 0.793$), indicating that model fit is acceptable (Figure 4). The degree of correlation is somewhat less than for the calibration data set ($r^2 = 0.875$), and observed and predicted probabilities of exceeding 4 mg/L nitrate concentration all are less than 0.6. Compared with the calibration data set, the validation data set has fewer agricultural sites relative to urban sites and fewer incidences of nitrate exceeding 4 mg/L (Table 2).

Considering both events (nitrate > 4 mg/L) and nonevents (nitrate ≤ 4 mg/L), the new LR model correctly predicted nitrate status in three out of four wells in the validation data set (Table 2). Although model capability to correctly predict nonevents ("specificity") increased to 96% with the validation data set, the capability to correctly predict events ("sensitivity") decreased to 12%. Only about 25% of wells in the validation data set have nitrate > 4 mg/L, compared with about 40% of wells in the calibration data set. This likely is because the 1994 NAWQA study units sampled fewer wells in agricultural areas. The 16 NAWQA study units that began in 1994 conducted 11 shallow groundwater land-use studies in agricultural areas and 12 in urban areas. In contrast, the 20 NAWQA study units that began in 1991 conducted 36 shallow groundwater land-use studies in agricultural areas and 13 in urban areas. Nitrate concentration typically is lower in shallow groundwater beneath urban land, compared with that beneath agricultural land (*28*).

General Verification of Logistic Regression Model. As an additional verification step, wells from both the calibration and validation data sets were intersected with the national probability map and assigned probabilities predicted with the new model. Box plots associated with wells grouped by mapped probability ranges are shown in Figure 5. Tukey's multiple comparison test on the ranks was performed to determine which groups are different, and test results were evaluated at the 0.05 level of significance. Box plots labeled with different letters (e.g., A and B in Figure 5) have medians that are significantly different at the 0.05 level. As the mapped probability of nitrate exceeding 4 mg/L increases, the observed median nitrate concentration increases from 0.24 to 8.30 mg/L. The strong relation between observed median nitrate concentration and mapped probability indicates that the overall fit of the LR model is good.

Uses and Limitations. The national probability map can help assess the vulnerability of source-water areas as mandated by amendments to the Safe Drinking Water Act (SDWA) (*43*), for scenarios where predominantly shallow groundwater is used as public supply. Aquifer vulnerability assessment is an integral component of the amended SDWA. The map also can help managers prioritize areas for monitoring, cleanup, or implementation of alternative management practices.

The national probability map is intended for regional (multicounty) use and has several limitations. Areas of high probability on the map have high potential for nitrate contamination but are not necessarily contaminated. Variables not significant in national-scale regression (such as percent artificially drained soils) or not considered or available during model calibration (such as irrigation) can affect nitrate leaching locally, so the map should not be used for local management decisions. Also, variations in local hydrogeologic conditions can cause variations in water quality that are inconsistent with mapped probabilities. For example, sinkholes in karst areas can facilitate nitrate leaching to groundwater, but karst features could not be mapped at the national scale.

Acknowledgments

The authors thank the many NAWQA personnel who collected the data used in this study. We also thank David L. Lorenz, Curtis V. Price, and David M. Wolock for compiling data used in this study.

Literature Cited

(1) Solley, W. B.; Pierce, R. R.; Perlman, H. A. *Estimated Use of Water in the United States in 1990*; U.S. Geological Survey Circular 1081, 1993.
(2) Hallberg, G. R.; Keeney, D. R. Nitrate. In *Regional Ground-Water Quality*; Alley, W. M., Ed.; Van Nostrand Reinhold: New York, 1993.
(3) Puckett, L. J. *Nonpoint and Point Sources of Nitrogen in Major Watersheds of the United States*; U.S. Geological Survey Water-Resources Investigations Report 94-4001, 1994.
(4) Boyce, J. S.; Muir, J.; Edwards, A. P.; Seim, E. C.; Olson, R. A. *J. Environ. Qual.* **1976**, *5*, 93–96.
(5) Hendry, M. J.; McCready, R. G. L.; Gould, W. D. *J. Hydrol.* **1984**, *70*, 177–198.
(6) U.S. Environmental Protection Agency. *Drinking Water Regulations and Health Advisories*; Office of Water: Washington DC, 1995.
(7) Spalding, R. F.; Exner, M. E. *J. Environ. Qual.* **1993**, *22*, 392–402.
(8) Centers for Disease Control and Prevention. *Morb. Mort. Weekly Rep.* **1996**, *45*, 569–572.
(9) Weyer, P. J.; Cerhan, J. R.; Kross, B. C.; Hallberg, G. R.; Kantamneni, J.; Breuer, G.; Jones, M. P.; Zheng, W.; Lynch, C. F. *Epidemiol.* **2001**, *11*, 327–338.
(10) Ward, M. H.; Mark, S. D.; Cantor, K. P.; Weisenburger, D. D.; Correa-Villaseñor, A.; Zahm, S. H. *Epidemiol.* **1996**, *7*, 465–471.
(11) Mueller, D. K.; Helsel, D. R. *Nutrients in the Nation's Waters—Too Much of a Good Thing?*; U.S. Geological Survey Circular 1136, 1996.
(12) Helsel, D. R.; Hirsch, R. M. *Statistical Methods in Water Resources*; Elsevier: New York, 1992.
(13) Eckhardt, D. A. V.; Stackelberg, P. E. *Ground Water* **1995**, *33*, 1019–1033.
(14) Teso, R. R.; Poe, M. P.; Younglove, T.; McCool, P. M. *J. Environ. Qual.* **1996**, *25*, 425–432.
(15) Nolan, B. T.; Clark, M. L. *J. Environ. Qual.* **1997**, *26*, 849–857.
(16) Rupert, M. G. *Probability of Detecting Atrazine/Desethyl-Atrazine and Elevated Concentrations of Nitrate ($NO_2 + NO_3$–N) in Ground Water in the Idaho Part of the Upper Snake River Basin*; U.S. Geological Survey Water-Resources Investigations Report 98-4203, 1998.
(17) Burkart, M. R.; Kolpin, D. W.; Jaquis, R. J.; Cole, K. J. *J. Environ. Qual.* **1999**, *28*, 1908–1915.
(18) Squillace, P. J.; Moran, M. J.; Lapham, W. L.; Price, C. V.; Clawges, R. M.; Zogorski, J. S. *Environ. Sci. Technol.* **1999**, *33*, 4176–4187.
(19) Squillace, P. J.; Moran, M. J. *Estimating the Likelihood of MTBE Occurrence in Drinking Water Supplied by Ground-Water Sources in the Northeast and Mid-Atlantic Regions of the United States*; U.S. Geological Survey Open-File Report 00-343, 2000.
(20) Nolan, B. T. *Ground Water* **2001**, *39*, 290–299.
(21) Tesoriero, A. J.; Voss, F. D. *Ground Water* **1997**, *35*, 1029–1039.
(22) Tesoriero, A. J.; Inkpen, E. L.; Voss, F. D. *Assessing Groundwater Vulnerability using Logistic Regression*. *In* Proceedings of the Source Water Assessment and Protection Conference, Dallas, TX, April 28–30, 1998.
(23) Hosmer, D. W.; Lemeshow, S. *Applied Logistic Regression*; John Wiley and Sons: New York, 1989.
(24) Kleinbaum, D. G. *Logistic Regression—A Self-Learning Text*; Springer-Verlag: New York, 1994.
(25) Nolan, B. T.; Ruddy, B. C.; Hitt, K. J.; Helsel, D. R. *Environ. Sci. Technol.* **1997**, *31*, 2229–2236.
(26) Koterba, M. T.; Wilde, F. D.; Lapham, W. W. *Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water-Quality Samples and Related Data*; U.S. Geological Survey Open-File Report 95-399, 1995.
(27) Fishman, M. J., Ed. *Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Inorganic and Organic Constituents in Water and Fluvial Sediments*; U.S. Geological Survey Open-File Report 93-125, 1993.
(28) Nolan, B. T.; Stoner, J. D. *Environ. Sci. Technol.* **2000**, *34*, 1156–1165.
(29) Association of American Plant Food Control. University of Kentucky, Lexington, KY, 2000.
(30) Vogelmann, J. E.; Howard, S. M.; Yang, L.; Larson, C. R.; Wylie, B. K.; Van Driel, N. *Photogram. Engin. Remote Sens.* **2001**, *67*, 650–662.

(31) Anderson, J. R.; Hardy, E. E.; Roach, J. T.; Witmer, R. E. *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*; U.S. Geological Survey Professional Paper 964, 1976.
(32) Hitt, K. J. *Refining 1970's Land-Use Data with 1990 Population Data to Indicate New Residential Development*; U.S. Geological Survey Water-Resources Investigations Report 94-4250, 1994.
(33) U.S. Geological Survey. The National Atlas of the United States of America. Reston, Virginia, 1998. http://www.nationalatlas.gov.
(34) Soller, D. R.; Packard, P. H. *Digital Representation of a Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains*; U.S. Geological Survey Digital Data Series DDS-38, 1998.
(35) U.S. Bureau of the Census. *1990 Census of Population and Housing*, Public Law 94−171 Data (United States); Washington DC, 1991.
(36) Soil Conservation Service. *State Soil Geographic (STATSGO) Data Base for the United States and Puerto Rico* (CDROM). U.S. Department of Agriculture, Soil Conservation Service, Ft. Worth, Texas, 1994. http://www.ftw.nrcs.usda.gov/stat_data.html.
(37) Hall, D. W. *Ground Water* **1992**, *30*, 720−730.
(38) Böhlke, J. K.; Denver, J. M. *Water Resour. Res.* **1995**, *31*, 2319−2339.
(39) Spruill, T. B.; Harned, D. A.; Ruhl, P. M.; Eimers, J. L.; McMahon, G.; Smith, K. E.; Galeone, D. R.; Woodside, M. D. *Water Quality in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia, 1992−95*; U.S. Geological Survey Circular 1157, 1998.
(40) Bevins, H. E.; Lico, M. S.; Lawrence, S. J. *Water Quality in the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California, 1992−96*; U.S. Geological Survey Circular 1170, 1998.
(41) Williamson, A. K.; Munn, M. D.; Ryker, S. J.; Wagner, R. J.; Ebbert, J. C.; Vanderpool, A. M. *Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992−95*; U.S. Geological Survey Circular 1144, 1998.
(42) Levings, G. W.; Healy, D. F.; Richey, S. F.; Carter, L. F. *Water Quality in the Rio Grande Valley, Colorado, New Mexico, and Texas, 1992−95*; U.S. Geological Survey Circular 1162, 1998.
(43) U.S. Environmental Protection Agency. *Safe Drinking Water Act Amendments of 1996*. Office of Ground Water and Drinking Water: Washington, DC, 1996.

Received for review October 24, 2001. Revised manuscript received February 4, 2002. Accepted February 19, 2002.

ES0113854

FKS-20

Western Group Rate Case

Exhibit FKS-20

ARIZONA COOPERATIVE EXTENSION

THE UNIVERSITY OF ARIZONA
College of Agriculture and Life Sciences

AZ1536

July 2011

Nitrate Contamination Potential in Arizona Groundwater: Implications for Drinking Water Wells

Kristine Uhlman, RG and Janick F. Artiola, Ph.D.

Introduction

Nitrate is the most common pollutant in Arizona's groundwater and is undetectable without testing because it is colorless, odorless, and tasteless.

The EPA Maximum Contaminant Level (MCL) for nitrate-nitrogen[1] in a public water supply is 10 milligrams per liter (mg/L) and is based on acute health effects, specifically the risk of methemoglobinemia (sometimes referred to as "blue baby syndrome"), in which blood lacks the ability to carry sufficient oxygen to the individual body cells. Acute health effects are those that result from ingestion of a contaminant over a short period of time.

Domestic, private well owners are not required to monitor their drinking water quality and information about local groundwater contamination may be difficult, if not impossible, to obtain. In areas with historic or current agricultural activities and/or served by individual septic systems and domestic wells, nitrate contamination may be prevalent if not expected.

The Nitrogen Cycle

Nitrogen (N) exists in many forms in the environment and has a very dynamic cycle. For example, the atmosphere is 78% nitrogen gas and it also contains trace amounts of other nitrogen gases produced naturally and from pollution such as from burning fossil fuel (see Figure 1).

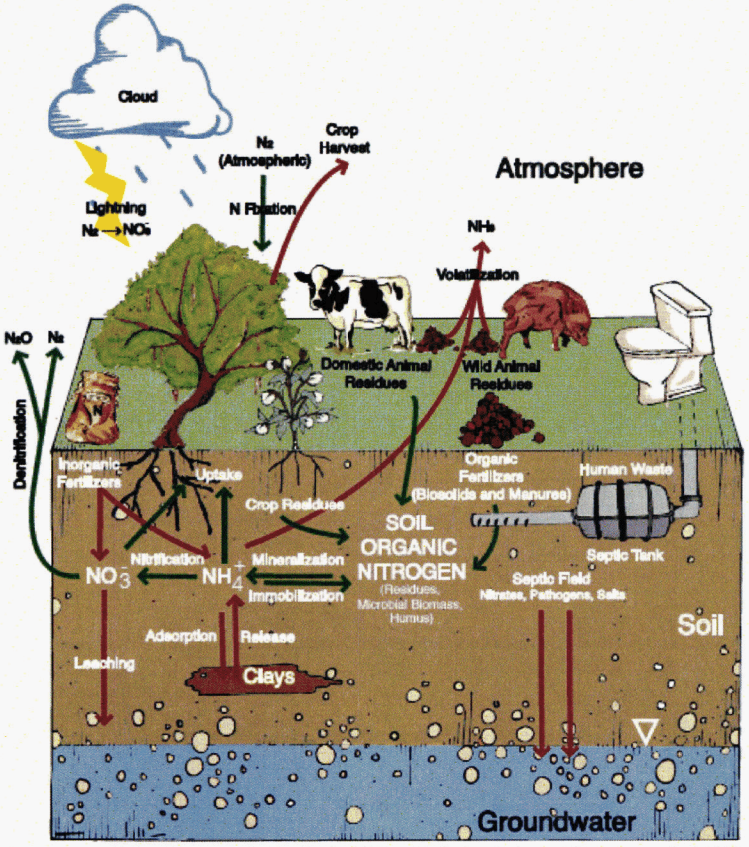


Figure 1:The Nitrogen Cycle. Revised from Pollution Science (Pepper et al., 1996)

[1] Nitrate concentrations in water are reported as 'nitrate-nitrogen (NO_3-N)' or total nitrate (NO_3). Use the following to compare the two reporting systems: 10 mg/L nitrate-nitrogen (NO_3-N) = 44.3 mg/L nitrate (NO_3).

The soil environment contains many forms of N, including organic (carbon-based) forms produced from decaying plant and animal residues. During the decay process inorganic forms of N are also produced, including ammonia gas, which reacts with water to form ammonium, and nitrate. Nitrate is very mobile in soil and groundwater because, unlike ammonium, nitrate does not adsorb onto soil or aquifer geologic materials, and only precipitates as a mineral under dry conditions. However, in the soil environment nitrate can be taken up by plants and microorganisms and recycled back into plant and animal tissue or transformed into nitrous oxide or transformed back into harmless nitrogen gas, as shown in Figure 1. Nitrous oxide, produced in water-logged soils and by animals, is a 'green-house' gas, partly responsible for global warming. (see AZ Cooperative Extension Bulletin AZ1458).

Fertilizers and Wastes

Nitrogen gas from the atmosphere is used to produce ammonia gas, which can be applied directly as an N fertilizer to irrigation water, but requires special equipment and precautions due to its toxicity and volatility. Ammonia is most often used to produce easy-to-handle fertilizers, which include granular forms such as urea, and ammonium and nitrate salts. These N fertilizers can be applied to soils directly or in liquid forms (pre-dissolved in water, called 'N solutions'), and in combination with other nutrients like phosphorus.

Although plants prefer nitrate to ammonium, plants can take up both forms. There are economical and environmental benefits to the application of ammonium-based fertilizer. Ammonium is cheaper than nitrate and is much less mobile than the nitrate ion in the soil environment. However, ammonium is quickly transformed to nitrate when applied to moist (irrigated) and warm soils of Arizona. The transformation occurs within days or weeks. Therefore, most of the inorganic nitrogen in well-drained soils is in the nitrate form. Nitrate groundwater contamination is common in agricultural areas and can occur due to 1) over-application of N fertilizer; 2) excessive irrigation; and/or; 3) poor N fertilizer application timing.

Municipal and animal wastes are very rich in nitrogen and contain many forms of this element. Therefore, nitrate contamination of surface and groundwater is also commonly associated with domestic septic systems, wastewater treatment plants, and concentrated animal feedlots.

Nitrate Groundwater Contamination in Arizona

High concentrations of nitrate in groundwater are usually due to human activities, however, some nitrate (low mg/l) is naturally occurring in arid soils (Graham, et. al., 2008). Large portions of aquifers within the Salt River Valley, areas in Glendale, Mesa, Chandler and Phoenix, contain groundwater with nitrate concentrations high enough to render the water unfit for potable use. In addition, high nitrate levels occur in Marana, St. David, Bullhead City, and other areas in Arizona. Quartzsite and Lake Havasu City have made significant efforts to address wastewater disposal problems that have contributed to groundwater contamination.

Septic system discharges are common nitrate sources in rural areas and this has contributed to the contamination of surface and groundwater in Arizona (ADEQ, 2006). Even properly designed and efficiently operating traditional septic tank/drain field systems discharge nitrate to the environment. Quartzsite, Bullhead City and Lake Havasu City are just a few locations with documented nitrate problems from septic systems.

Predicting Locations of Possible Nitrate Groundwater Contamination

The quality of drinking water supplied by public water systems is regulated by the Environmental Protection Agency and enforced by the Arizona Department of Environmental Quality (ADEQ). Information on nitrate in groundwater is available through annual water quality reports which suppliers must report to ADEQ. This data was used to develop a methodology to predict locations across the state vulnerable to nitrate contamination (Rahman, et al. 2009).

Groundwater quality data for 6,802 Arizona drinking water well locations were used to map and tabulate well, environmental, and land use characteristics (attributes) for each location, as shown in Figure 2.

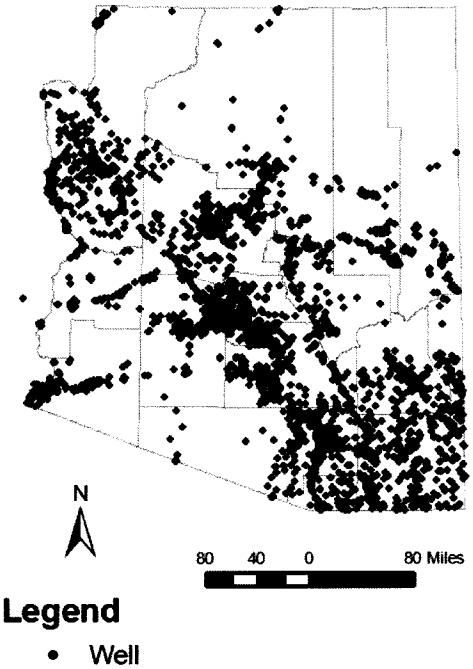


Figure 2: 'Multivariate logistic regression' was used to relate the probability of nitrate concentrations based on known physical attributes at each of the 6,802 well locations.

Environmental characteristics were tabulated for each location and included: geology; soils; population density; well depth; precipitation; and other factors, such as the presence of septic systems. A statistical analysis (Multivariate logistic regression) of the well data and associated water quality data predicted the chances (vulnerability) of groundwater to nitrate contamination in the areas of state where nitrate information is not available.

This study showed that groundwater contamination potential is highest in areas also associated with agricultural land use. Not surprisingly, most productive soils in Arizona are located in the Basin and Range province of the state where most of the state's groundwater resources sufficient to support agricultural irrigation are located (Artiola and Uhlman, 2009). Unfortunately, the porous soils and unconsolidated sedimentary geology of this region allow for the leaching of nitrate below the plant root zone to contaminate the groundwater. Lower concentrations across the Basin and Range in areas not known to have agricultural activities may be attributed to the deposition of naturally occurring nitrates in arid soils (Graham, et. al., 2008).

Fractured consolidated rock (common in the Colorado Plateau and the mountain highlands) such as granite also favors nitrate groundwater contamination. Fractured rock aquifers do not filter septic sources as efficiently as porous aquifers, and septic systems installed in rock with insufficient filtering capacity can result in well water contamination. This study also showed that well depth is also a significant factor with shallower wells more likely to be contaminated by nitrates.

Figures 3 and 4 show the areas of the state where the model as predicted varying chances of groundwater contamination. These figures show that, in general, the chances of having nitrate-nitrogen in groundwater are highest in the desert southwest region of the state – this could be due to both low-concentration naturally occurring nitrates as well as nitrates derived from historic agricultural practices. For example, in Figure 3, the areas mapped in red have a 90% to 100% chance (probability) that the nitrate-nitrogen contamination there is greater than 5 milligrams per liter (mg/L), half of the MCL of 10 milligrams per liter (mg/L). In Figure 4, the areas mapped in red have a 90% to 100% chance (probability) of nitrate-nitrogen contamination being greater than the drinking water MCL of 10 milligrams per liter (mg/L). Therefore, the red colored areas of Figure 4 indicate that wells installed within the agricultural regions of central Arizona, including portions of Phoenix and Casa Grande, are likely to be contaminated.

Testing for Nitrate in Well Water

Domestic well water used for drinking water supply should be tested annually to monitor changes in nitrate concentration. In addition, a water test is recommended for households with infants, pregnant women, nursing mothers, or elderly people. These groups are believed to be the most susceptible to nitrate health effects.

Tests to determine the presence of nitrate in drinking water should be done by a State-certified laboratory approved for nitrate testing, listed with the Arizona Department of Health Services, Bureau of State Laboratory Services – **http://www.azdhs.gov/lab/license/**. The selected laboratory will send you a special water sample container and sampling collection instructions. Follow these instructions carefully to obtain a representative sample. While a variety of test kits and dip strips are available for nitrate testing outside of a laboratory environment, laboratory analysis is needed for an accurate and reliable nitrate measurement.

Options for Managing Nitrate Contamination in Your Well Water

If nitrate exceeds a desirable concentration (recall footnote about the units on page one) in a domestic well, the well owner should consider an alternative drinking water source or water treatment. It may be possible to obtain an alternate water supply by drilling a new well in a different location or a deeper well in a different aquifer. Bottled water might be considered if the primary concern is water for infant food and drinking.

Nitrate levels in drinking water can be lowered with any of three treatment methods: distillation, reverse osmosis, and ion exchange. Home treatment equipment using these processes is available from several manufacturers. For more information about home water treatment systems see *Arizona Know Your Water* booklet (Artiola et al., 2006), available from the College of Agriculture and Life Sciences (CALS) publications website.

Note that carbon filters and standard water softeners do not remove nitrate. Merely boiling water may increase rather than decrease the nitrate concentration.

References

ADEQ, Arizona Department of Environmental Quality, 2008: Arizona 2006-2008 Integrated 305(b) and 303(d) Listing Reports. Phoenix, Arizona. **http://www.azdeq.gov/environ/water/assessment/assess.html**

Artiola, J.F., K.L. Farrell-Poe, and J.C. Moxley, 2006. *Arizona Know Your Water*. 2006. A consumer guide to water sources, quality, regulations and home water treatment options. University of Arizona, CALS. http://cals.arizona.edu/pubs/

Artiola., J.F. and K.Ulhman. 2009. *Arizona Well Owner's Guide to Water Supply*. University of Arizona, CALS Extension bulletin AZ1485. http://cals.arizona.edu/pubs/

Graham, R.C., and D. R. Hirmas, Y. A Wood, C. Amrhein. 2008. Large near-surface nitrate pools in soils capped by desert pavement in the Mojave Desert, California. *Geology*; March, 2008; v. 36; no. 3; p. 259-262

Pepper, I.L., C.P. Gerba, M.L. Brusseau. 1996. *Pollution Science*. Academic Press.

Rahman, T., and K. Uhlman: A. Posner; E. Westfall; P. Gunes. 2009. Predicting Ground Water Vulnerability to Nitrate in Arizona. University of Arizona, Water Resources Research Center Publication. Tucson, Arizona. **http://www.ag.arizona.edu/azwater/publications.php?rcd_id=68**

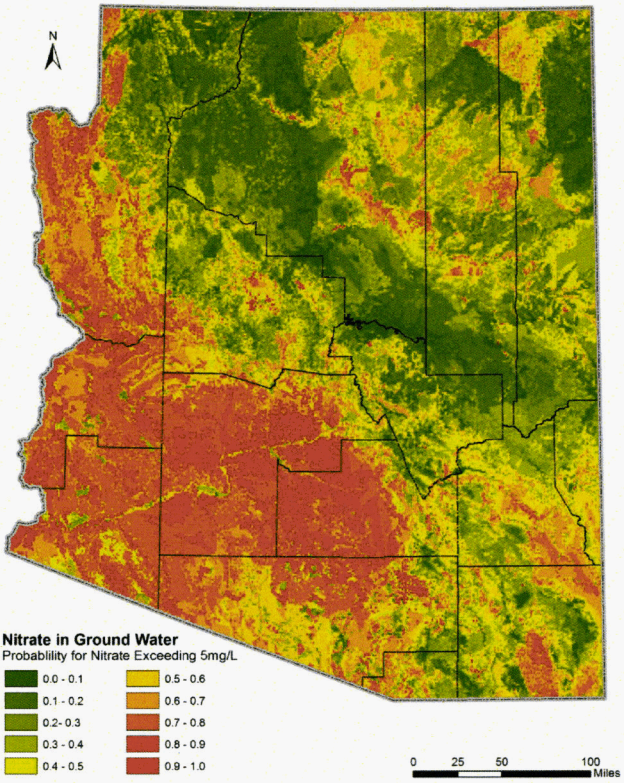


Figure 3: This figure shows predicted concentrations of nitrate-N in groundwater. Over 9% of the state, or 12,200 square miles, has an 80% chance (probability) of nitrate groundwater contamination exceeding 5 mg/L, half the drinking water MCL.

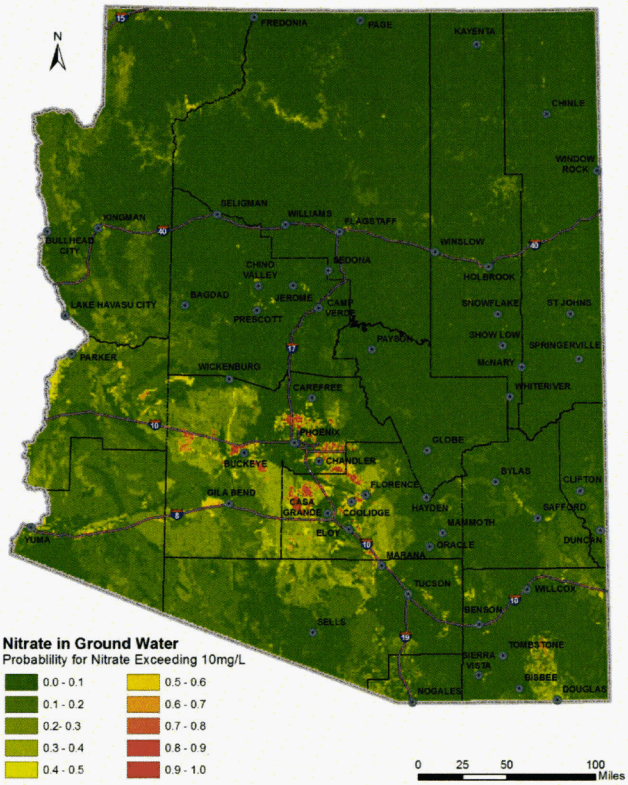


Figure 4: This figure shows predicted concentrations of nitrate-N in groundwater. Less than 1% of the state, or 226 square miles, has an 80% chance (probability) of nitrate groundwater contamination exceeding the EPA MCL of 10 mg/L.

ARIZONA COOPERATIVE EXTENSION
THE UNIVERSITY OF ARIZONA • COLLEGE OF AGRICULTURE AND LIFE SCIENCES

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

KRISTINE UHLMAN, RG
Area Assistant Agent, Natural Resources

JANICK ARTIOLA, PHD.
Associate Professor and Water Quality Specialist Department of Soil, Water & Environmental Sciences

CONTACT:
JANICK ARTIOLA
jartiola@cals.arizona.edu

This information has been reviewed by University faculty.
cals.arizona.edu/pubs/water/az1536.pdf

Other titles from Arizona Cooperative Extension can be found at:
cals.arizona.edu/pubs

Any products, services or organizations that are mentioned, shown or indirectly implied in this publication do not imply endorsement by The University of Arizona.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Kirk A. Astroth, Interim Director, Cooperative Extension, College of Agriculture Life Sciences, The University of Arizona.

The University of Arizona is an equal opportunity, affirmative action institution. The University does not discriminate on the basis of race, color, religion, sex, national origin, age, disability, veteran status, or sexual orientation in its programs and activities.

Western Group Rate Case

Exhibit FKS-21

USGS
science for a changing world

Water Quality in the Central Arizona Basins

Arizona, 1995–98

U.S. Department of the Interior
U.S. Geological Survey

Circular 1213

Natural Stream Water Quality

In the CAZB Study Unit, perennial streams draining areas with little or no agricultural or urban land use represent baseline or "natural" conditions in the basins. These natural streams are referred to as "forest/rangeland streams" in this report because they drain basins that are 93 to 100 percent forest and (or) rangeland. Examples of forest/rangeland streams include the upper Verde, upper Salt, and upper Gila Rivers and West Clear Creek in the Central Highlands province and the upper San Pedro River in the Basin and Range Lowlands province. Because some of the forest/rangeland streams provide drinking water for Phoenix or recharge aquifers used for drinking water, the quality of these streams is compared to drinking-water standards and guidelines as well as to other water-quality criteria.

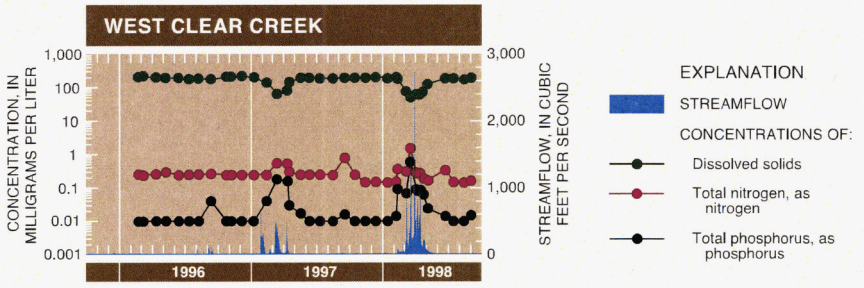


Figure 5. Concentrations of nutrients increase and concentrations of dissolved solids decrease during rainfall or snowmelt runoff.

The water quality of forest/rangeland streams is primarily determined by natural factors. Processes such as chemical weathering of bedrock and soils, biological activity in soils (Likens and others, 1977), groundwater discharge to streams, and runoff determine the water quality of these streams. Locally, streamwater quality may be affected by agriculture, mining, or urban land use.

Nutrient and dissolved-solids concentrations fluctuate seasonally in forest/rangeland streams. The patterns of rainfall and snowmelt runoff account for the seasonal fluctuations in concentrations of nutrients (fig. 5). Nutrient concentrations increase in streams during times of rainfall and snowmelt runoff because runoff carries nutrients washed off the land surface to streams, thereby increasing concentrations. Nitrogen in rainfall and snowmelt also adds to nutrient concentrations in streams. Conversely, during low streamflows, nutrient concentrations are lower because very little runoff reaches streams, and aquatic life in the streams take up the available nutrients.

Seasonal patterns of dissolved-solids concentrations are opposite to those of nutrients. During periods of low flow, the sources of streamflow are springs, which in some areas, such as the upper Salt River Basin, are quite saline (Feth and Hem, 1963). During periods of runoff, flow in streams is diluted, which lowers the dissolved-solids concentrations (fig. 5).

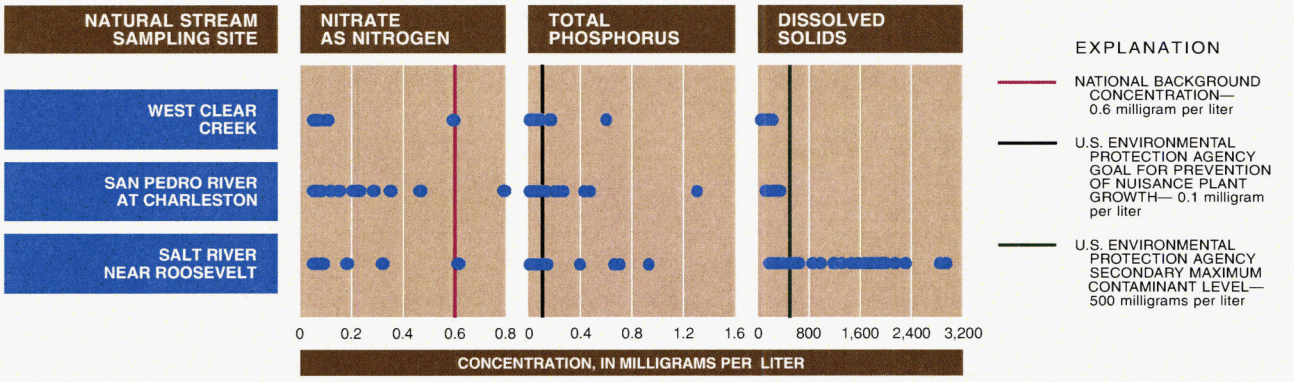


Figure 6. Nitrate concentrations in forest/rangeland streams are significantly lower than the maximum contaminant level of 10 mg/L. Most water samples from the upper Salt River exceeded the secondary maximum contaminant level for dissolved solids (500 mg/L) because saline springs sustain streamflow during periods of low flow.

Nitrate concentrations in forest/rangeland streams were significantly lower than the U.S. Environmental Protection Agency's (USEPA) Maximum Contaminant Level (MCL) of 10 mg/L. Nitrate was detected in 43 percent of the samples from forest/rangeland streams. None of the nitrate concentrations exceeded the MCL, which was established for the protection of human health (fig. 6), and less than 2 percent of the samples had concentrations of nitrate that were greater than the estimated national background concentration in streams of 0.6 mg/L (U.S. Geological Survey, 1999). Concentrations greater than background levels are generally considered to be the result of human activities. Samples that exceeded the background concentration were collected during high flows associated with rainfall or snowmelt runoff.

Twenty-four percent of the samples from forest/rangeland streams exceeded the USEPA desired goal for total phosphorus of 0.1 mg/L for the prevention of nuisance plant growth (fig. 6). The USEPA desired goal of 0.1 mg/L is the same as the estimated national background concentration for phosphorus (U.S. Geological Survey, 1999). Phosphorus enrichment in streams can lead to eutrophication; however, in the forest/rangeland streams, phosphorus concentrations exceeding the USEPA goal are generally limited to periods of rainfall and snowmelt runoff.

Dissolved-solids concentrations exceeded the USEPA Secondary Maximum Contaminant Level (SMCL) in 76 percent of samples from the upper Salt River. None of the samples from the upper San Pedro River or West Clear Creek exceeded the SMCL of 500 mg/L that is based on taste of drinking water (fig. 6). Samples that exceeded this drinking-water guideline were collected at times when streamflow was sustained by flow from springs. Saline springs drain into the upper Salt River (Feth and Hem, 1963), which accounts for the particularly large number of samples that exceeded the SMCL.

Total DDT concentrations in fish tissue samples from forest/rangeland streams were significantly less than the New York State guideline (Newell and others, 1987) for the protection of fish-eating wildlife. None of the other organochlorine pesticides and PCBs analyzed for were detected in fish tissue from forest/rangeland streams (Gebler, 2000). In addition, organochlorine compounds and PCBs were not detected in streambed sediment from these streams.

Stream water quality generally is improving on the basis of nutrient and dissolved-solids concentrations in forest/rangeland streams. Statistical analysis of nitrogen data for forest/rangeland streams indicates that concentrations have generally declined since the early 1980s (fig. 7). Phosphorus concentration data showed the same trend as nitrogen. In the upper, undeveloped parts of the Salt and Verde River Basins (upstream from reservoirs) the decrease in nutrients could be from a decrease in contributions from natural sources (see p. 10), a decrease as a result of better land-use management practices upstream, and (or) an increase in nitrogen use by aquatic life.

Dissolved-solids concentrations decreased substantially in outflow from reservoirs on the Verde River from 1950–90 (fig. 7). This downward trend, also seen on the Salt River, probably is caused by both increased rainfall and snowmelt runoff diluting the dissolved-solids concentrations and physical and chemical processes in the reservoirs that remove some dissolved solids from solution.

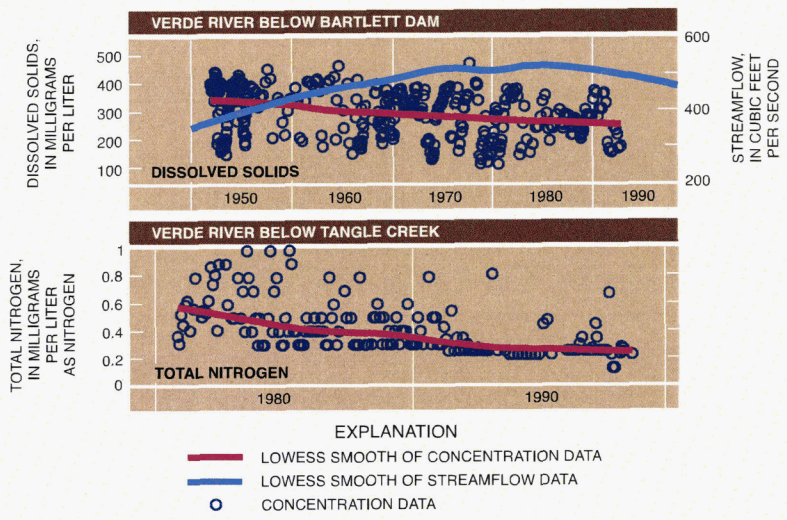


Figure 7. Water quality of forest/rangeland streams has improved, on the basis of decreases in dissolved-solids and nutrient concentrations during the past 30 to 50 years.

Effects of Human Activities on Stream Water Quality

Streams affected by human activities may have elevated concentrations of dissolved solids and nutrients from a variety of activities including urban and agricultural runoff. Manmade compounds such as pesticides and volatile organic compounds (VOCs) in streams are a direct result of human activities. To determine the factors affecting water quality in the CAZB, annual stream loads of dissolved solids (the mass of material transported in the water) entering the basins were compared to annual stream loads leaving the basins (see story at right). In addition, the quantifiable sources of nitrogen and phosphorus (nutrients) coming into major basins and leaving in streamflow were used to identify basins where water quality is affected by human activities (see p. 10). Water-quality characteristics of affected streams are indicative of the local effects of human activities.

Streams sampled in the CAZB that are affected by human activities can be divided into two main categories—effluent-dependent and agricultural/urban. Streamflow in effluent-dependent streams is almost entirely treated sewage effluent discharged from wastewater-treatment plants (WWTPs). These streams are referred to in this report as "effluent-dependent" or "effluent-dependent urban" streams (see p. 12) because the effluent reflects urban land uses. Some sampling sites in the CAZB receive irrigation return flows and rainfall runoff from agricultural fields as well as treated effluent, and these streams are referred to as "agricultural/urban" streams.

Dissolved solids are accumulating in basins with agricultural and urban irrigation.

Data collected as part of the CAZB NAWQA study indicate that in 1997, about 1.6 billion kilograms (kg) (1.76 million tons) of dissolved solids were carried into the Basin and Range Lowlands by streams draining the Central Highlands (Verde, Salt, and Gila Rivers) and by the Central Arizona Project (fig. 8). Only 440 million kg (0.48 million tons) were transported out of the study area in streams. The remaining 1.16 billion kg (1.28 million tons) are accumulating in soils, the unsaturated zone, and ground water in irrigated agricultural and urban areas.

Much of the streamflow from the Central Highlands and the Central Arizona Project Canal is used for irrigating agricultural fields and urban landscape. When plants are irrigated in the Basin and Range Lowlands, 50 to 80 percent of the water evaporates or is transpired by plants as pure water. The dissolved solids that were in the evapotranspired water remain in the soil or are concentrated in the water that remains. Over time these salts build up in soils and ground water. To prevent crop damage from salt accumulation, excess irrigation water is commonly applied to leach the salts out of the root zone.

Excess water that percolates below the root zone carries a higher concentration of salts than the original irrigation water (Cordy and Bouwer, 1999). If this deep-percolation water reaches the ground water, the upper part of the aquifer can be contaminated by dissolved solids, nutrients, and pesticide residues. Because deep-percolation water moves slowly through the unsaturated zone and ground water is several hundred feet deep in basins with substantial agricultural and urban development, the effects of the contamination may not be seen in ground water for years or decades after irrigation has declined or ceased.

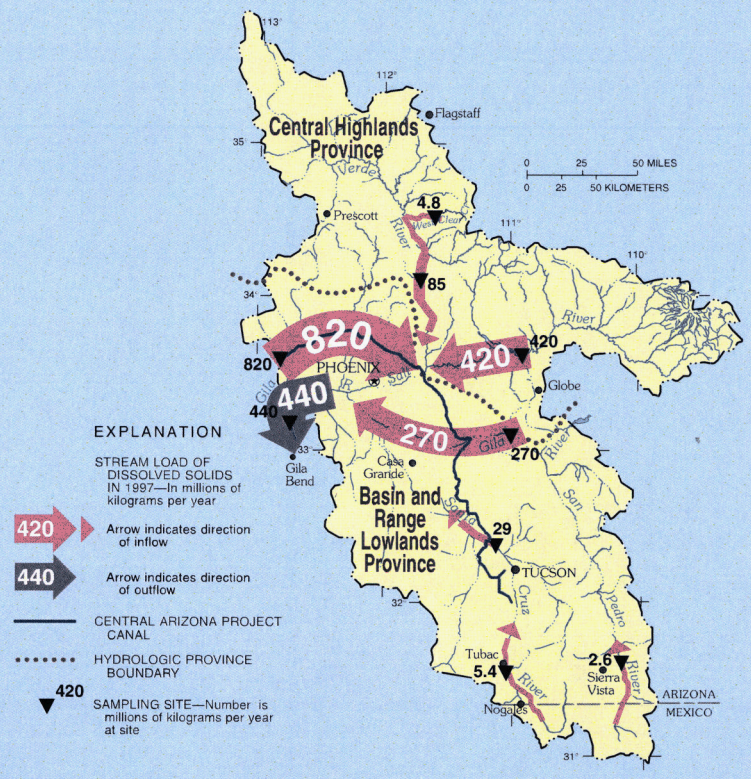


Figure 8. Streams and the CAP canal brought 1.6 billion kilograms of dissolved solids into the Basin and Range Lowlands in 1997, but only 440 million kilograms left the area in streams. The remaining dissolved solids accumulated in soils, the unsaturated zone, and ground water.

What are the sources of nitrogen and phosphorus in basins?

Major sources of nitrogen and phosphorus that can be quantified include fertilizers, livestock-feeding operations (commercial feedlot and dairy operations), inputs to sewer and septic systems, atmospheric deposition, industrial wastes, and streamflow into basins. For the CAZB Study Unit, the quantities of nitrogen and phosphorus contributed by each source annually were determined for selected drainage basins. Sources were quantified using records of fertilizer sales by county, livestock population counts, population and housing census information, National Atmospheric Deposition data for Arizona, USEPA Toxic Release Inventory data, and stream water-quality data collected in the CAZB for the NAWQA Program (Anning, 1998). The quantifiable sources of nitrogen and phosphorus in three basins are shown in figure 9.

Many sources of nitrogen and (or) phosphorus, such as the weathering of geologic formations and soils or the decomposition of vegetation, contribute nutrients to the basins but are difficult, if not impossible, to quantify. As a result, these and other unquantifiable sources of nitrogen and phosphorus are shown in figure 9 with question marks (?) to indicate that the quantities are unknown and may actually exceed the quantifiable sources.

The quantifiable and unquantifiable sources of nitrogen and phosphorus in basins represent potential contributors of nutrients to streams; however, the quantity of nutrients contributed annually from each source does not necessarily reach the streams. Some nutrients may be taken up in terrestrial ecosystems, transported to the ground water, or volatilized to the atmosphere. Conversely, nutrients can enter streams directly when treated sewage effluent from WWTPs is discharged to stream channels or excess irrigation water from agricultural areas discharges to streams. Best management practices and regulation of point-source pollution are methods used to reduce or control the quantity of nutrients entering streams.

In the drainage basins of the upper San Pedro River, upper Salt River, and other perennial streams with minimal agricultural and urban land use, the largest quantifiable source of nitrogen coming into these basins is from precipitation (fig. 9). Sewer and septic systems, livestock-feeding operations, and fertilizers are the largest quantifiable sources of phosphorus in these basins.

In basins with substantial agricultural and (or) urban land use such as the middle Gila River, the quantities of nitrogen and phosphorus from quantifiable sources are much greater per unit area than those for basins with little or no agricultural or urban land use. Additionally, fertilizers, livestock-feeding operations, and sewer (WWTPs) and septic systems account for a larger part of the total nutrients in basins with agricultural and (or) urban land use than in basins without these land uses.

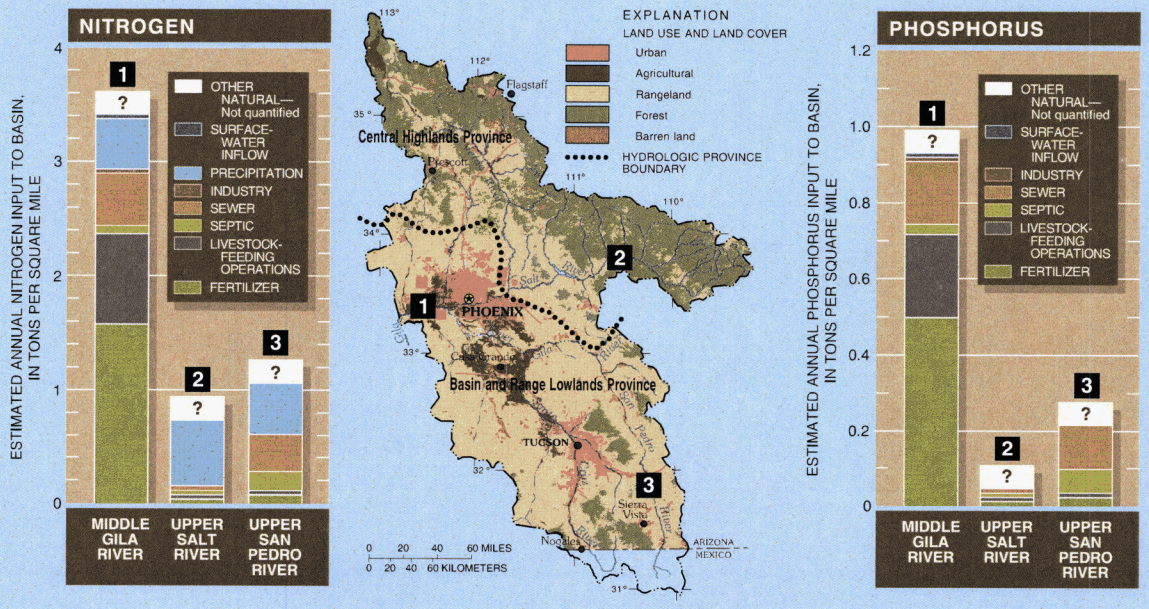


Figure 9. Precipitation and human wastes are the largest quantifiable sources of nitrogen and phosphorus entering basins with minimal agricultural and urban development. Human and animal wastes and fertilizers are the largest quantifiable sources entering basins with substantial agricultural and urban development.

Effluent-dependent streams

Nutrient concentrations in effluent-dependent streams exceeded the background concentrations found in forest/rangeland streams (see fig. 11). The 91st Avenue WWTP outfall near Phoenix and the Santa Cruz River at Tubac and at Cortaro Road (Tucson; see p. 26 for location of sites) are effluent-dependent streams that were sampled in the CAZB. Data from the San Pedro River at Charleston and the Salt River near Roosevelt represent background values for nutrients in the CAZB because these streams drain areas with relatively little urban or agricultural land use. By comparison, the nutrient concentrations at the effluent-dependent sites in the CAZB are elevated because the effluent discharged directly into the stream channels is a major source of nitrogen and phosphorus (U.S. Geological Survey, 1999).

Effluent-dependent streams can sustain riparian communities and aquatic life, but the water quality is poor. Some effluent-dependent streams in the CAZB can support valuable riparian communities with high biodiversity of terrestrial plants and animals; however, dissolved oxygen and phosphorus concentrations in these streams indicate that the water-quality is poor. At a minimum, most fish need 3 to 5 mg/L of dissolved oxygen (DO) over a long period of time to survive (Swenson and Baldwin, 1965). At the Santa Cruz River at Cortaro, DO concentrations were commonly lower than 3 mg/L (fig. 11), whereas concentrations at the other two effluent-dependent sites were in the minimal range. All the samples from the effluent-dependent streams exceeded the USEPA's desired goal for phosphorus of 0.1 mg/L for prevention of nuisance plant growth (eutrophication) (U.S. Environmental Protection Agency, 1986). Excessive algae and aquatic plant growth can lead to low DO concentrations (U.S. Geological Survey, 1999).

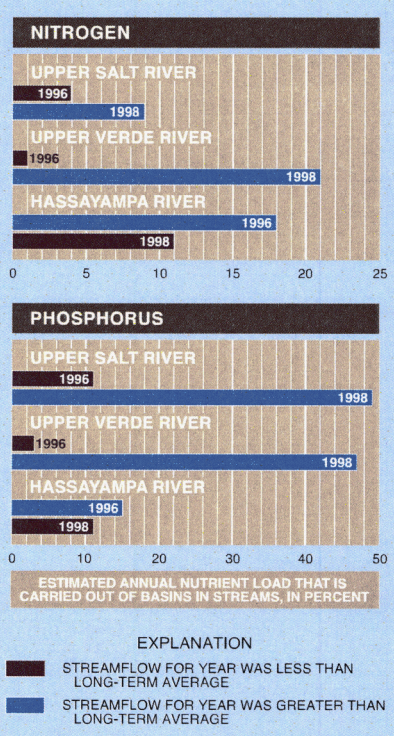


Figure 10. During years when average annual streamflow is greater than the long-term average, more nutrients are carried out of the basins in streams.

How much nitrogen and phosphorus actually leaves the CAZB Study Unit in streams?

A small fraction of nutrients applied to the land surface in the CAZB is transported to streams. The lack of rainfall in the Study Unit limits the transport of nutrients into streams and out of the basins. For the middle Gila River Basin, which includes most of the CAZB Study Unit, about 1,100 tons of nitrogen and 500 tons of phosphorus left the basin in 1998; these nutrient loads represent 1 percent of the quantifiable nitrogen and 2 percent of the quantifiable phosphorus for the basin. During 1996 and 1998, only 1 to 21 percent of the nitrogen and 3 to 48 percent of the phosphorus from quantifiable sources were transported out of basins in the CAZB in streamflow (D.W. Anning, U.S. Geological Survey, written commun., 1999).

Nutrient loads leaving the upper Salt and upper Verde River Basins in streamflow were greater during wet years (when streamflow was greater than the long-term average annual streamflow) than during dry years (when streamflow was less than the long-term average) (fig. 10). More nutrients were carried out of the Hassayampa River Basin in streamflow in 1996 than in 1998 because of more summer rainfall in 1996. Because runoff has higher concentrations of nutrients than does base flow (see fig. 5), wet years not only have additional streamflow but additional stream loads. Nutrients remaining in the basins are taken up by the plants and animals within the basin, adsorbed by streambed sediment (phosphorus only), volatilized to the atmosphere (nitrogen only), or transported to the ground water.

Effluent-dependent streams are valuable water resources in the CAZB

In many of the urban areas in Arizona, treated sewage effluent from wastewater-treatment plants is discharged into otherwise dry streambeds. Less than a century ago, some of these "effluent-dependent" streams, such as the Santa Cruz River in Tucson (see below) and the Salt River in Phoenix, had natural perennial streamflow, but ground-water pumping, damming of rivers, or other human activities have resulted in a loss of natural streamflow and associated riparian and aquatic communities (Tellman and others, 1997).

In the dry climate of Arizona, effluent-dependent streams provide perennial water resources with a variety of benefits. Effluent-dependent streams can support riparian communities with high biodiversity of terrestrial plants and animals. These streams support limited aquatic invertebrate and fish communities, which are food for organisms higher in the food chain. Riparian plant communities along these streams can help stabilize streambanks, reducing erosion and sedimentation. Trees and bushes provide plant material, creating habitat and food for aquatic organisms and shade that reduces evaporation. Effluent in streams is particularly important to cities and towns in Arizona because it recharges ground water in aquifers and can be used by cities to accrue "recharge credits" that allow for pumping elsewhere in the ground-water basin (Gelt and others, 1999).

Currently (2000), the water quality of effluent-dependent streams limits restoration of instream communities. If the water quality of these streams is improved by upgrading wastewater-treatment methods, it is likely that the streams would be able to support a greater number of aquatic species, and aquatic communities could even begin to resemble those of streams such as the upper San Pedro or upper Salt Rivers.

View of the Santa Cruz River seen from Sentinel Peak in Tucson in 1904. Perennial streamflow in the river sustained riparian vegetation along the banks, and aquatic communities in the river (Tellman and others, 1997). (Photograph by Walter Hadsell, courtesy of the Arizona Historical Society, Tucson, negative number 24868.

INSET: View of the Santa Cruz River near Tubac, 1997. The Santa Cruz is an effluent-dependent stream at this location, about 15 miles downstream from the Nogales International Wastewater-Treatment Plant in Arizona. A thick forest of riparian vegetation is supported by the streamflow. (Photograph by Gail E. Cordy).

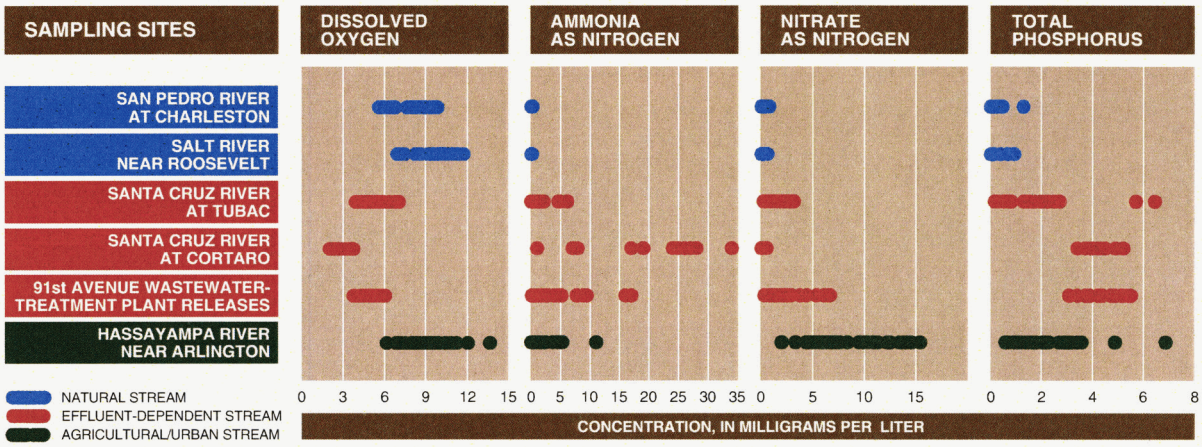


Figure 11. Nutrient enrichment in effluent-dependent streams contributes to abundant algal growth, which results in decreased dissolved oxygen and limited aquatic communities.

The level of sewage treatment and the distance effluent travels downstream from the discharge point influence the water quality of effluent-dependent streams. Ammonia concentrations in effluent at the Santa Cruz River at Cortaro are extremely variable and typically higher than those in the Santa Cruz River at Tubac or the 91st Avenue WWTP (fig. 11). Effluent at the Cortaro site has had secondary treatment, which results in nitrogen remaining in the effluent as ammonia (David Garrett, Pima County Wastewater, oral commun., 2000). In contrast, effluent sampled at the discharge point from the 91st Avenue WWTP has had tertiary treatment in which the ammonia is converted to nitrate. Converting ammonia to nitrate during treatment limits the direct threat of toxicity to fish that ammonia presents, but it does not change the potential for eutrophication of the stream (Mueller and others, 1996).

The lowest nutrient concentrations in effluent-dependent streams were at the Santa Cruz River at Tubac (fig. 11). Effluent in this stream receives secondary treatment and travels about 15 miles downstream to Tubac. As the effluent moves downstream, ammonia is lost to the atmosphere or converted to nitrate, some nitrate and phosphorus are taken up by plants and aquatic life, and phosphorus may be adsorbed by streambed sediments. Each of these processes reduces concentrations of nitrogen and (or) phosphorus, resulting in lower concentrations with distance downstream from the WWTP.

Abundant algal growth from nutrient enrichment in effluent-dependent streams may adversely affect aquatic organisms. Phosphorus, nitrate, and ammonia in effluent-dependent streams encourage algal growth. Chlorophyll *a* concentrations (fig. 12), which are indicators of the quantity of algae in a stream, were much higher in effluent-dependent streams than in forest/rangeland streams (Gebler, 1998).

Abundant algal growth and the resulting increase in decaying organic material in effluent-dependent streams can cause decreased DO concentrations, particularly at night when plants cease photosynthesis and decrease their oxygen production. The decreased DO can adversely affect aquatic invertebrates and fish.

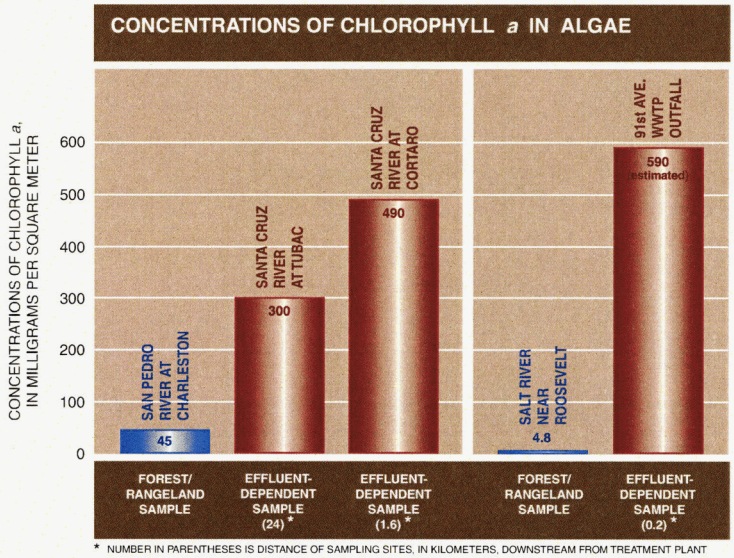


Figure 12. Nutrients in effluent-dependent streams encourage algal growth, as indicated by chlorophyll *a* concentrations.

Effluent-dependent streams support limited instream communities of aquatic invertebrates. The diversity of pollution-sensitive aquatic invertebrates such as mayflies, stoneflies, and caddisflies in effluent-dependent streams is very low, especially when compared to the high diversity in forest/rangeland streams (fig. 13). Pollution-tolerant species of aquatic worms and midges account for more than 90 percent of the numbers of aquatic invertebrates in effluent-dependent stream reaches sampled in the CAZB (fig. 14). In forest/rangeland streams, mayflies, stoneflies, and caddisflies were the most abundant of all aquatic invertebrate groups, which is consistent with good water quality and instream habitat (Gebler, 1998).

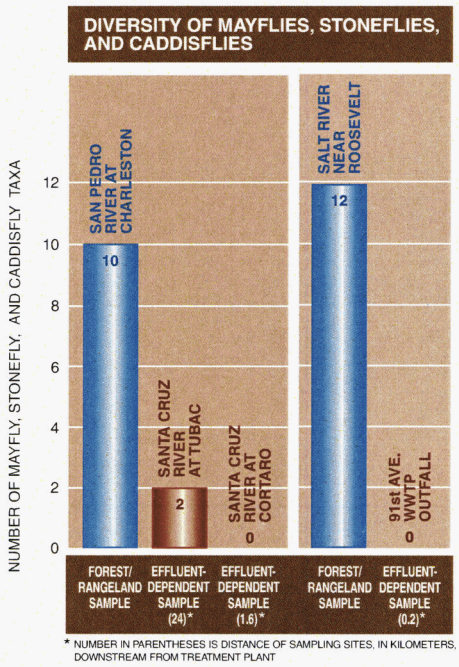


Figure 13. Aquatic invertebrate communities in effluent-dependent streams lack diversity.

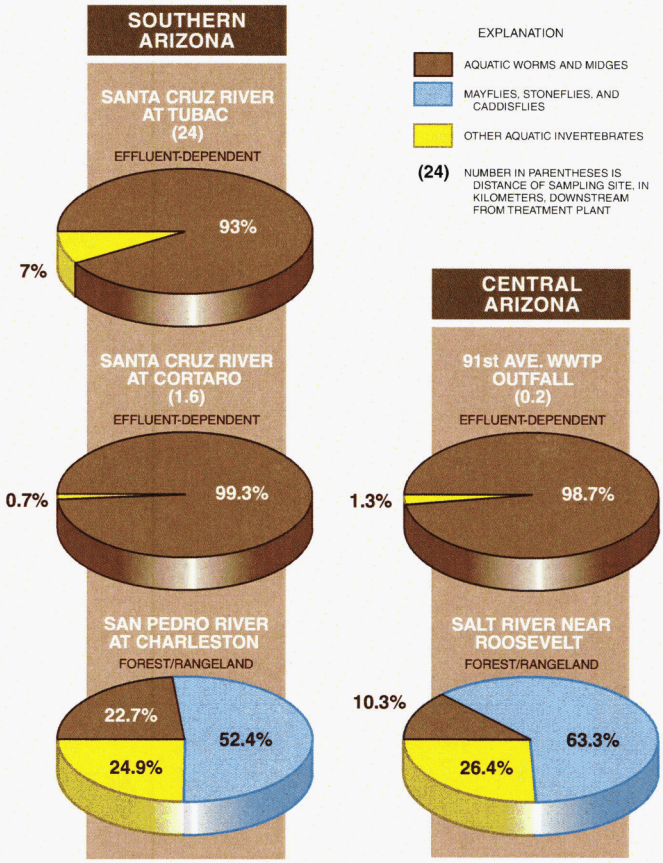
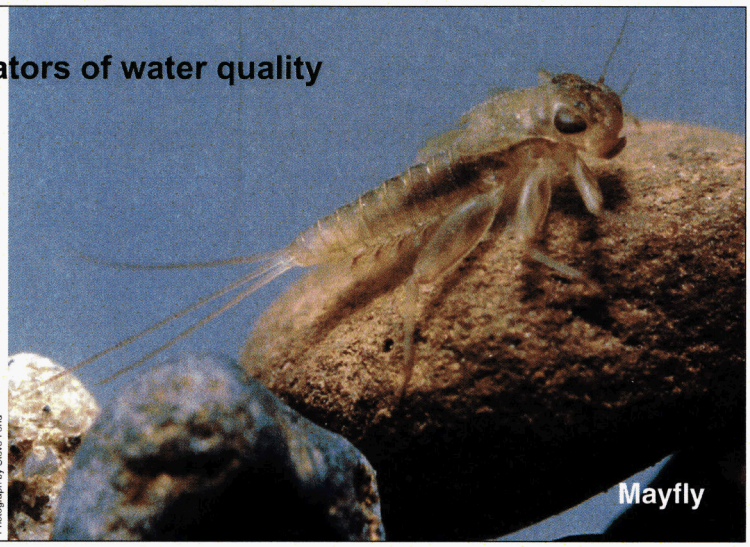


Figure 14. Pollution-tolerant aquatic invertebrates are most abundant in effluent-dependent streams.

Aquatic invertebrates are indicators of water quality

Aquatic invertebrates are animals such as worms and insects that live in water. Fly fishermen know that game fish such as trout and bass eat insects such as mayflies, stoneflies, and caddisflies. Biologists who study water quality have found that some aquatic invertebrates, such as certain aquatic worms and midges, can tolerate poor water quality. Many types of mayflies, stoneflies, and caddisflies are sensitive to water-quality degradation and are most abundant in streams with good water quality. Biologists can sample for aquatic invertebrates and determine the relative quality of the water by the numbers and types of invertebrates found.



Photograph by Steve Fend

Organochlorine pesticides and PCBs in streambed sediment and fish tissue from effluent-dependent streams exceeded guidelines for protection of aquatic life and fish-eating wildlife. Probable effect levels (PELs) for sediment (Canadian Council of Ministers of the Environment, 1999) were exceeded for DDE and total chlordane in samples from the 91st Avenue WWTP and at a site near the discharge point from the Nogales WWTP into the Santa Cruz River. The PEL is a concentration above which adverse effects to aquatic organisms are predicted to occur frequently. Exceedance of the PEL concentrations indicates that bottom-dwelling aquatic organisms may be adversely affected by toxicity. Total DDT (91st Avenue WWTP) and PCBs (Santa Cruz River at Tubac) in fish-tissue samples exceeded New York State guidelines (Newell and others, 1987) for the protection of fish-eating wildlife. These guidelines are being applied to findings from NAWQA Study Units nationwide. DDT, which breaks down to form DDE and DDD, is associated with past use of DDT in agricultural areas. Use of DDT was discontinued in Arizona in 1969. PCBs were primarily used in industrial and urban settings, but their use was discontinued in 1979. Exceedances of tissue guidelines can result in reduced reproductive ability and other possible adverse effects in wildlife that eat contaminated fish (Faber and Hickey, 1973).

Agricultural/urban streams

As in effluent-dependent streams, nutrient concentrations in agricultural/urban streams were elevated compared with concentrations in forest/rangeland streams (fig. 11). This is no surprise given that the two agricultural/urban streams—Buckeye Canal near Avondale and Hassayampa River near Arlington—receive effluent from the 91st Avenue WWTP in Phoenix. The effluent is mixed with ground water in Buckeye Canal and used to irrigate cotton and other crops. Downstream, effluent and irrigation return flows in Buckeye Canal are discharged into the Hassayampa River near Arlington. At this point, the water has been used and reused for agricultural irrigation, and nitrate concentrations are typically higher than those in the original effluent (fig. 11) because of the use of fertilizers in the agricultural area near Buckeye.

Herbicides were detected in streams soon after application to agricultural lands, but concentrations did not exceed guidelines for protection of aquatic life. In the West Salt River Valley west of Phoenix, the pre-emergent herbicides dacthal, EPTC, simazine, and trifluralin are applied to tilled fields prior to cotton planting in the early spring to control weeds. They may be reapplied in the fall to fields where winter crops are grown. These herbicides were detected in surface-water samples from the agricultural/urban streams in the early spring and fall, soon after application. Changes in concentrations of dacthal at the Hassayampa River near Arlington (fig. 15) are representative of the patterns seen for herbicide concentrations at both sites. Agricultural and rainfall runoff carry these pesticides to streams. Because streamflow at these sites is not used for drinking water but does sustain aquatic life, guidelines for the protection of aquatic life were used to evaluate water quality. Aquatic-life guidelines for simazine and trifluralin were not exceeded in any samples from these sites. There are no aquatic-life guidelines for dacthal and EPTC.

Organochlorine pesticides that persist in streambed sediment and in fish tissue from an agricultural/urban stream are a concern for aquatic ecosystem health. PEL concentrations for sediment were exceeded for DDE and DDT at the agricultural/urban stream site on the Buckeye Canal

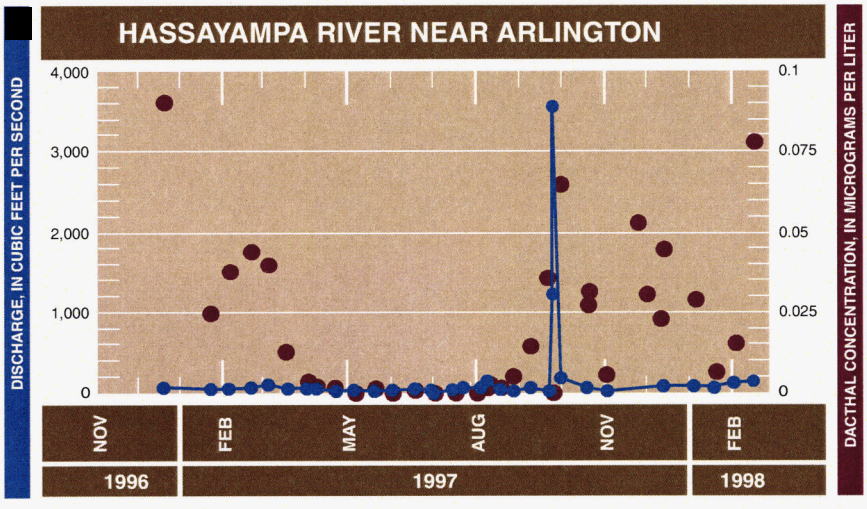
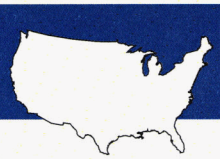


Figure 15. Herbicides were detected in streams soon after being applied to crops.

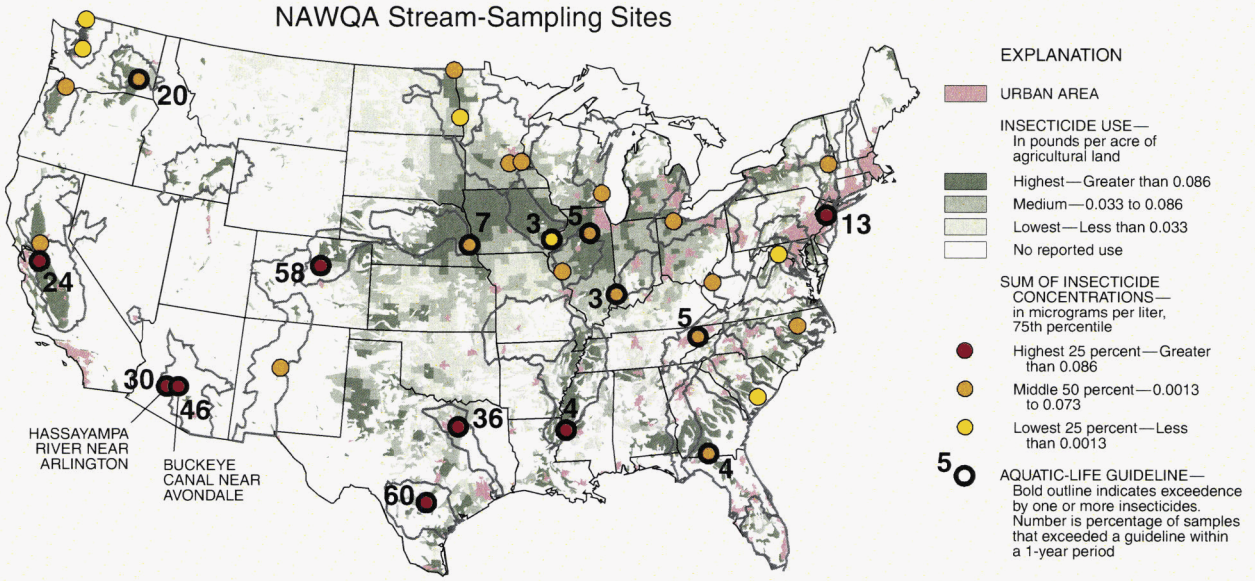
near the Hassayampa River (adjacent to the Hassayampa River at Arlington site, see p. 26). Concentrations of DDE in fish-tissue samples from this site exceeded guidelines established by New York State (Newell and others, 1987) for the protection of fish-eating wildlife. Concentrations of toxaphene in two out of three fish-tissue samples from the same site exceeded the National Academy of Science/National Academy of Engineering (1973) guideline for the protection of fish-eating wildlife. Past use of pesticides including DDT, toxaphene, and others on agricultural areas in the West Salt River Valley is the source of these pesticides. Though use of these pesticides was discontinued decades ago, the pesticides persist over time and their breakdown products continue to enter streams by erosion of contaminated soils, surface-water runoff, and atmospheric deposition. Exceedances of tissue guidelines indicate possible adverse effects, such as reduced reproductive ability and eggshell thinning, to birds and other wildlife that eat contaminated fish (Faber and Hickey, 1973).



In the CAZB Study Unit, insecticide concentrations in agricultural/urban streams are among the highest in the Nation

Pesticides in water were measured at 117 sampling sites on 114 rivers and streams across the United States as part of the NAWQA Program from 1992–1998. At each site, concentrations of all insecticides detected during a 1-year period were summed and categorized as low (lowest 25 percent), middle (middle 50 percent), and high (highest 25 percent) compared to concentrations at all of the sites monitored (see figure below). This information was compared, by county, to insecticide use during the early to mid-1990's on agricultural lands.

In the CAZB Study Unit, insecticide concentrations in streams with mixed agricultural/urban land use were among the highest in the Nation. These sites—the Buckeye Canal near Avondale and the Hassayampa River near Arlington in the West Salt River Valley—are dominated by treated effluent and irrigation return flows that contain insecticides from urban and agricultural land uses. Nearly one-half the samples (46 percent) collected from the Buckeye Canal during 1 year exceeded aquatic-life guidelines for one or more of the following insecticides: diazinon, malathion, lindane, and chlorpyrifos. At the Hassayampa River site, 30 percent of samples collected in a 1-year period exceeded aquatic-life guidelines for one or more of the following pesticides: chlorpyrifos, azinphos-methyl, DDE, dinoseb, malathion, diazinon, and parathion. Although these streams are not used for drinking water, the water quality does present a potential hazard to aquatic life. In addition, little is known about the effects of mixtures of pesticides, even at low concentrations, on aquatic life (Gilliom, 1999).



Insecticide concentrations in streams in the West Salt River Valley near Phoenix are among the highest in the Nation.

Natural Ground-Water Quality

It is important to understand how natural processes affect ground-water quality in order to identify the effects of urban and agricultural development under similar hydrogeologic conditions. In the CAZB, the majority of ground-water basins do not have significant urban or agricultural development. The ground-water quality in these basins is primarily a product of natural processes such as the interaction of ground water with rocks and sediment in the basins (Robertson, 1991).

Natural sources of dissolved-solids and nitrate can control ground-water quality in basins with minimal urban development. Specific-conductance values (an indirect measure of the dissolved-solids concentration) and nitrate concentrations for ground water in basins with minimal urban development increase northwestward from southeastern Arizona toward the central part of the State (figs. 16 and 17). The increasing specific-conductance values can be attributed to a corresponding increase in evaporite deposits in basin sediments from southeast to northwest (Gellenbeck and Coes, 1999). Evaporite deposits in the basins contain minerals such as halite (salt) and gypsum that can be easily dissolved in ground water. (Robertson, 1991). The increasing nitrate concentrations can be largely attributed to natural sources; however, human activities such as agriculture can be a source in some basins. In some locations in the CAZB, high nitrate concentrations in ground water reported prior to any agricultural or urban development indicate that natural

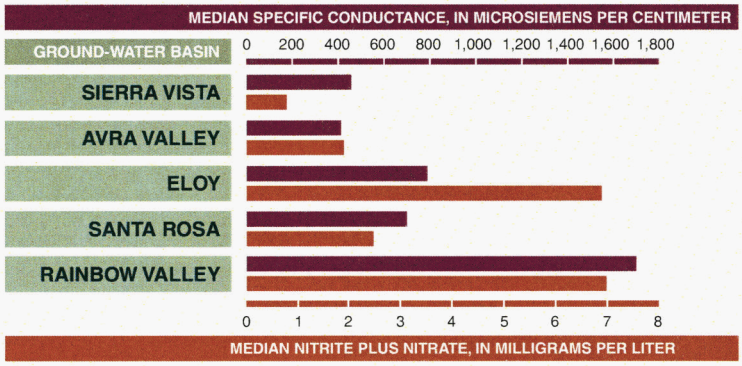


Figure 16. Nitrate concentrations and specific conductance values in ground water from basins with minimal urban development increase from the southeast to the northwest. (Basins shown below in figure 17.)

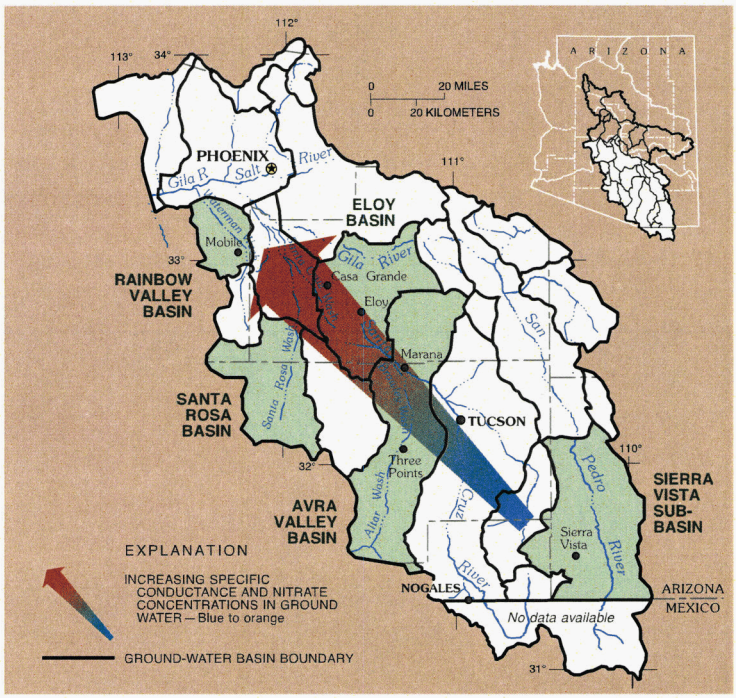


Figure 17. Increasing specific conductance values in ground water from southeast to northwest can be attributed to an increase in soluble evaporite deposits in basin sediments. Increasing nitrate concentrations in the same direction may be the result of naturally occurring nitrate and of human activities that include agriculture.

sources of nitrate are present in some basins (Hem, 1985; Robertson, 1991; Gellenbeck, 1994; Gellenbeck and Coes, 1999). Dissolution of evaporite deposits, decay of buried organic matter, precipitation, weathering of rocks and soils, and fixation by microorganisms are just a few of the possible sources of naturally occurring nitrate in ground water.

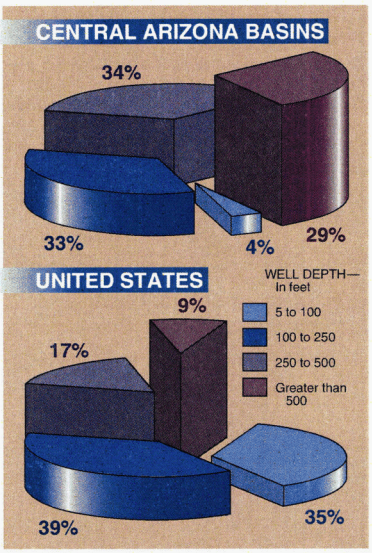


Figure 18. Ground water sampled in the CAZB Study Unit generally is from greater depths than ground water sampled in NAWQA Study Units across the Nation.

Quality of deep, older ground water unaffected by human activities

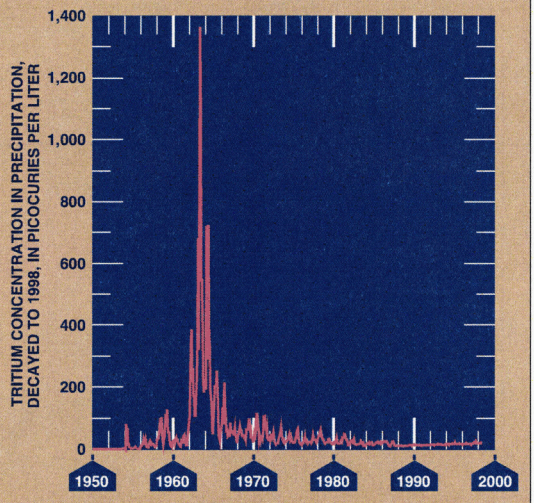
In general, ground water in Arizona is replenished (recharged) at very slow rates because of little precipitation, high evaporation losses, and the long distance water must travel to recharge deep aquifers. In the CAZB, 63 percent of the wells sampled that draw water from aquifers used for drinking water were at least 250 feet deep compared to 26 percent of NAWQA wells sampled nationwide (fig. 18). Recharge takes longer to reach deep aquifers than shallow aquifers; therefore, deep ground water typically was recharged earlier and is older than shallow ground water. Tritium age dating of ground water (see below) confirms that 55 percent of the wells sampled in the CAZB yielded ground water that was recharged prior to 1953 and possibly thousands of years earlier. For example, some ground water in the Upper Santa Cruz Basin was determined to be about 6,500 years old (Kalin, 1994). Across the Nation, only 27 percent of the NAWQA wells sampled for tritium yielded ground water that was recharged prior to 1953.

The age and depth of ground water in the CAZB have important implications for water quality and quantity. Because much of the deep ground water sampled in the CAZB was recharged prior to 1953 and has not mixed with younger recharge, drinking-water quality generally has not been substantially affected by human activities that took place after 1953. The movement of contaminants from the land surface to the deep ground water is hindered by the thickness of basin-fill sediments through which contaminants must travel. Ground-water quantity is affected because ground water pumped from deep aquifers is not being replaced by recharge (see p. 5), resulting in a net decrease in the quantity of ground water available for consumption.

Method for dating ground water

Tritium is a radioactive isotope that can be used to estimate whether ground water has been recharged before or after 1953. Large quantities of tritium were released to the atmosphere during testing of thermonuclear weapons from 1952 until the late 1960s. Atmospheric tritium is incorporated into water molecules in the atmosphere prior to precipitation and recharge to ground water. The concentration of tritium in ground water at a given time is controlled by both the quantity of tritium in the atmosphere when precipitation and recharge occur and the radioactive decay rate of tritium. Ground water that does not contain detectable tritium (less than 2.5 picocuries of tritium per liter) can be assumed to have been recharged prior to 1953, and ground water that does contain detectable tritium (more than 2.5 picocuries of tritium per liter) is assumed to contain some component of ground water that was recharged after 1953.

Tritium concentrations in precipitation are a guide for determining when ground water was recharged.



Concentrations of arsenic, fluoride, and molybdenum exceeded drinking-water standards in samples from major aquifers. The median arsenic concentration in ground water for the three CAZB basins sampled was 4 µg/L. One sample from the Upper Santa Cruz Basin and one sample from the West Salt River Valley exceeded the current MCL for arsenic of 50 µg/L; however, a new, lower standard of 5 µg/L has been proposed by the USEPA because of the cancer risk posed by arsenic in drinking water (U.S. Environmental Protection Agency, rev. August 25, 2000). When arsenic concentrations in ground water sampled in the CAZB are compared to the proposed standard, more than 50 percent of samples from aquifers in West Salt River Valley that are used for drinking water exceed 5 µg/L. Seventeen percent of samples in the Upper Santa Cruz Basin and 10.5 percent of samples in the Sierra Vista subbasin exceed 5 µg/L. The USEPA may not settle on 5 µg/L, but the new standard is likely to be significantly lower than the current MCL.

The median concentration of fluoride was 0.5 µg/L; about 2 percent of the samples exceeded the current MCL for fluoride of 4 µg/L. The median concentration of molybdenum was 3 µg/L; about 1 percent of the samples exceeded the current lifetime health advisory for molybdenum of 40 µg/L established by the USEPA.

Radon and uranium are detected in most ground-water samples. Radon is a colorless and odorless radioactive gas that is carried in the water pumped from wells (fig.19) and released to indoor air by activities such as cooking and showering. Breathing radon increases the risk of lung cancer (U.S. Environmental Protection Agency, rev. October 18, 1999). Radon is naturally formed in rocks and soils from the radioactive decay of radium, an intermediate product in the uranium decay process. In the CAZB Study Unit, radon was present in 100 percent of the samples, and uranium was detected in 90 percent of the samples. The median concentrations for radon and uranium were 584 picocuries per liter and 3 micrograms per liter, respectively. Currently (2000), there are no USEPA MCLs for radon and uranium; however, proposed MCLs could result in increased costs for water suppliers to treat drinking water for these constituents or find alternate supplies. Additional costs would probably be passed on to the water user (see information on proposed standards for arsenic, radon, and uranium on p. 20).

Effects of Human Activities on Ground-Water Quality

The contamination of major aquifers is largely controlled by hydrology and land use (U.S. Geological Survey, 1999). In the CAZB Study Unit, deep ground water that was recharged prior to 1953 typically has not been affected by human activities (see p. 18). In areas with recent recharge (after 1953), ground water is more likely to be contaminated by nutrients and man-made chemicals associated with urban and agricultural land uses.

Ground-water quality deteriorates in irrigated areas. Irrigation water that seeps downward is a principal source of ground-water recharge in irrigated areas of the CAZB. Dissolved-solids concentrations in seepage can be as much as five times those in the original irrigation water (Bouwer, 1990) because of concentration by evaporation and plant use (see p. 9). The greater the dissolved-solids concentration in the applied irrigation water, the greater the concentration in the seepage moving downward to the ground water.

To determine the effects of irrigated agriculture on shallow ground-water quality, nine monitoring wells were drilled and sampled in the southwestern part of the West Salt River Valley (see "Study Unit Design," p. 26). Because the average depth to ground water in the nine wells is 32 feet (table 1) compared to 230 feet for wells sampled basinwide, irrigation seepage does not have to travel far to reach the shallow ground water in the agricultural area. Sources of irrigation water in this area include treated sewage effluent, water from the Salt River and CAP canal, irrigation return flows, and ground water. Dissolved-solids concentrations of these sources range from about 900 mg/L for treated sewage effluent (Tadayon and others, 1998) to 650 mg/L for CAP water and 470 mg/L for Salt River water (Salt River Project, 1997).

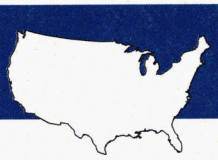
The median dissolved-solids concentration in water from the nine shallow wells exceeded 3,000 mg/L (table 1). In addition, the effects of nitrate from fertilizer applications and reuse of irrigation return flows were evident from the median nitrate concentration that was nearly twice the MCL of 10 mg/L (table 1).

Figure 19. Samples are collected at the well head for radon analysis to prevent possible sample contamination from exposure to the atmosphere.

Table 1. Median concentrations of nitrate and dissolved solids were highest in shallow ground water from an agricultural area in the West Salt River Valley

Study area	Median concentration, in milligrams per liter		Average depth to ground water, in feet
	Nitrate	Dissolved solids	
West Salt River Valley			
Agricultural area	*19.0*	*3,050*	*32*
Basinwide	*2.7*	*560*	*230*
Upper Santa Cruz Basin	*1.5*	*305*	*230*
Sierra Vista subbasin	*0.78*	*262*	*171*
U.S. Environmental Protection Agency drinking-water standard	*[1]10*	*[2]500*	

[1] Maximum Contaminant Level.
[2] Secondary Maximum Contaminant Level.

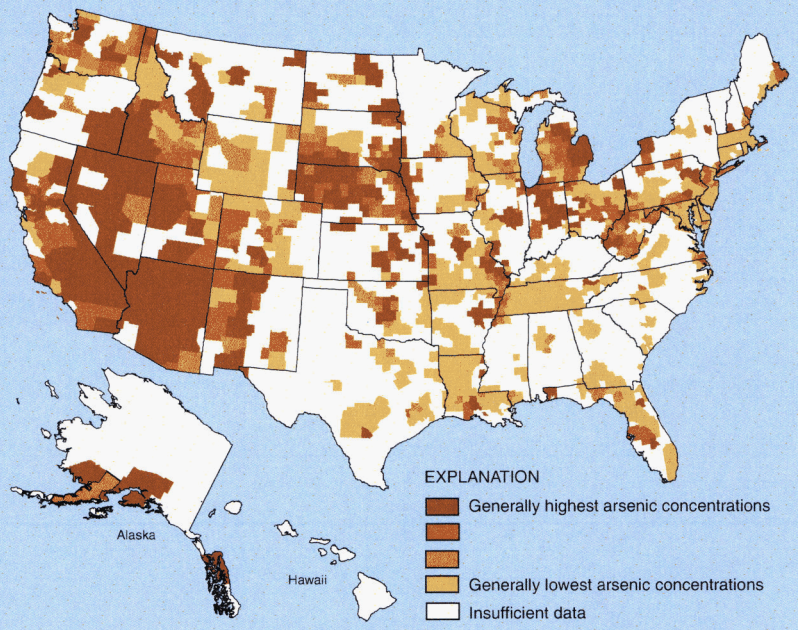


Proposed drinking-water standards for arsenic, radon, and uranium have major implications for ground-water supplies

During 1991–98, arsenic, radon, and uranium were measured in ground-water samples from 36 NAWQA Study Units across the United States. If the ground-water samples from these Study Units are representative of ground water across the Nation, MCLs (see Glossary) proposed by the USEPA for these constituents will affect many water suppliers and municipalities in the United States. Because ground-water supplies in many parts of the Nation will likely exceed the proposed MCLs, public-water systems would be required to either specifically treat their water to decrease concentrations of the constituents or find alternative sources of supply. Costs of these options would probably be passed on to water users.

Arsenic

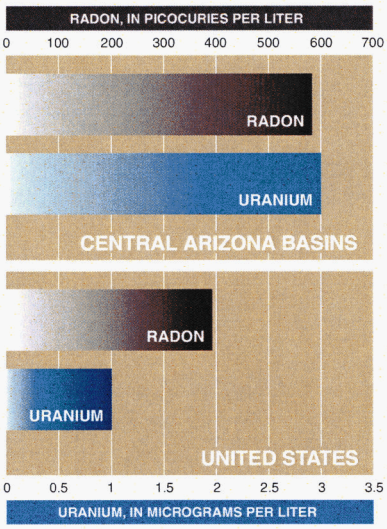
The current USEPA MCL for arsenic in drinking water, 50 µg/L, is under review after recognition of the risks of developing cancers (National Research Council, 1999). In 2000, the USEPA proposed a new, lower arsenic MCL of 5 µg/L (U.S. Environmental Protection Agency, rev. June 2, 2000). In samples collected in three CAZB basins, only 2 percent exceeded the current USEPA MCL; however, 32 percent exceeded the lower, proposed MCL. In samples collected across the Nation, only 0.6 percent exceeded the current USEPA MCL; however, 14 percent exceeded the lower proposed MCL. Arizona, including the CAZB, is among the areas in the Nation where 10 percent or more of ground-water samples are likely to exceed the lower MCL (figure at right; Welch and others, 2000).



High concentrations of arsenic in ground water are more widespread in the West.

Radon and uranium

Currently, USEPA MCLs for radon and uranium do not exist. Because of public health concerns, including increased risks for developing lung cancer, the USEPA proposed an MCL of 20 µg/L for uranium in 1991. In 1999, the USEPA proposed an MCL of 300 picocuries per liter (pCi/L) for radon; however, if States or water suppliers implement methods to lower radon levels in indoor air, they would only be required to meet an Alternate MCL (AMCL) of 4,000 pCi/L (U.S. Environmental Protection Agency, rev. April 21, 2000; U.S. Environmental Protection Agency, rev. October 18, 1999). Of the ground-water samples collected in the three CAZB basins, 9 percent exceeded the proposed uranium MCL, 91 percent exceeded the proposed radon MCL, and 1 percent exceeded the proposed radon AMCL. In the NAWQA samples collected nationwide, 4 percent exceeded the proposed uranium MCL, 61 percent exceeded the proposed radon MCL, and 4 percent exceeded the proposed radon AMCL (Dennis Wentz and others, U.S. Geological Survey, written commun., 1999). The Study Units with the highest radon concentrations were in the Colorado Rockies and the Eastern United States. Median concentrations of radon and uranium in the CAZB Study Unit were higher than median concentrations for the United States (figure at right).



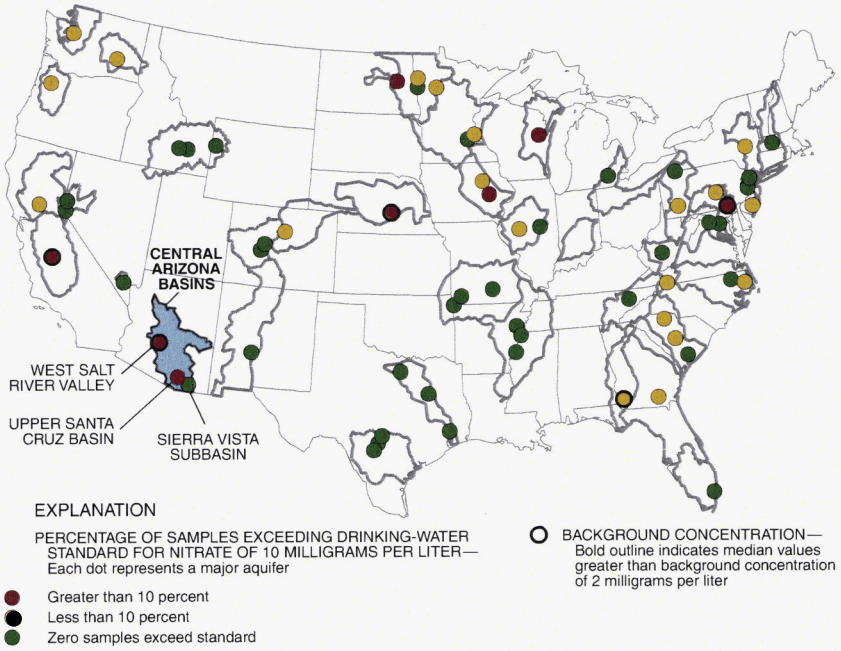
Median concentrations of radon and uranium in ground water in the CAZB exceeded those for the Nation.

Nitrate concentrations in ground water in the West Salt River Valley are among the highest in the Nation

The study of water quality in deep aquifers that provide drinking water in the West Salt River Valley is one of eight NAWQA ground-water studies nationwide that had more than 10 percent of samples that exceeded the USEPA MCL for nitrate of 10 mg/L (figure at right). Of 35 samples collected basinwide in the West Salt River Valley, 34 percent had concentrations greater than the USEPA MCL. Seventy-eight percent of shallow ground-water samples from the agricultural land-use study in the West Salt River Valley had concentrations greater than the USEPA MCL for nitrate. Only 10 percent of samples from the Upper Santa Cruz Basin and none of the samples from the Sierra Vista subbasin had concentrations that exceeded the USEPA MCL for nitrate.

Excessive nitrate in drinking water is a health concern for children and adults. In children, high nitrate concentrations can result in "blue-baby syndrome," in which oxygen levels in the blood of infants are low, sometimes fatally so (National Governor's Association, 1991).

Birth defects also have been attributed to high nitrate concentrations (National Governor's Association, 1991). In adults, high nitrate concentrations have been associated with cancer (National Academy of Sciences, 1977).



The CAZB is one of eight Study Units in the Nation with nitrate concentrations in ground water that exceed the drinking-water standard in more than 10 percent of samples.

Sources of nitrate in the Central Arizona Basins Study Unit include evaporite deposits in basin sediments, precipitation, agricultural fertilizers, animal-feeding operations, WWTP outflow, and others (see p. 10). In areas with agricultural and (or) urban development, sources of nitrate related to human activities are prevalent, whereas precipitation and geologic sources of nitrate predominate in undeveloped areas.

The highest concentrations of nitrate and dissolved solids were in shallow ground water beneath an irrigated agricultural area. Shallow ground water from the agricultural land-use study area in the West Salt River Valley had median concentrations of nitrate (19 mg/L) and dissolved solids (3,050 mg/L) that exceeded the USEPA MCL and SMCL, respectively (table 1). Nitrate and dissolved solids from irrigation and agricultural practices are accumulating in shallow ground water (see p. 9 and 11). The shallow ground water in this area is not used for drinking water, and clay beds reduce the likelihood of contamination of the aquifers below that are used for drinking water (see p. 22).

Deeper ground water from urban, rangeland, and agricultural areas in other parts of the West Salt River Valley had a median nitrate concentration that was less than the MCL of 10 mg/L; however, the median concentration of dissolved solids exceeded the SMCL of 500 mg/L (table 1). Median concentrations of nitrate from the Upper Santa Cruz Basin and the Sierra Vista subbasin also were less than the MCL, and median concentrations of dissolved solids were less than the SMCL (table 1).

Clay beds that currently protect deep ground water from contamination may not do so in the future.

In the agricultural land-use study area of the West Salt River Valley (fig. 20), the tops of low-permeability clay beds are about 150 to 400 ft below the land surface. These clay beds impede the downward movement of irrigation seepage and reduce the likelihood of contaminants reaching deeper drinking-water supplies. Domestic wells in the area yield water from beneath the protective clay beds. Ground water above the clay beds has higher nitrate and dissolved-solids concentrations than ground water from beneath the clay beds (fig. 21). In this area, ground-water samples from above the clay beds had a median dissolved-solids concentration of 3,050 mg/L and a median nitrate concentration of 19.0 mg/L (table 1). Ground-water samples from below the clay beds had a median dissolved-solids concentration of 702 mg/L and a median nitrate concentration of 1.9 mg/L. Care must be taken in drilling and completing drinking-water wells below the clay beds to ensure that shallow ground water above the clay beds does not contaminate the well and aquifer below.

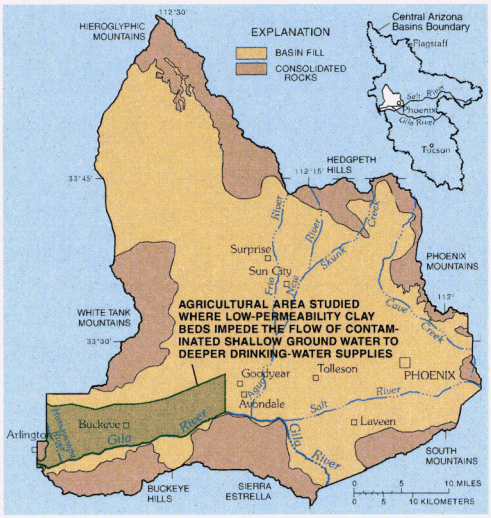


Figure 20. Low-permeability clay beds in an agricultural area in the West Salt River Valley reduce the likelihood of contamination reaching deeper drinking-water supplies.

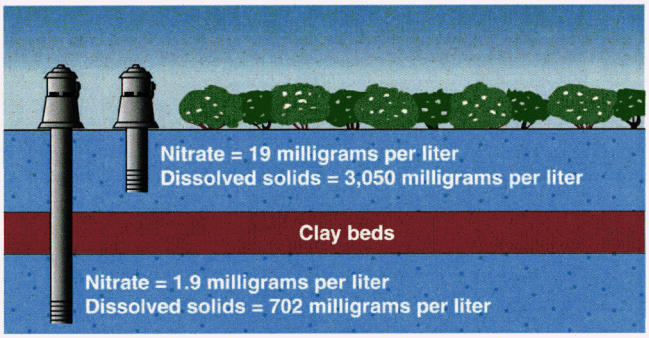


Figure 21. Ground water above the clay beds was recharged after 1953 and has been affected by agricultural activities.

Analyses of the tritium from ground water in this area indicated that water above the clay beds generally had been recharged after 1953, and water below the clay beds generally had been recharged before 1953 (see information about age dating ground water on p. 18). Although the clay beds currently reduce the likelihood that irrigation seepage will contaminate the ground water below, future large-scale withdrawals of ground water from below the clay beds could possibly result in the movement of shallow, poor quality water through the clay beds and into the domestic ground-water supply.

Occurrence and distribution of pesticides in ground water in the CAZB reflect both agricultural and urban land uses. Ten pesticides were detected in shallow ground water from the agricultural land-use study area in the West Salt River Valley, west of Phoenix (fig. 22). In other parts of the West Salt River Valley, consisting of agricultural, urban, and rangeland areas, eight pesticides were detected in ground water. Five pesticides were detected in ground water from the Upper Santa Cruz Basin, where there is a mixture of land-use types, but 60 percent of the basin is undeveloped rangeland (Coes and others, 2000). In the Sierra Vista subbasin, where urban and agricultural land uses are minimal (3.3 percent of basin; Coes and others, 1999) and have been minimal in the past, no pesticides were detected in ground-water samples. During 1996–98, the largest quantities of pesticides used among the three basins were for agriculture in the West Salt River Valley (Ken Agnew, University of Arizona, Pesticide Information and Training Office, written commun., 1999).

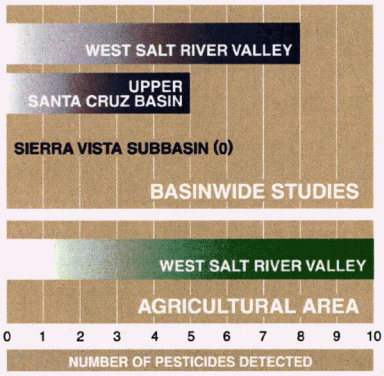


Figure 22. The largest number of pesticides was detected in an agricultural area in the West Salt River Valley.

Most of the pesticides detected in ground water in the CAZB were herbicides used to control unwanted plants in urban and agricultural areas (fig. 23). Herbicide use in urban areas is indicated by detections of simazine and prometon in the West Salt River Valley and prometon and 2,4-D in the Upper Santa Cruz Basin. These herbicides are used primarily in nonagricultural areas (U.S. Geological Survey, 1999). Detections of atrazine and deethylatrazine (a breakdown product of atrazine) in the West Salt River Valley and the Upper Santa Cruz Basin are an indication that herbicides used in areas of present and historical agriculture are affecting ground-water quality. Atrazine is one of the most heavily used herbicides in agricultural areas in the United States (U.S. Geological Survey, 1999).

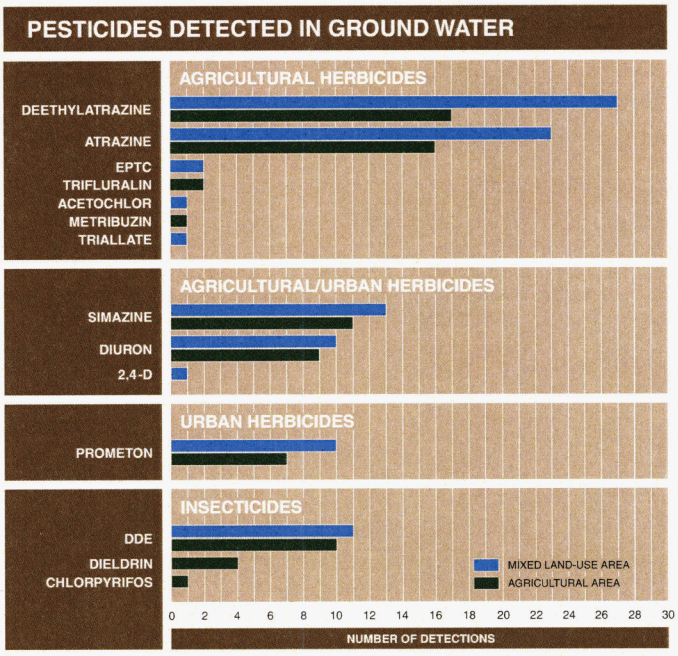


Figure 23. Most of the pesticides detected in ground water in the CAZB were herbicides used in agricultural and urban environments.

Concentrations of pesticides in ground water did not exceed drinking-water standards or guidelines. Although deethylatrazine, simazine, prometon, DDE, atrazine, and diuron were detected in more than 30 percent of the ground-water samples from the agricultural land-use study area of the West Salt River Valley, none of the concentrations exceeded drinking-water standards or guidelines. Similarly, pesticides detected in ground water from the basinwide sampling in the West Salt River Valley during 1996–98 did not exceed drinking-water standards or guidelines.

DDE was detected in 10 (56 percent) of the shallow ground-water samples from the agricultural land-use study area in the West Salt River Valley. Detections of DDE in this area are the result of the persistence of this insecticide breakdown product in the environment and the physical characteristics of the ground-water system in the area. In particular, the shallow depth to ground water in the agricultural land-use study area means that irrigation seepage and recharge, containing pesticides and their breakdown products, do not have to travel far to contaminate the ground water. Clay layers impede the movement of pesticides into the deeper aquifers in the area. The soils in the agricultural area have been identified as a source of DDE for the ground water (Brown, 1993). The only detection of DDE in the West Salt River Valley outside of the agricultural area was in a sample from the northern part of the Phoenix metropolitan area. DDE was not detected in samples from the Upper Santa Cruz Basin or the Sierra Vista subbasin.The large depths to ground water and small amounts of DDT used in most of the West Salt River Valley, the Upper Santa Cruz Basin, and the Sierra Vista subbasin limit the potential for introduction of DDE to the ground water.

Pesticides and Human Health

Laboratory studies, mostly on animals, have shown that pesticides can cause health problems such as birth defects, nerve damage, cancer, and disruption of the endocrine system (USEPA, rev. June 12, 2000). The health effects on humans are not adequately understood, particularly when estimating the risks of exposure to mixtures of pesticides in water (U.S. Geological Survey, 1999). The USEPA determines risk on the basis of toxicity and exposure to a single pesticide (U.S. Environmental Protection Agency, rev. November 17, 1999), whereas NAWQA studies in the CAZB (see p. 24) and nationwide have shown that most contamination in water occurs as pesticide mixtures (U.S. Geological Survey, 1999). The effects of exposure to low concentrations of pesticide mixtures in drinking water is not known and will require further study to determine if standards or guidelines can be developed.

Detections of multiple pesticides indicate the complexity of contamination from land-surface activities. No standards or guidelines currently exist for mixtures of pesticides in drinking water because their effect on human health is not known (U.S. Geological Survey, 1999). All 9 wells in the agricultural land-use study area had 3 or more pesticides detected, whereas only 3 of the 35 wells sampled basinwide in the West Salt River Valley had 3 or more pesticides detected, and none of the wells in the Upper Santa Cruz Basin had 3 or more pesticides detected (fig. 24). No pesticides were detected in the Sierra Vista subbasin.

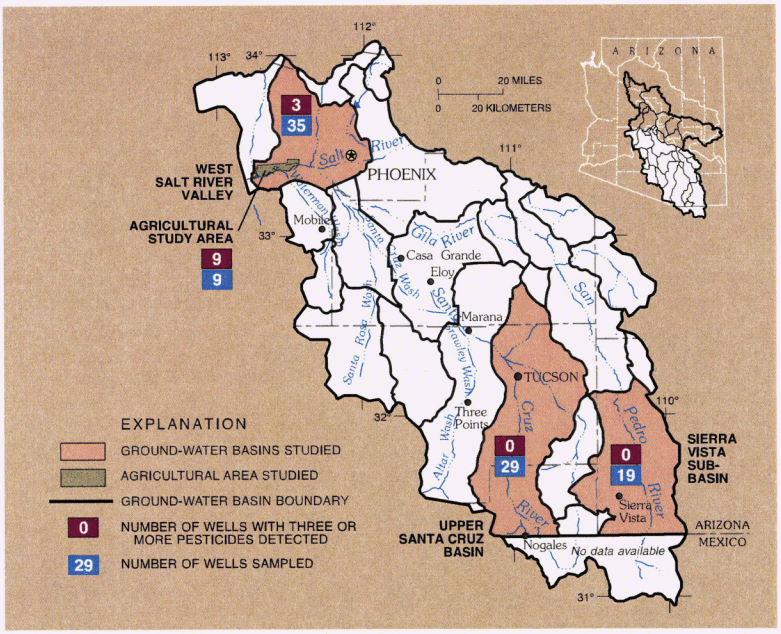


Figure 24. Multiple pesticides were detected in all nine monitoring wells in the agricultural land-use study area of the West Salt River Valley.

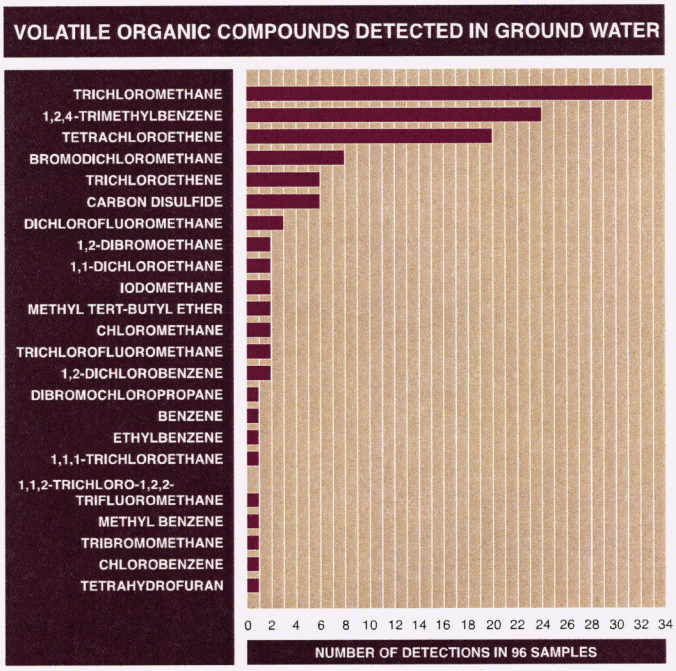


Figure 25. The VOCs trichloromethane, 1,2,4-trimethylbenzene, and tetrachloroethene were detected most frequently in ground water.

Volatile organic compounds (VOCs), including gasoline compounds, solvents, and refrigerants, have been identified as a major concern for ground-water contamination in Arizona (Marsh, 1994). Leaking underground storage tanks and disposal of solvents have been linked to most of the documented cases of ground-water contamination by VOCs. Electronic- and aerospace-manufacturing facilities use solvents for degreasing and are known to be sources of some of the largest VOC contamination problems in Arizona. Disposal of solvents from these types of facilities has occurred since the 1950s (Marsh, 1994). Dry-cleaning facilities also have been identified as sources of recent ground-water contamination by VOCs. Some municipal supply wells in the urban areas of Phoenix and Tucson are no longer used because of contamination by VOCs (Marsh, 1994).

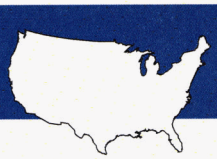
VOCs were detected in ground water from all three basins sampled during 1996–98 (fig. 25). Of the 96 samples collected, 33 (34 percent) contained trichloromethane, 24 (24 percent) contained 1,2,4-

trimethylbenzene, and 20 (21 percent) contained tetrachloroethene (otherwise known as perchloroethylene, PCE, a solvent commonly used in dry cleaning). Only two VOC detections exceeded drinking-water regulations—PCE (5.48 µg/L) in the Upper Santa Cruz Basin and 1,2-dibromoethane (0.080 µg/L) in shallow ground water in the agricultural area of the West Salt River Valley.

Shallow ground water from the nine wells in the agricultural land-use study area had the largest number of VOC detections (35). Ground water from the other 35 wells in the West Salt River Valley had 32 detections. The Upper Santa Cruz Basin (18) and the Sierra Vista subbasin (13) had fewer detections. The larger area of urban land use in the West Salt River Valley appears to be the reason for the greater number of detections there than in the other basins sampled.

Three wells that had five or more VOCs detected in ground water were located in the metropolitan area of Phoenix in the West Salt River Valley. The VOCs detected in these wells were either refrigerants, solvents and chemicals used to make solvents, or gasoline additives. These detections are typical of detections found in small-capacity wells in the metropolitan Phoenix area (Marsh, 1994). Combinations of solvents and gasoline additives are often detected in ground water because their use is widespread, not necessarily because they are from the same source (Squillace and others, 1999).

Detections of VOCs in ground water in the relatively undeveloped Sierra Vista subbasin indicate that ground water in localized areas of the subbasin may be affected by human activities. These detections are not widespread; therefore, the effects of human activity on present-day ground-water quality are not considered significant for the entire subbasin. These detections are an "early warning" of what could occur in the future in a basin that is presently considered minimally affected by urban activities.



Trichloromethane was the most commonly detected VOC in the Nation and in the CAZB Study Unit

Trichloromethane (chloroform), tetrachloroethene (PCE), and 1,2,4-trimethylbenzene were three of the five most commonly detected VOCs in the Nation and in the CAZB when concentrations above an assessment level of 0.1 µg/L were considered. The national data collected by the NAWQA Program during 1996–99 represent ambient ground water for all land-use types. Trichloromethane and PCE have been shown to cause cancer in laboratory animals from long-term exposure at concentrations greater than USEPA MCLs.

Trichloromethane is a by-product created during the use of chlorine to disinfect water, a solvent, and a degradation product of carbon tetrachloride. It can enter ground water from lawn irrigation, leaking sewers and water mains, and spills or improper disposal at industrial sites. The use of treated effluent from sewage-treatment plants for irrigation also provides a way for trichloromethane to reach the ground water in the CAZB, specifically in the agricultural land-use study area in the West Salt River Valley.

PCE is a solvent used primarily for degreasing and at dry-cleaning facilities. 1,2,4-trimethylbenzene is used to make trimellitic anhydride, dyes, and pharmaceuticals. Because there are many individual sources of these compounds in urban areas of the CAZB, it is difficult to identify the exact sources of ground-water contamination without site-specific studies, which were beyond the scope of the NAWQA sampling program.

Five most frequently detected volatile organic compounds in the CAZB and the Nation

Central Arizona Basins Study Unit		Nation	
Compound name	Frequency of detection, in percent	Compound name	Frequency of detection, in percent
Trichloromethane	*16*	*Trichloromethane*	*12*
Chloromethane	*6*	*Toluene*	*4*
Tetrachloroethene	*5*	*Tetrachloroethene*	*4*
1,2,4-Trimethylbenzene	*4*	*Carbon disulfide*	*4*
Bromodichloromethane	*2*	*1,2,4-Trimethylbenzene*	*4*

(Data include all land-use types; assessment level of 0.1 microgram per liter)

Western Group Rate Case

Exhibit FKS-22

Appendix I
GROUNDWATER ASSESSMENT
Authors: Wayne Hood, R.G. (retired), Douglas Towne and GIS Analysis by Steve Callaway

Introduction

Arizona's communities, agriculture, industries, energy production, and ecosystems, such as wetlands and aquatic habitats, depend on adequate water supplies of suitable quality. About 3.1 million acre-feet (maf), or 43 percent of Arizona's water use annually, comes from groundwater sources; remaining water supplies come from the Colorado River and in-state streams (3.8 maf) and reclaimed water (0.2 maf) (ADWR, 2009). Groundwater is the major source for crop irrigation and public water supply in both cities and rural areas across the state. This report summarizes groundwater quality conditions on a regional-scale partially based on water monitoring results by ADEQ and collaborators from 1995 to 2009 for basin-fill aquifers in Arizona. This extensive hydrologic system within the Basin and Range Lowlands and Central Highlands Provinces represent the vast majority of the state's groundwater withdrawals. Basin-fill aquifers provide a useful framework for regional synthesis of water quality data within basins of comparable geologic or depositional setting, land and water uses, and climate. However, water quality can vary significantly within these aquifers, reflecting the heterogeneity of natural systems.

The data analyzed for regional groundwater quality conditions represent investigations with different monitoring objectives (e.g., ambient and targeted groundwater studies) and do not collectively denote statistically-based sampling designs. This high quality dataset is adequate for assessments on occurrence and general concentrations of contaminants evaluated for potential human health impacts. Statistical summaries are derived and provided for several water quality constituents in selected alluvial basins. In basin-fill aquifers with sufficient monitoring results for nitrate, due to special concerns as a widespread contaminant, a geostatistical general kriging approach was used to depict nitrate (as N) variations spatially by extrapolating available groundwater quality data to unmonitored areas. Finally, this report also includes summaries of comprehensive basin/sub-basin ambient water quality and geochemical studies based on data collected by ADEQ's Ambient Groundwater Monitoring program over the past 15 years using statistical sampling designs (Hood, Meyers and Totman, 1988; Hood, 1991).

Arizona's Groundwater Management Act of 1986 protects all aquifers for drinking water use. Many ecosystems are also dependent on direct access to groundwater or from groundwater discharge to streams, lakes, and wetlands. Major pollutant sources in Arizona are well documented including agricultural activities, wastes from industry, leaking underground storage tanks, on-site wastewater treatment systems (e.g., septic tanks), landfills, mining, wastewater treatment plants, and natural

sources. Over the past 24 years, state groundwater protection programs have been effective in protecting aquifers and preventing contamination. Generally, groundwater quality throughout the state meets primary drinking water standards, however there are numerous exceptions due to human-caused contamination and pollutants present at naturally elevated levels.

Pollutants detected in groundwater include nitrate, volatile organic compounds (typically industrial solvents), dissolved-solids (TDS) and sulfate, metals (e.g., arsenic, chromium), pesticides, petroleum hydrocarbons (usually gasoline or diesel), radiochemicals (e.g., radon-222) and bacteria. Although groundwater contamination is a serious problem, the quality of water delivered in public supplies is strictly regulated and monitored to meet state and federal standards set to protect public health. However, there are more than 100,000 private domestic well owners representing about 5% of Arizona's population that are not subject to State drinking water regulations, and are not required to periodically conduct water quality tests. Every year more than 3,000 new domestic wells are constructed adding to the number of private well owners who are often unfamiliar with the water quality condition of their wells and may not be aware of local water contaminants that could adversely affect health. Comprehensive and reliable information on the occurrence and levels of contaminants in groundwater is essential for the protection of public health and the environment.

Principal Aquifers

Aquifers in Arizona are composed of unconsolidated sediments (alluvial aquifers), consolidated sedimentary strata (sandstone and limestone aquifers), and crystalline rocks of igneous and metamorphic origin (fractured and decomposed bedrock aquifers). These aquifers are located within the three physiographic provinces of the state based on hydrogeology, altitude and other factors: the Basin and Range Province, the Central Highlands Province, and the Plateau Uplands Province. ADEQ has adopted groundwater basin and sub-basin boundaries delineated by the Arizona Department of Water Resources; basin designations are based on physiography, surface drainage patterns, subsurface geology and aquifer characteristics (Figure 1).

The desert Basin and Range Lowlands Province constitutes 45 percent of the State's land surface area and majority of population in the Phoenix and Tucson metropolitan areas. Other major communities include Yuma, Parker, Bullhead City, Lake Havasu City, Safford, Sierra Vista, and Willcox. This province is characterized by broad alluvial basins bounded by long mountain ranges rising sharply from the desert floor. The basins are filled by great thicknesses of fine-grained and coarse-grained sediments eroded from the mountains. The sediments deposited in the basins show much variation laterally and vertically in groundwater storage and transmission properties. Groundwater occurs in confined, unconfined and perched conditions. This basin-fill alluvium forms the most productive aquifers in Arizona, from which a majority of all groundwater is pumped. Depth to groundwater ranges from just below land surface to more than 1,000 feet.

The Central Highlands Province, covering 15 percent of the state, provides a geologic and physiographic transition from the Plateau Uplands to the Basin and Range Lowlands. Major population centers include the city of Prescott and towns of Payson, Chino Valley, and Prescott Valley. The Mogollon Rim marks the northern boundary of this province. Aquifers in this province are varied, including alluvial aquifers occupying relatively small basins, aquifers in consolidated sedimentary rocks, and fractured and decomposed basalt (volcanic rocks) aquifers. For instance, in the upper and middle Verde river watershed, the Big Chino sub-basin aquifer consisting of limestone and dolomite units and subsurface basalt flows are likely directly linked to Tertiary sediments (gravels and playa deposit facies) forming part of the substantial regional basin-fill aquifer in that area. Much of the surface water flow within Arizona originates in the Central Highlands Province. The streams and rivers within this province are often fed by groundwater along parts of their length.

The Plateau Uplands Province in the northeastern 40 percent of the state is underlain by extensive consolidated sedimentary rock formations. Most of the groundwater is withdrawn from these strata, although localized alluvial aquifers also provide supplies. A relatively small percentage of the state's population occupies this province, but includes the city of Flagstaff. While groundwater may be found near land surface, it generally occurs at a depth of more than 1,000 feet in the consolidated sedimentary rocks. The multi-aquifer systems of the province contain three major systems: 1) C-aquifer consists of Coconino Sandstone as the primary water-bearing unit that underlies all of Apache, Navajo, and Coconino Counties occurring near the surface along the Mogollon Rim extending northward to depths up to 5,000 feet in the Black Mesa and Monument Valley areas; 2) N-aquifer overlies the C-aquifer consisting of Navajo Sandstone, Kayenta Formation, Moenave Formation, and Wingate Sandstone outcropping in the Kanab area of northwestern Coconino county extending eastward at depths near the surface to 1300 feet below land surface in the Tuba City area; and 3) the D-aquifer system overlies the N-aquifer comprised of Dakota Sandstone, Morrison Formation, Cow Springs Sandstone, and Entrada Sandstone, but the main water-bearing unit is the Dakota Sandstone extending over the Black Mesa area in Navajo County and northeastward to the Chinle areas in eastern Apache County with usually small well yields. The Bidahochi Formation and basalt consisting of volcanic rocks form relatively minor aquifers in the province.

Figure 1. Arizona Groundwater Basins and Watersheds

Groundwater Basin Designations (Figure 1).

AGF Agua Fria	PAR Paria
ARA Aravaipa Canyon	PHX Phoenix AMA
BIS Big Sandy	PIN Pinal AMA
BON Bonita Creek	PKB Parker
BUT Butler Valley	PRE Prescott AMA
BWN Bill Williams	PSC Peach Springs
CCK Cienega Creek	RAN Ranegras Plain
COP Coconino Plateau	SAC Sacramento Valley
DET Detrital Valley	SAF Safford
DON Donnelly Wash	SBV San Bernadino Valley
DOU Douglas	SCA Santa Cruz AMA
DSW Dripping Springs Wash	SHV Shivwits Plateau
DUN Duncan Valley	SRB Salt River
GIL Gila Bend	SRF San Rafael
GWA Grand Wash	SSW San Simon Wash
HAR Harquahala	TIG Tiger Wash
HUA Hualapai Valley	TON Tonto Creek
KAN Kanab Plateau	TUC Tucson AMA
LCR Little Colorado River	USP Upper San Pedro
LGB Lower Gila	UHA Upper Hassayampa
LKH Lake Havasu	VRB Verde River
LSP Lower San Pedro	VRG Virgin River
MEA Meadview	WIL Willcox
MHV Lake Mohave	WMD West Mexican Drainage
MMU McMullen Valley	YUM Yuma
MOR Morenci	

Regional Groundwater Quality Conditions

Contaminants found in drinking water supplies are of concern when they approach or exceed levels that may be harmful to human health. State and federal legally enforceable standards for drinking water are Primary Maximum Contaminant Levels (MCLs). These enforceable standards define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system and are based on a lifetime daily consumption of two liters per person (WQA, 2006). Non-health-based standards, or Secondary MCLs (SMCLs), have mostly cosmetic effects (such as color and taste or odor) but are also important standards to gage general water potability. These are unenforceable aesthetic guidelines that define the maximum concentration of a constituent that can be present in drinking water without an unpleasant taste, color, odor, or other effect (WQA, 2006). Also, USGS Health Based Screening Levels (HBSLs) are used for those contaminants without MCLs or SMCLs, such as radon. USGS HBSLs are non-regulatory benchmarks and guidelines developed using EPA toxicity data and methods

(Toccalino and Norman, 2006). Table 1 lists the water quality parameters selected and analyzed for the regional assessment of conditions in principal basin-fill aquifers. These parameters are of special interest locally and nationally.

Table 1. Health-based criteria and sources for selected water quality parameters.

Water Quality Parameter	*Health-Based Standard or Guideline*	*Potential Health Effects*	*Potential Sources*
Arsenic (As)	EPA MCL 10 µg/L	Skin damage or problems with circulatory systems, and possible increase in cancer	Naturally occurring as Arsenic sulfide and other minerals; elevated levels favor low dissolved oxygen and high pH
Fluoride (F)	EPA MCL 4 mg/L EPA SMCL 2 mg/L	Bone disease (pain and tenderness of bones); mottled teeth	Naturally occurring; elevated levels correlated with TDS levels
Hardness	Hardness Classification: Soft <75 mg/L as $CaCO_3$ Moderately Hard 75-150 mg/L Hard 150-300 mg/L Very Hard >300 mg/L	Describes effectiveness of soap in water and tendency for scale deposition in water heaters	Ca and Mg principal contributors
Nitrate (NO_3 as N)	EPA MCL 10 mg/L as N	Restricts oxygen transport in bloodstream, particularly in infants resulting in methemoglobinemia; other serious health effects documented	Runoff from fertilizer use, leaching from septic tanks, erosion of natural deposits; levels >2 to 3 mg/L suggest human-caused sources
Radon-222	EPA Proposed MCL of 300 / 4,000 pCi/L (EPA recommends indoor air radon reductions if levels = or > 4 pCi/L)	Adverse effects primarily from inhalation from water aspiration contributing to risk of lung and gastrointestinal cancers	Naturally occurring water soluble radioactive gas originating from radium-226 (part of uranium-238 decay series); levels controlled by distribution of uranium bearing minerals
Sulfate (SO_4)	EPA SMCL 250 mg/L	Elevated levels tend to deposit scale on heating, cause unpleasant taste and gastrointestinal effects	Naturally occurring by gypsum dissolution, oxidation of sulfide-bearing minerals, fertilizer application, and mining operations; positively correlated with TDS
Dissolved-solids (TDS)	EPA SMCL 500 mg/L Salinity Classification: Fresh Water <1,000 mg/L Slightly Saline >1,000 – 3,000 mg/L Moderately Saline >3,000- 10,000 mg/L	Indicator of salinity, degrading suitability of water for certain uses; effects of high levels include objectionable taste, increase use of detergents and soaps, corrosion of metallic surfaces	TDS major constituents include calcium, magnesium, sodium, bicarbonate, chloride, and sulfate; and increases through salt concentration and pickup naturally or human-caused by industrial and municipal waste discharges, agriculture fertilizers and irrigation-return flows, mining, and activities leading to soil erosion

A statistical summary of the selected water quality variables compiled from ADEQ's groundwater database is presented in Tables 2 through 8. The statistics are based on data collected from 1995 to 2009 from basin-fill aquifers representing the Basin and Range Lowlands and Central Highlands provinces. Percentile concentrations of these variables provide valuable information on overall water quality conditions that reflect the multiplicity of land uses and differing hydrologic characteristics of aquifers within the state's hydrologic provinces. The statistics derived are based on non-parametric procedures accounting for censored data and do not consider water quality changes with depth or areal spatial distribution.

Table 2. Summary Statistics for Arsenic (As) Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 10.0 µg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (µg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	16	3	0	1.00 - 3.00	>80% data reported below MRLs			
Big Sandy	220	45	11	9	11.00 - 88.00	>80% data reported below MRLs			
Bill Williams	200	42	8	6	8.60 - 56.00	>80% data reported below MRLs			
Cienega Creek	220	20	2	1	3.30 - 29.00	>80% data reported below MRLs			
Detrital Valley	590	27	7	3	5.60 - 14.00	>80% data reported below MRLs			
Douglas	263	51	8	5	3.00 - 150.00	>80% data reported below MRLs			
Dripping Spring Wash	228	11	1	0	1.00	>80% data reported below MRLs			
Duncan Valley	118	55	37	15	4.00 - 59.00	>50% data reported below MRLs	20.00	29.00	23.45
Harquahala	300	2	0	0					
Hualapai Valley	600	28	8	3	5.80 - 110.00	>80% data reported below MRLs			
Lower Gila	118	22	101	8	0.61 - 31.40	>50% data reported below MRLs	4.60	16.00	9.44
Lake Havasu	160	5	2	0		>70% data reported below MRLs			
Lake Mohave	205	100	95	34	5.00 - 187.00	>50% data reported below MRLs	24.00	60.00	44.03
Lower San Pedro	140	64	18	14	4.30 - 48.00	>70% data reported below MRLs			
McMullen Valley	700	66	39	8	4.50 - 18.00	>40% data reported below MRLs	7.70	9.50	8.57
Phoenix AMA	145	489	2455	90	0.004 - 260.00	>40% data reported below MRLs	17.00	60.00	39.67
Pinal AMA	1040	42	25	16	4.50 - 40.00	>50% data reported below MRLs	18.00	25.00	19.07
Parker	98	16	30	0	5.00 - 6.00	>90% data reported below MRLs			
Ranegras Plain	400	2	0	1					
Sacramento Valley	225	52	8	6	5.00 - 21.00	>80% data reported below MRLs			
Safford	152	192	109	58	1.00 - 370.00	>60% data reported below MRLs	20.00	34.00	31.32
San Bernardino Valley	281	14	0	0					
San Rafael	110	20	2	0	5.00 - 5.20	>90% data reported below MRLs			
San Simon Wash		1	0						
Santa Cruz AMA	202	2	0						

Table 2. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 10.0 µg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (µg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	195	399	31	1.40 - 79.00	>60% data reported below MRLs	25.00	39.00	27.09
Upper Hassayampa	110	124	163	62	10.00 - 79.00	>10% data reported below MRLs	11.00	34.00	24.12
Upper San Pedro	252	64	6	5	3.00 - 33.00	>90% data reported below MRLs			
Virgin River	160	37	12	6	10.00 - 20.00	>90% data reported below MRLs			
Willcox	300	62	12	9	10.00 - 75.00	>80% data reported below MRLs			
Yuma	105	107	331	23	1.00 - 47.00	>50% data reported below MRLs	12.00	16.00	13.93
CENTRAL HIGHLANDS									
Agua Fria	152	41	20	10	4.50 - 34.60	>60% data reported below MRLs	13.00	16.00	14.33
Bonita Creek	144	3	0						
Morenci	251	5	1	1	8.90 - 87.00	>90% data reported below MRLs			
Prescott AMA	305	67	27	15	10.00 - 548.00	>70% data reported below MRLs			
Salt River	129	55	136	11	2.20 - 42.00	>30% data reported below MRLs	6.10	15.00	10.99
Tonto Creek	120	71	100	13	1.50 - 1000.00	>30% data reported below MRLs	100.00	1000.00	303.50
Verde River	70	84	87	6	2.00 - 1000.00	>50% data reported below MRLs	100.00	100.00	100.72

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 10.0 µg/L, and lab analyses include dissolved and total constituents.

[2] Of 2,299 sites sampled statewide, about 20% exceed 10.0 µg/L (Arsenic Primary MCL).

[3] Summary statistics calculated using Kaplan-Meier method to account for censored data and multiple minimum reporting levels (Kaplan and Meier, 1958).

Table 3. Summary Statistics for Fluoride (F) Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 4.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3]			
						25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	17	23	0	0.21 - 3.50	0.29	0.40	1.01	0.83
Big Sandy	220	51	63	9	0.11 - 13.00	0.39	0.80	2.20	1.78
Bill Williams	200	44	60	5	0.13 - 9.40	0.68	1.25	3.00	2.10
Cienega Creek	220	21	24	0	0.19 - 0.74	>10% data reported below MRLs	0.34	0.58	0.39
Detrital Valley	590	29	36	0	0.32 - 2.20	0.60	0.80	1.00	0.84
Douglas	263	52	59	0	0.20 - 3.60	0.39	0.66	1.30	1.07
Dripping Spring Wash	228	11	15	0	0.15 - 0.75	0.23	0.30	0.45	0.36
Duncan Valley	118	56	82	6	0.29 - 11.00	0.57	1.60	2.50	1.94
Harquahala	300	16	21	4	1.88 - 11.00	2.60	2.84	3.59	3.73
Hualapai Valley	600	32	46	2	0.20 - 5.00	0.80	1.20	2.10	1.59
Lower Gila	118	28	34	13	0.39 - 10.00	1.70	2.64	5.70	3.78
Lake Havasu	160	32	170	0	0.35 - 3.60	0.84	1.20	1.60	1.32
Lake Mohave	205	110	154	4	0.14 - 6.10	0.58	0.92	1.90	1.42
Lower San Pedro	140	66	83	8	0.13 - 13.00	0.48	1.20	2.00	1.81
McMullen Valley	700	70	116	9	0.32 - 22.00	1.07	2.35	3.70	3.20
Phoenix AMA	145	312	1361	20	0.06 - 72.00	0.26	0.34	0.51	0.73
Pinal AMA	1040	48	66	3	0.15 - 7.30	0.37	0.63	1.60	1.30
Parker	98	16	27	2	0.22 - 5.5	>10% data reported below MRLs	0.70	2.40	1.57
Ranegras Plain	400	14	19	9	0.46 - 8.50	2.00	4.54	7.42	4.62
Sacramento Valley	225	56	71	3	0.24 - 5.90	0.81	1.27	2.88	1.90
Safford	152	200	249	47	0.12 - 17.00	0.89	2.00	4.10	2.93
San Bernardino Valley	281	15	21	0	0.24 - 3.10	0.41	0.59	1.10	1.00
San Rafael	110	32	40	0	0.14 - 2.80	>10% data reported below MRLs	0.30	0.60	0.65
San Simon Wash		2	0	0					
Santa Cruz AMA	202	2	3	0	0.21 - 0.70	>20% data reported below MRLs	0.70	0.70	0.54

Table 3. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 4.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	320	519	3	0.10 - 10.00	>40% data reported below MRLs	0.49	0.72	0.88
Upper Hassayampa	110	42	57	0	0.06 - 3.50	0.36	0.49	1.03	0.80
Upper San Pedro	252	75	86	3	0.10 - 6.90	>10% data reported below MRLs	0.40	0.95	1.00
Virgin River	160	37	42	0	0.32 - 2.20	0.67	0.84	1.20	0.94
Willcox	300	63	72	7	0.09 - 10.00	0.57	1.10	2.20	1.92
Yuma	105	70	91	1	0.22 - 14.00	0.43	0.68	1.19	1.00
CENTRAL HIGHLANDS									
Agua Fria	152	46	59	5	0.14 - 10.80	0.24	0.35	0.69	1.33
Bonita Creek	144	3	3	0	0.40 - 0.46	0.42	0.46	0.46	0.44
Morenci	251	5	6	1	0.21 - 8.60	0.31	0.51	0.68	1.79
Prescott AMA	305	57	62	3	0.10 - 14.00	>10% data reported below MRLs	0.34	0.60	0.96
Salt River	129	53	83	3	0.07 - 14.00	0.21	0.32	0.63	1.11
Tonto Creek	120	79	108	0	0.10 - 3.70	>10% data reported below MRLs	0.58	1.00	0.82
Verde River	70	77	101	0	0.10 - 1.90	>30% data reported below MRLs	1.00	1.00	0.74

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 0.10 mg/L, and lab analyses include dissolved and total constituents.

[2] Of 1,962 sites sampled statewide, about 7% exceed 4.0 mg/L (Fluoride Primary MCL).

[3] Summary statistics calculated using Kaplan-Meier method to account for censored data and multiple minimum reporting levels (Kaplan and Meier, 1958), or calculated using Cleveland method (Cleveland, 1993).

Table 4. Summary Statistics for Hardness Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L as CaCO3)[2]			
					25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	14	16	34.0 - 280.0	87.5	160.0	210.0	151.8
Big Sandy	220	49	58	38.0 - 630.0	170.0	250.0	340.0	254.9
Bill Williams	200	44	53	26.0 - 1400.0	170.0	240.0	350.0	288.8
Cienega Creek	220	20	25	100.0 - 540.0	140.0	190.0	242.5	228.0
Detrital Valley	590	27	31	79.0 - 1300.0	127.5	210.0	335.0	302.0
Douglas	263	51	56	10.0 - 2280.0	107.5	156.5	226.5	253.4
Dripping Spring Wash	228	10	26	51.0 - 360.0	180.0	285.0	320.0	250.1
Duncan Valley	118	55	73	5.0 - 1400.0	67.3	140.0	222.5	182.8
Harquahala	300	2	4	280.0 - 560.0	280.0	300.0	510.0	412.5
Hualapai Valley	600	28	34	38.0 - 920.0	180.0	310.0	410.0	345.1
Lower Gila	118	9	11	390.0 - 1800.0	447.5	880.0	950.0	850.9
Lake Havasu	160	0					520.0	
Lake Mohave	205	100	138	28.0 - 2200.0	170.0	275.0	310.0	412.2
Lower San Pedro	140	65	82	5.3 - 2630.0	120.0	240.0	160.0	291.7
McMullen Valley	700	107	181	10.0 - 830.0	>10% data reported below MRLs	87.1	340.0	124.1
Phoenix AMA	145	80	374	21.0 - 2100.0	250.0	290.0	400.0	332.7
Pinal AMA	1040	38	80	31.0 - 840.0	130.0	250.0	810.5	295.7
Parker	98	15	25	77.0 - 2230.0	342.8	568.0		634.8
Ranegras Plain	400	2	3	72.0 - 170.0			390.0	134.0
Sacramento Valley	225	51	59	66.0 - 1900.0	140.0	250.0	320.0	350.6
Safford	152	190	232	2.1 - 1300.0	92.0	180.0	412.5	239.2
San Bernardino Valley	281	14	17	36.0 - 600.0	93.3	150.0	310.0	240.6
San Rafael	110	31	44	35.0 - 750.0	155.0	190.0		252.8
San Simon Wash		1	1	12.0				
Santa Cruz AMA	202	2	3	210.0 - 258.0			520.0	238.0

Table 4. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L as CaCO3)[2] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	94	121	35.0 - 950.0	120.0	200.0	320.0	241.1
Upper Hassayampa	110	37	44	92.0 - 1300.0	204.0	260.0	330.0	316.0
Upper San Pedro	252	64	73	3.25 - 3540.0	130.0	188.0	353.3	331.6
Virgin River	160	37	12	6.33 - 2400.0	10.0	13.0	19.0	14.1
Willcox	300	62	70	17.0 - 910.0	77.0	140.0	240.0	184.0
Yuma	105	73	96	146.0 - 5040.0	442.5	681.0	940.0	773.8
CENTRAL HIGHLANDS								
Agua Fria	152	38	81	53.0 - 880.0	240.0	310.0	387.5	316.1
Bonita Creek	144	3	3	160.0 - 170.0				163.3
Morenci	251	5	6	410.0 - 1770.0	532.0	666.5	1400.0	907.5
Prescott AMA	305	55	64	35.0 - 530.0	130.0	175.0	240.0	201.7
Salt River	129	53	132	7.0 - 970.0	225.0	290.0	330.0	273.5
Tonto Creek	120	65	104	61.0 - 570.0	180.0	212.0	260.0	227.4
Verde River	70	28	33	45.0 - 490.0	119.0	210.0	272.5	216.4

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 10.0 mg/L.

[2] Summary statistics calculated using Cleveland method (Cleveland, 1993).

Table 5. Summary Statistics for Nitrate (as N) Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 10.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L Nitrate as N)[3]			
						25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	17	36	0	0.04 - 2.20	0.25	0.73	0.89	0.73
Big Sandy	220	51	104	0	0.02 - 9.50	>10% data reported below MRLs	2.00	3.20	2.29
Bill Williams	200	45	100	3	0.11 - 110.00	>10% data reported below MRLs	1.60	3.30	6.89
Cienega Creek	220	21	28	0	0.06 - 2.50	>10% data reported below MRLs	0.57	1.10	0.74
Detrital Valley	590	29	52	2	0.05 - 16.00	1.00	3.40	5.40	4.05
Douglas	263	52	112	1	0.34 - 10.60	1.29	1.80	3.89	2.99
Dripping Spring Wash	228	11	22	0	0.02 - 3.30	0.35	1.50	2.50	1.52
Duncan Valley	118	56	114	2	0.04 - 17.00	0.68	1.10	2.39	2.08
Harquahala	300	16	23	10	0.56 - 57.60	3.4	5.44	17.61	13.37
Hualapai Valley	600	32	44	2	0.02 - 61.00	1.18	3.40	5.40	6.74
Lower Gila	118	33	50	8	0.08 - 71.00	0.61	2.00	15.00	12.18
Lake Havasu	160	42	189	9	0.02 - 40.00	>10% data reported below MRLs	5.20	8.60	6.61
Lake Mohave	205	108	212	5	0.02 - 15.00	0.96	2.30	4.80	3.27
Lower San Pedro	140	65	75	1	0.03 - 30.00	>10% data reported below MRLs	0.52	0.99	1.44
McMullen Valley	700	84	167	12	0.60 - 64.00	2.80	3.90	6.00	8.15
Phoenix AMA	145	567	2562	179	0.02 - 317.40	1.80	4.20	9.90	8.75
Pinal AMA	1040	56	89	15	0.02 - 36.40	3.30	5.99	11.00	8.31
Parker	98	18	37	0	0.11 - 8.90	>10% data reported below MRLs	0.54	2.50	1.58
Ranegras Plain	400	15	22	8	4.3 - 52.02	5.50	7.00	11.99	11.14
Sacramento Valley	225	53	89	6	0.03 - 28.00	1.60	2.60	4.80	4.54
Safford	152	202	345	14	0.02 - 31.00	>10% data reported below MRLs	1.20	4.47	3.20
San Bernardino Valley	281	15	37	1	0.05 - 15.00	0.26	0.88	1.90	1.59
San Rafael	110	32	66	0	0.02 - 9.80	>10% data reported below MRLs	0.53	2.60	1.88
San Simon Wash		1	0	0					
Santa Cruz AMA	202	2	6	0	0.30 - 3.00	0.30	2.60	3.00	1.97

Table 5. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >MCL 10.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L Nitrate as N)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	256	770	27	0.02 - 110.0	1.30	2.20	6.50	5.11
Upper Hassayampa	110	50	82	5	0.10 - 19.0	0.60	1.50	2.90	3.00
Upper San Pedro	252	71	171	1	0.15 - 14.00	0.62	0.99	2.41	2.09
Virgin River	160	37	78	0	0.18 - 5.40	0.46	1.05	1.60	1.33
Willcox	300	63	95	5	0.02 - 18.00	0.40	0.76	3.40	2.55
Yuma	105	123	207	21	0.03 - 130.00	>20% data reported below MRLs	5.20	14.00	15.61
CENTRAL HIGHLANDS									
Agua Fria	152	46	53	0	0.04 - 5.60	>20% data reported below MRLs	0.98	1.90	1.59
Bonita Creek	144	3	0	0					
Morenci	251	5	4	0	0.66 - 1.83	>30% data reported below MRLs	1.47	1.78	1.44
Prescott AMA	305	57	113	1	0.29 - 10.85	>10% data reported below MRLs	1.80	3.60	2.87
Salt River	129	54	190	1	0.04 - 12.00	>10% data reported below MRLs	1.90	4.40	2.69
Tonto Creek	120	85	301	4	0.03 - 29.00	0.77	2.10	5.33	3.43
Verde River	70	84	269	4	0.05 - 16.00	1.10	3.10	5.30	3.83

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 0.10 mg/L, and lab analyses include dissolved and total constituents.

[2] Of 2,259 sites sampled statewide, about 15% exceed 10.0 mg/L (Nitrate Primary MCL).

[3] Summary statistics calculated using Kaplan-Meier method to account for censored data and multiple minimum reporting levels (Kaplan and Meier, 1958), or calculated using Cleveland method (Cleveland, 1993).

Table 6. Summary Statistics for Radon (Radon-222) Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >HBGL 300 pCi/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (pCi/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	14	14	6	31.0 - 782.0	124.0	239.0	400.0	307.4
Big Sandy	220	30	33	14	18.0 - 3351.0	167.3	293.0	1129.3	772.8
Bill Williams	200	22	22	12	96.0 - 3686.0	279.0	334.5	439.0	495.7
Cienega Creek	220	10	11	9	170.0 - 3918.0	422.5	720.0	838.0	1031.2
Detrital Valley	590	12	12	8	78.0 - 4839.0	238.2	461.6	578.0	777.1
Douglas	263	0							
Dripping Spring Wash	228	6	6	5	239.0 - 449.0	358.0	377.0	444.0	374.0
Duncan Valley	118	15	15	9	45.0 - 1270.0	282.8	370.0	596.5	432.9
Harquahala	300	0							
Hualapai Valley	600	11	12	9	18.0 - 6925.0	334.0	677.0	1690.0	1383.0
Lower Gila	118	0							
Lake Havasu	160	0							
Lake Mohave	205	30	30	6	29.0 - 1464.0	120.0	158.9	254.0	236.8
Lower San Pedro	140	21	24	18	80.0 - 1080.0	318.5	450.0	589.0	512.7
McMullen Valley	700	50	48	42	82.0 - 9465.0	326.5	543.0	781.0	887.1
Phoenix AMA	145	1	0						
Pinal AMA	1040	19	19	13	146.0 - 6757.0	275.8	365.0	750.3	867.1
Parker	98	0							
Ranegras Plain	400	1	0						
Sacramento Valley	225	1	0						
Safford	152	52	55	40	25.0 - 4419.0	290.5	432.0	758.2	664.2
San Bernardino Valley	281	13	13	6	50.0 - 633.0	62.8	298.0	423.5	279.0
San Rafael	110	5	5	4	190.0 - 1605.0	383.5	577.0	939.8	707.6
San Simon Wash		1	2	0	30.0 - 35.1		32.6		32.6
Santa Cruz AMA	202	1	0						

Table 6. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >HBGL 300 pCi/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (pCi/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	51	59	36	90.0 - 84009.0	235.0	380.0	626.3	1899.8
Upper Hassayampa	110	12	12	4	47.0 - 2641.0	179.0	236.5	661.0	555.2
Upper San Pedro	252	0							
Virgin River	160	0							
Willcox	300	3	3	2	74.7 - 3249.0		641.0		1321.6
Yuma	105	0							
CENTRAL HIGHLANDS									
Agua Fria	152	22	23	8	75.0 - 1032.0	140.0	259.0	361.5	307.0
Bonita Creek	144	0		0					
Morenci	251	0		0					
Prescott AMA	305	0		0					
Salt River	129	6	6	4	188.0 - 1581.0	265.0	372.5	433.0	535.3
Tonto Creek	120	3	3	3	391.0 - 906.0		689.0		662.0
Verde River	70	0		0					

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 30.0 pCi//L, and lab analyses include dissolved and total constituents.

[2] Of 412 sites sampled statewide, about 63% exceed 300 pCi//L (Radon-222 USGS HBGL).

[3] Summary statistics calculated using Cleveland method (Cleveland, 1993).

Table 7. Summary Statistics for Sulfate Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >SMCL 250.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	17	23	1	3.7 - 550.0	12.0	15.0	26.3	43.3
Big Sandy	220	51	63	2	7.4 - 390.0	13.0	33.0	61.0	53.8
Bill Williams	200	46	62	3	9.0 - 1500.0	30.5	49.0	99.5	141.0
Cienega Creek	220	21	22	0		>20% data reported below MRLs	34.0	54.0	71.1
Detrital Valley	590	29	37	5	9.2 - 860.0	20.0	42.0	250.0	140.4
Douglas	263	52	50	2		>10% data reported below MRLs	41.7	100.0	222.3
Dripping Spring Wash	228	11	15	0	5.4 - 67.0	15.8	28.0	45.0	30.5
Duncan Valley	118	56	83	13	7.6 - 1200.0	49.0	78.2	220.0	171.3
Harquahala	300	16	21	5	73.7 - 880.2	113.7	128.6	285.9	246.7
Hualapai Valley	600	32	46	2	9.2 - 270.0	28.7	46.5	110.0	81.4
Lower Gila	118	30	38	17	0.2 - 10000.0	160.0	515.0	970.0	887.8
Lake Havasu	160	31	173	30	42.3 - 800.0	304.8	356.0	469.3	382.1
Lake Mohave	205	111	162	50	19.0 - 1800.0	67.0	165.0	363.0	284.1
Lower San Pedro	140	75	77	12	1.5 - 2630.0	32.0	76.0	240.0	228.0
McMullen Valley	700	110	138	5	17.0 - 810.0	34.0	47.0	72.5	75.8
Phoenix AMA	145	598	3155	92	0.15 - 4400.0	85.0	110.0	149.8	134.0
Pinal AMA	1040	48	67	13	41.0 - 943.29	84.5	117.2	217.5	201.9
Parker	98	18	30	14	119.0 - 1340.0	240.0	379.0	687.0	506.0
Ranegras Plain	400	14	19	7	8.173 - 1864.0	79.0	309.0	387.4	392.1
Sacramento Valley	225	56	72	7	12.0 - 1300.0	37.0	67.0	110.0	135.4
Safford	152	200	250	64	3.8 - 2700.0	47.0	140.0	310.0	233.3
San Bernardino Valley	281	15	20	0	5.2 - 240.0	11.0	21.0	60.0	57.5
San Rafael	110	32	42	3	3.6 - 490.0	>10% data reported below MRLs	37.3	79.4	76.7
San Simon Wash		1	2	0	10.0 - 11.0				
Santa Cruz AMA	202	2	3	0	35.0 - 88.0				

Table 7. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >SMCL 250.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	246	662	44	2.0 - 1100.0	50.4	94.0	180.0	139.2
Upper Hassayampa	110	48	63	1	0.84 - 1100.0	15.0	38.0	53.9	58.5
Upper San Pedro	252	75	71	12		>20% data reported below MRLs	46.6	271.0	200.2
Virgin River	160	37	42	18	58.0 - 2000.0	10.0	13.0	19.0	14.1
Willcox	300	63	61	5		>10% data reported below MRLs	58.0	98.0	112.9
Yuma	105	94	125	87	77.7 - 2500.0	417.8	611.0	1085.0	785.7
CENTRAL HIGHLANDS									
Agua Fria	152	46	60	3	1.0 - 2000.0	19.0	59.0	120.0	114.3
Bonita Creek	144	3	3	0					
Morenci	251	5	6	5		478.0	490.0	1370.0	812.0
Prescott AMA	305	53	47	1		17.0	26.0	55.0	48.6
Salt River	129	55	164	3	2.1 - 790.0	47.7	130.0	140.0	112.5
Tonto Creek	120	85	164	1	0.89 - 376.3	11.7	19.0	25.0	24.7
Verde River	70	79	138	0	0.5 - 113.24	11.0	18.7	25.9	20.8

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 5.0 mg/L, and lab analyses include dissolved and total constituents.

[2] Of 2,561 sites sampled statewide, about 21% exceed 250.0 mg/L (Sulfate Secondary MCL).

[3] Summary statistics calculated using Kaplan-Meier method to account for censored data and multiple minimum reporting levels (Kaplan and Meier, 1958), or calculated using Cleveland method (Cleveland, 1993).

Table 8. Summary Statistics for Dissolved-Solids (TDS) Levels in Groundwater for Selected Basins (1995 - 2009).

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >SMCL 500.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Aravaipa Canyon	120	14	17	0	76.0 - 390.0	187.5	240.0	320.0	251.4
Big Sandy	220	49	58	19	170.0 - 1700.0	270.0	430.0	570.0	466.0
Bill Williams	200	44	58	17	210.0 - 3100.0	360.0	440.0	630.0	642.0
Cienega Creek	220	20	25	2	170.0 - 700.0	235.0	280.0	340.0	322.8
Detrital Valley	590	27	32	10	220.0 - 2100.0	290.0	390.0	620.0	556.3
Douglas	263	51	56	9	154.0 - 14200.0	253.0	292.0	396.0	658.7
Dripping Spring Wash	228	10	14	0	110.0 - 440.0	230.0	375.0	420.0	320.0
Duncan Valley	118	51	69	22	170.0 - 3600.0	349.5	450.0	800.0	749.7
Harquahala	300	2	2	2	930.0 - 1600.0		1265.0		1265.0
Hualapai Valley	600	28	34	11	280.0 - 1800.0	370.0	490.0	730.0	609.4
Lower Gila	118	11	14	11	1200.0 - 5200.0	1700.0	2550.0	4400.0	3050.0
Lake Havasu	160	39	190	39	430.0 - 3800.0	985.0	1480.0	1720.0	1435.1
Lake Mohave	205	100	135	71	270.0 - 4900.0	590.0	960.0	1475.0	1185.8
Lower San Pedro	140	66	83	24	39.0 - 4030.0	262.5	400.0	717.5	613.4
McMullen Valley	700	107	127	23	200.0 - 1600.0	325.0	380.0	460.0	477.8
Phoenix AMA	145	190	895	140	7.4 - 6000.0	688.0	790.0	925.0	907.4
Pinal AMA	1040	39	45	25	230.0 - 2200.0	457.5	680.0	1300.0	870.0
Parker	98	15	25	15	488.0 - 8190.0	710.0	1240.0	1785.0	1677.8
Ranegras Plain	400	2	2	1	440.0 - 580.0		510.0		510.0
Sacramento Valley	225	49	56	24	220.0 - 3700.0	300.0	490.0	860.0	721.9
Safford	152	191	229	116	49.0 - 6000.0	332.3	750.0	1285.0	1014.3
San Bernardino Valley	281	14	18	5	180.0 - 1100.0	220.0	340.0	770.0	506.1
San Rafael	110	31	43	5	93.0 - 1070.0	250.0	300.0	430.5	367.8
San Simon Wash		1	2	0	58.0 - 68.0		63.0		63.0
Santa Cruz AMA	202	1	1	0	360.0		360.0		360.0

Table 8. Continued.

GROUNDWATER BASIN BASIN & RANGE LOWLANDS	MEDIAN WELL DEPTH (ft bls)	SITES SAMPLED	SAMPLE DETECTS[1]	SITES >SMCL 500.0 mg/L[2]	MIN-MAX DETECTS	CONCENTRATION PERCENTILE (mg/L)[3] 25TH	50TH (MEDIAN)	75TH	MEAN
Tucson AMA	240	132	257	50	120.0 - 1700.0	280.0	470.0	720.0	561.6
Upper Hassayampa	110	32	39	8	200.0 - 2300.0	312.5	390.0	520.0	500.5
Upper San Pedro	252	64	75	15	120.0 - 3820.0	211.5	287.0	563.3	500.4
Virgin River	160	37	43	25	320.0 - 4300.0	10.0	13.0	19.0	14.1
Willcox	300	60	70	10	46.0 - 1100.0	200.0	280.0	450.0	361.2
Yuma	105	73	96	70	720.0 - 13000.0	1255.0	1910.0	3100.0	2418.6
CENTRAL HIGHLANDS									
Agua Fria	152	38	50	18	130.0 - 2100.0	370.0	500.0	622.5	545.9
Bonita Creek	144	3	3	0	280.0		280.0		280.0
Morenci	251	5	6	2	815.0 - 2600.0	1120.0	1195.0	2250.0	1529.2
Prescott AMA	305	54	63	4	160.0 - 790.0	210.0	270.0	430.0	324.9
Salt River	129	44	57	10	83.0 - 2400.0	277.5	360.0	485.0	494.9
Tonto Creek	120	53	63	4	82.0 - 820.0	254.8	295.0	392.5	339.3
Verde River	70	14	16	2	79.0 - 700.0	125.0	280.0	479.0	309.2

[1] Multiple minimum reporting levels (MRLs) reported, most frequent MRL = 10.0 mg/L.

[2] Of 1,761 sites sampled statewide, about 46% exceed 500.0 mg/L (TDS Secondary MCL).

[3] Summary statistics calculated using Cleveland method (Cleveland, 1993).

The local lithology and mineralogy of the alluvial sediments in the Basin and Range Lowlands and Central Highlands provinces greatly affect the chemical composition of groundwater. On examining tables 2 through 8 there are several important inferences. Naturally occurring arsenic levels vary from trace amounts to over 100 times the drinking water MCL of 10.0 µg/L in Tonto Creek and Verde River basins, and median levels exceed the MCL in many basins across the state. Fluoride is found at trace amounts to more than 15 times the MCL of 4.0 mg/L, with median concentrations exceeding the MCL in only the Ranegras Plain basin. Water hardness can be generally classified as hard to very hard (greater than 120 mg/L as calcium carbonate) throughout the state. Nitrate (as nitrogen) median concentrations do not exceed the MCL of 10.0 mg/L, however many basin-fill aquifers have concentrations greater than 2.0 to 3.0 mg/L suggesting anthropogenic caused impacts. Median concentrations of radon exceed the USGS HBGL of 300 picocuries per liter (pCi/L) in many basins with measurements. Median sulfate concentrations vary from 13.0 mg/L in Virgin River basin to 611.0 mg/L in Yuma basin, exceeding the 250.0 mg/L SMCL in only 6 basins. Median dissolved-solids (TDS) levels in water from all alluvial aquifers measured range from less than 100 mg/L to more than 2,500 mg/L with 12 basins exceeding the 500 mg/L SMCL.

Of groundwater samples collected in basin-fill aquifers statewide (1995-2009), about 20% exceed the arsenic MCL, 7% exceed the fluoride MCL, and about 63% exceed the radon USGS HBGL. These results for naturally occurring contaminants in Arizona are much higher than results recently released by a USGS study of water quality from domestic wells sampled in principal aquifers across the nation (DeSimone, 2008). USGS reports that of the 2,100 wells surveyed in 48 states, 6.8% exceed the arsenic standard, 1.2% exceed the fluoride standard, and about 65% exceed the radon guideline. These dramatic differences are not unexpected, given climatic and hydrogeologic conditions of the Southwest aquifers generally favor greater levels of natural contaminants such as arsenic and fluoride. Also, notable is the frequency of nitrate (as nitrogen) MCL exceedances at about 15% is more than three times greater than USGS national estimates at 4.4%. Sulfate concentrations were greater than the standard in about 21% of wells in Arizona basins as compared to national findings at 3.79%. The frequency of wells exceeding the dissolved-solids (TDS) SMCL of 500 mg/L, an overall indicator of water quality conditions, was reported at 15% nationally as compared to estimates at 46% in this study.

These findings on regional groundwater conditions advocate for the importance of sustained water quality sampling and testing to determine the safety of consuming water from principal aquifers. Monitoring programs are severely under funded in Arizona undermining efforts to more fully characterize aquifer-specific water quality conditions for drinking water and environmental impacts to surface waters and sensitive wetland habitats. Additionally, greater attention to the quality of drinking water from rural domestic wells and public education efforts are important goals to protecting public health. Private well owners are responsible for testing the quality of their well water and necessary treatment. Information and guidance about well maintenance, water quality and testing options, and in-home water treatment devices is available through local and State health and environmental protection agencies and at several online resources – http://water.usgs.gov/nawqa/studies/domestic_wells/ and

http://sahra.arizona.edu/wells .
Many human-caused groundwater quality problems are located in the Phoenix and Tucson metropolitan areas, but as evidenced in the statistical summaries of several parameters, groundwater quality problems are found statewide. A list of major groups of pollutants found in Arizona groundwater is provided in Table 9 followed by pollutant summaries.

Table 9: Major Types of Pollutants Contaminating Groundwater in Arizona.

Pollutant Group	Pollutant
Nutrients	Nitrate
Volatile Organic Compounds	Trichlorethylene (TCE)
	Tetrachloroethylene (PCE)
	Chloroform
	1,1,1-trichloroethane (TCA)
	Methylene chloride
	Freon-11®, Freon-12®, Freon-113®
	1,1-dichloroethane (DCA)
	Vinyl chloride
	BTEX
	MTBE
Major Cations/Anions	Fluoride
	Total Dissolved Solids (TDS)
	Sulfate
Metals	Arsenic
	Lead
	Chromium (Cr_{+3}, Cr_{+6})
	Iron
	Manganese
	Selenium
Physical	pH
Pesticides	Ethylene Dibromide (EDB) (banned)
	Dibromochloropropane (DBCP) (banned)
	Diuron
	Prometryn
	Imidacloprid
	Methoxyfenozide
	Dimethomorph
	Flutolanil
	Atrazine
Petroleum Hydrocarbons	Gasoline & Jet Fuel
	Diesel
Radiological	Uranium
	Radium-226 and 228
	Radon
Microorganisms	Total Coliform Bacteria
	Fecal Coliform Bacteria

Nutrients - Nitrate

Nitrate is one of the most common pollutants in the state's groundwater and is associated with both human activities and, infrequently, natural nitrogen sources. Nitrate reduces the ability of red blood cells to carry oxygen, particularly damaging to infants who drink water with high levels of nitrate. Other serious health conditions may include increased risks of spontaneous abortion or certain birth defects, ovarian and bladder cancer, and non-Hodgkins lymphoma (CDC, 1996; Ward et al, 1996; Weyer et al, 2001; Fewtrell, 2004). Nitrate levels in groundwater have decreased in some areas where agricultural activities have been replaced with urbanization, but have increased in other areas. Percolation of nitrate-laden water from irrigation, septic tanks, wastewater treatment plants, concentrated animal feedlots and natural nitrate occurrences are likely causes of elevated nitrate levels. Nitrate is not significantly attenuated by the soil and therefore travels with the groundwater largely unchanged. Large portions of aquifers within the Salt River Valley, including areas in Glendale, Mesa, Chandler and Phoenix, contain groundwater with nitrate concentrations high enough to render the water unfit for potable use. In addition, high nitrate levels in some wells have been detected in Marana, St. David, Quartzsite, Bullhead City, Lake Havasu City and other areas. Septic tank discharges are common nitrate sources in rural areas of Arizona and have contaminated drinking water wells. Quartzsite, Bullhead City and Lake Havasu City are just a few locations with elevated nitrate in groundwater that have taken significant steps to address wastewater disposal problems.

Basin and Sub-basin scale maps (Appendix A) of nitrate levels in selected basin-fill aquifers have been developed to represent the general magnitude and distribution of this serious public health concern. Ordinary kriging analysis was employed, using ESRI, Inc. ArcMap geostatistical analyst extension, to synthesize nitrate groundwater monitoring data for discrete locations (wells and springs) into maps of the spatial pattern of water quality variations. Few studies in Arizona have conducted spatial mapping of groundwater quality monitoring data through kriging approaches that can be used to provide an optimal estimate of the spatial extent of water quality parameters. The maps are for regional use only and have limitations at the field scale. There are many complexities that affect the concentration of nitrate in groundwater and in a particular well. This spatial representation of nitrate levels in basin-fill aquifers is a starting place for future assessments on potential drinking water risks and determination of areas of concern.

Volatile Organic Compounds (VOCs) and Superfund Sites

Aside from gasoline leaks reaching groundwater, disposal of solvents has resulted in most of the state's documented cases of volatile organic compound-contaminated groundwater. High-technology manufacturing facilities (often electronics and aerospace), which use these solvents for degreasing are generally located in urbanized areas where most of the volatile organic compound problems have been found. Disposal of solvents has been documented from the early 1950s and probably began earlier. Specific industrial waste disposal practices leading to groundwater contamination by VOCs include injection into dry wells and disposal into surface impoundments, leach fields, dry washes and unregulated landfills (Graf, 1986). Many of

the recently discovered volatile organic compound problems can be traced to disposal or leaks at dry cleaning facilities. Surface spills are less common causes of volatile organic compounds in groundwater. In the past, public drinking water wells in the Phoenix and Tucson metropolitan areas and in Payson have been closed because of volatile organic compound contamination. An overview of major sites in Arizona where groundwater and/or soil contamination is present is summarized in Table 10, including the site name and type of investigations employed, general groundwater conditions, primary water quality parameters/contaminants of concern, and known impacts to private or public drinking water wells. Detailed Superfund/WQARF program site information, maps and definitions of terms in the table are at www.azdeq.gov/environ/waste/sps/index.html .

Table 10. Status of Federal and State (WQARF) Superfund Sites in Arizona.

Site Name & Location	*Investigation & Action Types*[1]	*Depth to Groundwater (ft bls)*	*Water Quality Parameters & Max Levels Detected (µg/L)*[2]	*Drinking Water Wells Impacted*
20th St & Factor Ave - Yuma	WQARF RI	Basin-fill 75 to 150+	PCE @ 520 TCE Cyanide @ 200	No
Klondyke Tailings – 4.5 miles upstream of Aravaipa Canyon Wilderness Area	WQARF RI	Basin-fill 10 to 60	Lead, Cadmium, Antimony, Beryllium, Copper, Manganese, Arsenic, Zinc in soils & fish tissue	No
Payson PCE - Payson	WQARF Remediation expanded	Granite 10 to 15	PCE @ 13,600	Yes, 2 wells
Pinal Creek – Globe-Miami area	WQARF Remediation	Basin-fill <5 to 100+	Aluminum, Arsenic, Beryllium, Cadmium, Copper Cobalt, Iron, Manganese, Nickel, Sulfate, Zinc, Acid, Uranium, Radium, Fluoride, Chromium, Lead, Mercury	Yes, several private wells
Tonto & Cherry - Payson	WQARF ROD completed	Granite 10+	PCE @ 47 TCE	Yes, 5 private wells
Tyson Wash - Quartzite	WQARF Remediation	Basin-fill: Upper (perched) 40 to 70 Lower 400 to 500	PCE @ 44 in Upper TCE @ 2.8 in Upper	Yes, 7 private wells
Vulture Mill – 1 mile NW Wickenburg	WQARF Remediation completed	Basin-fill <5 to 50+	Lead, Arsenic, Iron, Manganese	Yes, several private wells
Apache Powder – 2.5 miles SW St. David	NPL Remediation	Basin-fill: Perched (local) ~ dry Shallow 40 to 70 Regional (artesian)	Nitrate, perchlorate, Arsenic, Fluoride	Yes, several private wells

Site Name & Location	Investigation & Action Types[1]	Depth to Groundwater (ft bls)	Water Quality Parameters & Max Levels Detected (µg/L)[2]	Drinking Water Wells Impacted
		350+		
Hassayampa Landfill – 10 miles West of Buckeye	NPL Remediation	Basin-fill 70+	DCE, Freon 113, TCA, DCA, TCE, PCE, Freon 11, 1,2-DCP, Toluene	No
Iron King Mine-Humboldt Smelter – Dewey-Humboldt	NPL RI	Basin-fill 30 to 50 Bedrock 200 to 1,000	Arsenic @ > 10 Lead @ > 15	Yes, several public and private wells
Yuma Marine Corps Air Station - Yuma	NPL Remediation	Basin-fill: Upper 40 to 50 Regional	TCE, DCE, and PCE @ 500 Petroleum Hydrocarbon	
Mountain View Mobile Home Estates - Globe	NPL - Delisted	Basin-fill: Regional - Gila conglomerate	Asbestos in soil	No
Barry M. Goldwater Range – 2.7 million acres in SW Arizona	MMRP SI	Basin-fill 24 to 660+		
Camp Navajo (OB/OD Area) – 10 miles West of Flagstaff	IRP, RI/FS Remediation, Post Closure	Alluvial >10 Perched 350+ Consolidated - Coconino-Supai sandstone 1500+	Metals, explosives, dioxin/furans, perchlorate, VOCs, Pesticides, PCBs	
Fort Huachuca – Sierra Vista	IRP SI	Basin-fill 300+	Organochlorine Pesticides, metals, VOCs, Petroleum Hydrocarbon	No
Luke Waterdog Rec Annex – East shore of Apache Lake	IRP Remediation	Granite 14 to 27	BTEX: Benzene @ >5 Toluene @ > 1000	No
Yuma Army Proving Grounds (YPG) – 32 miles NE Yuma	IRP	Basin-fill: Upper 30+	Petroleum Hydrocarbon, VOCs, semi-VOCs, metals, Pyrotechnics	
ASARCO Hayden Plant – Hayden and Winkelman	SA Cleanup & Sampling	Basin-fill: Gila R. Alluvium 10+	Arsenic, Cadmium, Chromium, Lead, Copper in soils, air Selenium & Molybdenum in GW	
7th Ave & Bethany Home - Phoenix	WQARF ERA, RI	Basin-fill: Upper 85	PCE @ 15,000 TCE > 5 Vinyl Chloride > 2 1,2-DCA, MTBE	No
16th St & Camelback – Phoenix	WQARF ERA, GW monitoring	Basin-fill: Upper 60 to 65	PCE @ 89 1,2-DCA @ 7	No
56th St & Earll – Phoenix	WQARF ERA, RI	Basin-fill: Upper 13 to 75	PCE @ 46 TCE @ 770	No
Central &	WQARF	Basin-fill:	PCE @ 20,000	

Site Name & Location	Investigation & Action Types[1]	Depth to Groundwater (ft bls)	Water Quality Parameters & Max Levels Detected (µg/L)[2]	Drinking Water Wells Impacted
Camelback – Phoenix	ERA, RI	Upper 65 to 80	TCE Cis-1,2-DCE, Benzene, 1,2-DCA, Vinyl Chloride, MTBE, BTEX	
Cooper/Commerce - Gilbert	WQARF ERA, RI	Basin-fill: Upper 130	PCE @ 6,600 TCE @ > 5 Metals & TPH in soils	No
East Central Phoenix (ECP) 24th St & Grand Canal – Phoenix	WQARF ERA, RI	Basin-fill: Upper 30 to 60	PCE @ 200 TCE @ > 5 BTEX, MTBE,	No, 1 irrigation well
East Central Phoenix (ECP) 32nd St & Indian School Rd – Phoenix	WQARF ERA, RI	Basin-fill: Upper 45	PCE @ 3,600	No
ECP 38th St & Indian School Rd – Phoenix	WQARF ERA, RI	Basin-fill: Upper 45	PCE @ 98	No
ECP 40th St & Indian School Rd – Phoenix	WQARF ERA, RI	Basin-fill: Upper 45	PCE @ 180 TCE	No
ECP 40th St & Osborn Rd – Phoenix	WQARF ERA, RI	Basin-fill: Upper 32	PCE @ 210 TCE	No
ECP 48th St & Indian School Rd – Phoenix	WQARF ERA, RI	Basin-fill: Upper 25	PCE @ 78	No
East Washington Fluff – Phoenix	WQARF Remediation completed	Basin-fill: Upper 76 to 85	Lead, Cadmium, Arsenic, PCBs in soil	No
Estes Landfill – Phoenix	WQARF Finalizing PRAP & Monitoring	Basin-fill: Upper 60	Arsenic Chromium cis-1,2-DCE @ > 70 TCE @ 2.8 Vinyl Chloride @ 510 Benzene, Barium, Lead, Manganese	No
South Mesa – Mesa	WQARF ERA (SVE) RI	Basin-fill: Upper 110 to 130 Middle Lower	PCE @ 350 TCE, cis-1,2-DCE	No, 2 irrigation wells
West Central Phoenix (WCP) East Grand Ave – Phoenix	WQARF ERA, FS	Basin-fill: Upper 130 to 139 Middle Lower	TCE, PCE, 1,1-DCE BTEX	Yes, 4 wells
WCP West Grand Ave – Phoenix	WQARF ERA, RI, RO	Basin-fill: Upper 130 Middle Lower	TCE	Yes
WCP North Plume – Phoenix	WQARF ERA, RI	Basin-fill: Upper 120 to 145	TCE, PCE, 1,1-DCE, Vinyl Chloride,	Yes

Site Name & Location	Investigation & Action Types[1]	Depth to Groundwater (ft bls)	Water Quality Parameters & Max Levels Detected (µg/L)[2]	Drinking Water Wells Impacted
		Middle Lower	Chromium BTEX, MTBE, Nitrate	
WCP North Canal Plume – Phoenix	WQARF ERA, RI	Basin-fill: Upper 126 to 133	TCE, PCE, 1,1-DCE, Vinyl Chloride, Chromium, MTBE, Nitrate	Yes
WCP West Osborn Complex – Phoenix	WQARF ERA, FS	Basin-fill: Upper 128 to 138 Middle Lower	TCE @ > 5 PCE, MTBE, Nitrate	Yes
West Van Buren – Phoenix	WQARF ERA, RI	Basin-fill: Upper 90 to 140 Middle 200 to 400 Lower	PCE @ 90 TCE @ 150 1,1-DCE, Cis-1,2-DCE, 1,1-DCA	No, irrigation wells
Western Ave PCE – Avondale/Goodyear	WQARF ERA, RI Remediation	Basin-fill: Upper 61 to 72	PCE @ 12	No
19th Ave Landfill – Phoenix	NPL-delisted			
Luke Air Force Base - Glendale	NPL-delisted			
North Indian Bend Wash – Scottsdale	NPL RI/FS Remediation	Basin-fill: Upper 90 to 130 Middle 140 to 180 Lower unknown	TCE @ 2,500 in Upper, 700 in Middle PCE, 1,1-DCE, 1,1,1-TCA	Yes, 6 wells
South Indian Bend Wash – Tempe	NPL RI/FS completed, SVE, MNA	Basin-fill: Upper 50 to 60 Middle Lower	TCE @ 540 in UAU PCE	Yes
Motorola 52nd St - Phoenix	NPL Many RPs and three Operable Units ongoing PRP, RI/FS Preliminary remedial actions – SVE & GW	Basin-fill: Upper 40 to 90 Middle Lower	TCE @ 640+ TCA, DCE, DCA, Vinyl Chloride, PCE	
Phoenix-Goodyear Airport North – Phoenix	NPL RI/FS Remediation – SVE & GW	Basin-fill: Upper Middle Lower	TCE Perchlorate @ 130	
Phoenix-Goodyear Airport South – Goodyear	NPL RI/FS Remediation – SVE & GW	Basin-fill: Upper Middle Lower	TCE, PCE, Chromium	

Site Name & Location	Investigation & Action Types[1]	Depth to Groundwater (ft bls)	Water Quality Parameters & Max Levels Detected (µg/L)[2]	Drinking Water Wells Impacted
Williams Air Force Base - Mesa	NPL RI/FS Six Operable Units Remediation – SVE & GW	Basin-fill: Upper 140 to 180 Lower 245	Jet fuel, TCE, assorted VOCs, Radiological	No
161st Air National Guard - Phoenix	DOD RI - Monitoring Remediation – SVE/AS	Basin-fill: Upper 70 to 80 Middle Lower	Benzene, Ethylbenzene, PCE, TCE, DCE, DCA	No
7th St & Arizona Ave – Tucson	WQARF ERA (SVE/AS), RI	Basin-fill: Upper 65 Lower 173	PCE, TCE, cis 1,2 DCE	No
Broadway-Pantano – Tucson	WQARF ERA (SVE/GW GAC) RI/FS	Basin-fill: Upper 315 to 370	PCE @ 4.9 TCE, Vinyl Chloride, Methylene Chloride	Yes, Four city wells
Los Reales Landfill – Tucson	WQARF RI/FS Remediation – SVE/GW	Basin-fill: Regional 190 to 210	PCE @ > 5 TCE @ > 5	
Miracle Mile – Tucson	WQARF ERA, RI/FS	Basin-fill: Upper (perched) 70 Lower 160	TCE 1,1 DCE Chromium	Yes
Park-Euclid – Tucson	WQARF ERA (SVE/MPE) RI, monitoring	Basin-fill: Upper (perched) 90 Lower 200	PCE @ > 5 TCE @ > 5 cis 1,2 DCE @ > 70 Diesel free product	
Shannon Rd/El Camino del Cerro – Tucson	WQARF ERA (SVE/GW GAC) RI/FS	Basin-fill: Upper 120 to 135	PCE, TCE, 1,1-DCE, 1,1-DCA, cis 1,2-DCE Freon12, Benzene, Vinyl Chloride	Yes, many private wells & city well
Silverbell Landfill - Tucson	WQARF ERA, RAP (SVE/GW pump & treat)	Basin-fill: Upper 145	PCE @ > 5 TCE @ > 5	Yes, private wells
Tucson International Airport Area (TIAA) – Tucson	NPL RI/FS completed Remediation	Basin-fill: Regional 80 to 240	TCE @ > 270 PCE @ > 43 1,1-DCE cis 1,2-DCE	Yes, city and private wells
Air Force Plant 44/Raytheon Project Area (part of TIAA) – Tucson	NPL RI/FS completed Remediation	Basin-fill: Regional 90 to 160	TCE Chromium 1,4-Dioxane @ 600 1,1-DCE	Yes, city and private wells
Airport Property Project Area (part of TIAA) - Tucson	NPL RI/FS completed Remediation	Basin-fill: Regional 80 to 240	Carbon Tetrachloride 1,4-Dioxane @ 36 1,1-DCE	Yes, city and private wells
Arizona Air National	NPL	Basin-fill:	TCE @ 46	Yes, city and

Site Name & Location	Investigation & Action Types[1]	Depth to Groundwater (ft bls)	Water Quality Parameters & Max Levels Detected (µg/L)[2]	Drinking Water Wells Impacted
Guard 162nd Project Area (part of TIAA) – Tucson	RI/FS completed Remediation	Regional 90		private wells
Texas Instruments Project Area (part of TIAA) - Tucson	NPL RI/FS completed Remediation	Basin-fill: Regional 85	TCE @ 13 PCE	Yes, city and private wells
Tucson Airport Remediation Project (part of TIAA) – Tucson	NPL RI/FS Remediation	Basin-fill: Regional 80 to 240	TCE @ 100 1,4-Dioxane @ 12	Yes, city and private wells
West-Cap Project Area (part of TIAA) - Tucson	NPL RI/FS Remediation	Basin-fill: Regional 85 to 100	TCE @ 530 PCE 1,1,1-TCA	Yes, city and private wells
West Plume B Project Area (part of TIAA) - Tucson	NPL RI/FS, MNA	Basin-fill: Regional 75 to 90	TCE @ 15	Yes, city and private wells
Davis-Monthan AFB - Tucson	DOD IRP, SVE & GW monitoring	Basin-fill: Regional 350	PHC & BTEX in soils	No

[1] Abbreviations: **ERA** = early response action; **FS** = feasibility study; **GW** = groundwater; **IRP** = installation restoration program; **MNA** = monitored natural attenuation; **MMRP** = military munitions response program; **NPL** = national priorities list or superfund; **RA** = remedial actions; **RI** = remedial investigation; **RPs** = responsible parties; **SA** = superfund alternative approach; **SVE** = soil vapor extraction; **V** = voluntary investigation by responsible party; **WQARF** = water quality assurance revolving fund.

[2] Chemical/compound abbreviations: **TCE** = Trichlorethylene; **PCE** = Tetrachloroethylene; **TCA** = 1,1,1-Trichloroethane; **DCA** = 1,1-Dichloroethane; **1,2-DCA** = 1,2-Dichloroethane; **BTEX** = Benzene, Toluene, Ethylbenzene, & Xylene; **DCE** = Dichloroethene; **1,1-DCE** = 1,1-Dichloroethene; **cis-1,2-DCE** = cis-1,2-Dichloroethylene; **1,2-DCP** = 1,2-Dichloropropane; **PHC** = petroleum hydrocarbons; **Freon11** = Fluorotrichloromethane; **Freon12** = Dichlorodifluoromethane; **Freon113** = 1,1,2-Trichloro-1,2,2-trifluoroethane; **VOCs** = volatile organic compounds;

Major Cations and Anions (Dissolved Mineral Content)

Ambient groundwater quality can vary widely within and between aquifers. TDS content, which can be used to gage overall potability, generally falls within the range of suitability for human consumption, although higher concentrations are relatively common. Some areas in the state, particularly in some alluvial basins and along the Gila River, exhibit much higher TDS concentrations, rendering the groundwater unsuitable for drinking and other uses. Mining activities have been responsible for high levels of dissolved cations and anions (the individual constituents composing the dissolved mineral content) in groundwater in certain areas. Sulfate, TDS and hardness are commonly elevated

downgradient from historic mining operations and tailings ponds. Excessive amounts of sulfate and TDS in groundwater may also result from discharge of treated wastewater effluent and deep percolation of salts leached by irrigated agriculture. Fluoride, which occurs naturally in groundwater, is found in moderate to high levels in some basin-fill aquifers, particularly in those which are confined aquifers.

Metals

Heavy metals occur naturally in groundwater, and elevated levels are often associated with mineralized areas. For example, hexavalent chromium is found in groundwater at elevated levels in Paradise Valley (Robertson, 1975). Arsenic also occurs naturally in some areas at elevated levels. Currently, the federal and state maximum contaminant level for arsenic in drinking water is 0.01 milligrams per liter. Arsenic occurs in groundwater above this level at several localities in Arizona, which prevents its use in public drinking water systems unless treated. Much groundwater in Arizona contains naturally-occurring arsenic above this level. As a result, many public water systems in Arizona must implement treatment, blending or alternative supply measures to meet the new standard. Metals may also reach groundwater from anthropogenic sources. Chromium has been found in groundwater in several locations in the Phoenix and Tucson metropolitan areas due to industrial discharges from electronics, aviation and plating firms. Metals such as manganese, copper, iron, chromium and others have been found in groundwater downgradient from mining operations and tailings ponds, particularly where acid drainage has developed. Groundwater downgradient from landfills commonly contains elevated concentrations of iron, manganese and barium, and lower pH.

Pesticides

Prior to 1980, only two pesticides had been detected repeatedly in groundwater – dibromochloropropane (DBCP) and ethylene dibromide (EDB). These pesticides were found in groundwater in the Yuma area and in the Salt River Valley. DBCP and EDB were applied from the 1950s through the 1970s to soils in citrus and cotton fields as fumigants for the control of nematodes (Daniel, et al., 1988). These pesticides were banned more than a decade ago because of their potential carcinogenicity. More recently, the agricultural pesticide chemicals 2,4-D Acid, 2,4-D, atrazine, azoxystrobin, bromacil, carbaryl, dicamba, dimethomorph, diuron, endosulfan, flutolanil, imazamox, imazethapyr, imidacloprid, linuron, methomyl, methoxyfenozide, metribuzin, oxamyl, prometon, and prometryn have been detected in shallow monitoring wells located in areas of intensive irrigated farming within Maricopa and Yuma counties (Olade, per com). The detections are localized and transitory, not found in production wells, and do not represent a regional contamination problem. All detections are below MCLs and health-based guidance levels.

Petroleum Hydrocarbons

Many underground storage tanks (USTs), primarily those containing petroleum fuels, have leaked and are a significant source of groundwater contamination in Arizona. Leaking USTs (LUSTs) are located throughout the state, but are concentrated in urban areas. Many reported LUST sites are associated with service stations. Other locations included utility, transportation and shipping companies; municipal facilities; pipelines;

and mining, food, lodging, high technology and paint companies. Benzene, toluene, ethylbenzene and xylene (BTEX), which are aromatic hydrocarbon components of petroleum fuels, are the most commonly detected LUST-related chemicals in groundwater. At some LUST sites, total petroleum hydrocarbons (TPH), methyl tertiary-butyl ether (MTBE) and 1,2-dichloroethylene (1,2-DCE) have been detected. As of June 30, 2009, there were 987 LUSTs at 451 UST facilities in the state. About 345 of those sites have releases to both groundwater and soil, and 106 have impacted soil only. Since UST program inception in 1990, the department has closed 7,505 releases of a total 8,512 reported (88%) and has reimbursed $306,130,995 to UST owners, operators, and volunteers for eligible cleanup costs.

Radionuclides

Radioactive elements such as uranium, radon (radon-222) and radium occur naturally in the soil and water at locations throughout Arizona, sometimes in concentrations elevated enough to be of concern. Radionuclide concentrations such as gross alpha usually occur in areas located in or near granite rock or alluvial areas composed of eroded granite (Lowry, 1988). Mining activity also increases gross alpha concentrations because of the increased rock surface exposure. Gross alpha exceedances occurred where other radionuclide exceedances occurred, making this constituent an important harbinger of elevated radionuclides concentrations in general.

Even though radon is not monitored as uranium and radium are for public water systems, it is considered by EPA to be a potential health threat through inhalation primarily. Studies by ADEQ, the Arizona Geological Survey, U.S. Geological Survey, and Arizona State University found that radon concentrations greater than 300 Pico curies per liter (pCi/L) are normal for groundwater in several areas across the state (Barnett, McKlveen and Hood, 1990; Duncan and Spencer, 1991; Wirt, Gray and Van Metre, 1989). Groundwater sampling by various agencies prior to 1992 have revealed generally high levels (> 300 pCi/L) of radon in wells in Phoenix, Cave Creek/Carefree, McMullen Valley, South Tucson, and the Puerco River Basin. Based on known uranium rich deposits, generally corresponding to higher radon levels, in Prescott (Dells area), Payson, Yuma, Kingman, Bagdad, Camp Verde, Kirkland, Tombstone, Sierra Vista, and St. Johns may have potential significant radon levels although there is a lack of testing in these and many areas statewide. Contamination of groundwater has resulted from uranium mining activities (waste dumps and mine tailings) and mine dewatering. These uranium mining activities mainly occurred in the Plateau Uplands Province.

Bacteria

Septic tank effluent often has been linked to groundwater contamination by bacteria.

The 2000 census estimated that approximately 377,000 septic tank systems are operating in Arizona, serving about 17.4 percent of the population. Contamination of groundwater by microorganisms may result when the tanks are installed in areas with inadequate soils or shallow depth to groundwater. Bad well construction and well seals also can lead to the entry of microorganisms into a well so as to contaminate the drinking water. Generally, however, most microorganisms will be removed from the septic tank effluent after passing through a few feet of soil and do not survive long in aquifers.

Water Quality Summaries for Selected Aquifers

The Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring program was started in 1991 and charged with characterizing regional groundwater conditions in the state. Since then, the program has sampled 31 of the 51 groundwater basins in Arizona. These reports are available in both a comprehensive Open File Report (OFR) as well as a compact four-page fact sheet (FS) and are available online at http://www.azdeq.gov/environ/water/assessment/ambient.html . A summary of each report follows.

Agua Fria Basin - In 2004-2006, the ADEQ conducted a baseline groundwater quality study of the Agua Fria basin (AGF) located between Phoenix and Prescott in central Arizona. This groundwater basin encompasses the drainage of the Agua Fria River from below the Prescott Active Management Area to Lake Pleasant and includes the Bradshaw Mountains to the west and Bloody Basin to the east. This lightly populated basin consists primarily of federal lands (U.S. Forest Service and Bureau of Land Management), State Trust and private land (Littin, 1986). Minimal water developments have occurred except around the communities of Mayer in the Bradshaw Mountains and Cordes Junction and Black Canyon City along Interstate 17.

To characterize regional groundwater quality, samples were collected from 46 sites located throughout the basin. Most sample sites consisted of shallow wells used for domestic uses and wells and springs used for stock watering. All sites were sampled for inorganic constituents and, at selected sites, for oxygen and deuterium isotopes (44 sites), radon (40 sites), and radiochemistry (33 sites). Nine isotope samples were also collected from surface water sources.

Analytical results indicate that of the 46 sites sampled, 14 sites (30 percent) had concentrations of at least one constituent that exceeded a health-based, primary federal or State water-quality standard (MCLs). These enforceable standards define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system and are based on a lifetime daily consumption of two liters per person (EPA, 1993; WQA, 2006). Health-based MCL exceedances included arsenic (12 sites), fluoride (5 sites), gross alpha (1 site), and nitrate (1 site). Elevated concentrations of arsenic, fluoride and gross alpha appear to be the result of natural sources; the nitrate exceedance appears to be impacted by septic systems (Madison and Brunett, 1984). At 31 sites (67 percent), concentrations of at least one constituent exceeded an aesthetics-based, secondary federal water-quality guideline (SMCLs). These are unenforceable guidelines that define the maximum concentration of a constituent that can be present in drinking water without an unpleasant taste, color, odor, or other effect (EPA, 1993; WQA, 2006). Aesthetics-based SMCL exceedances included chloride (4 sites), fluoride (7 sites), iron (2 sites), manganese (9 sites), pH-field (1 site), sulfate (3 sites), and total dissolved solids or TDS (26 sites).

Groundwater quality in the AGF is remarkably homogeneous in many aspects. The majority of sample sites are of *calcium-bicarbonate* or *mixed-bicarbonate* chemistry,

have concentrations of TDS that typically vary between 450 to 625 milligrams per Liter (mg/L) range, have *hard*-to-*very hard* water, have low concentrations of nutrients including nitrate, and have few occurrences of trace elements other than fluoride and arsenic.

The exception to the uniformity of the basin's groundwater quality involves a limited subgroup of sample sites that have sodium as their major cation and are almost devoid of calcium and magnesium. The sodium chemistry sites tended to occur, interspersed with calcium or mixed chemistry sites, in the southern portion of the basin along the flanks of the Bradshaw Mountains stretching to the floodplain of the Agua Fria River. Besides very different water chemistry, the sodium chemistry sites tend to have significantly higher TDS, chloride, sulfate, fluoride and arsenic concentrations than the calcium or mixed chemistry sites (Kruskal-Wallis test, $p \leq 0.05$). The arsenic and fluoride concentrations at these sodium chemistry sites are frequently above MCLs often by several orders of magnitude. A sample from a well near Black Canyon City had an arsenic concentration of 2.25 mg/L (or 225 µg/L), one of the highest arsenic concentrations ever found in groundwater in Arizona.

Water chemistry differences appear to be influenced by a 100-to-200 feet thick confining layer of clay and silica-rich caliche that separates the unconsolidated deposits of the Agua Fria River in the Black Canyon City area from the underlying, water-bearing schist that is also present in places north of Lake Pleasant (Littin, 1981). Water produced from the schist contains elevated concentrations of TDS, fluoride and arsenic while water produced from shallower wells that only penetrate the overlying gravel, sand and silt have significantly lower concentrations of these constituents (Littin, 1981).

The elevated fluoride samples all occur at sites with sodium as the dominant cation. The main control on fluoride concentrations are calcium concentrations through precipitation or dissolution of the mineral fluorite. If a source of fluoride ions is available for dissolution, large concentrations of dissolved fluoride may occur if the groundwater is depleted in calcium (Robertson, 1991). The elevated arsenic samples, all located in the Bradshaw Mountains, are less predictable in occurrence. Although sites with sodium as the dominant cation had the highest concentrations, MCLs were also exceeded at sites at which the dominant cation was calcium or mixed. The cause of the elevated arsenic concentrations is uncertain, although in Arizona such conditions are often associated with clay-rich sediments, volcanic rocks, geothermal environments and/or areas with gold deposits (Spencer, 2002).

Big Sandy Basin - The Big Sandy groundwater basin (BIS) covers approximately 1,900 square miles of rugged terrain in northwestern Arizona stretching from north of Route 66 to south of the town of Wikieup along Highway 93 (Cady, 1981). Located in Mohave and Yavapai Counties, most lands are federally managed by the Bureau of Land Management with the remainder consisting chiefly of State trust and private lands. Rangeland is the predominant land use with private land increasingly subdivided for dispersed housing. Knight Creek and Trout Creek drain the northern part of the BIS and converge 15 miles north of Wikieup to form the Big Sandy River. This waterway flows southward exiting the basin and eventually debouching into the Santa Maria River just

upstream of Alamo Lake. Groundwater is the source of the vast majority of water uses in the BIS and occurs in at least five hydrologic settings: floodplain alluvium, unconfined basin-fill, confined basin-fill, sedimentary rock in the east-northeast portion of the basin, and the consolidated bedrock of the Hualapai, Peacock, Aquarius, and Mohon Mountains (ADWR, 1994; Cady, 1981).

To support an ADEQ Total Maximum Daily Load study examining elevated mercury concentrations in fish tissue, sediment and water from Alamo Lake, in 2003-2004, the department conducted a baseline groundwater quality study of the BIS (Fitch, 2006). Samples were collected for inorganic constituents (57 sites), isotopes of oxygen and hydrogen (57 sites), radon (37 sites), radiochemistry (30 sites), and ultra-clean mercury (21 sites) analyses. Samples were collected mainly from relatively shallow domestic or stock wells and springs. ADEQ was denied permission to sample deep wells owned either by the Phelps Dodge Corporation or Caithness Energy. Ninety-five (95) percent of groundwater pumped in the BIS is transported by Phelps Dodge to the Bill Williams basin for use at the company's Bagdad copper mine (ADWR, 1994). Caithness Energy wells were drilled for use at their proposed Big Sandy power plant which was denied a permit in 2001 by the Arizona Corporation Commission (ACC, 2006).

Although 42 percent of the sites sampled contained one or more constituents that exceeded a health-based MCL, most of these sites were located in the south-central portion of the basin; other areas—particularly in the northeast—had relatively few exceedances. Of the 57 sites sampled, 24 sites had concentrations of at least one constituent that exceeded an MCL. Health-based MCL exceedances included arsenic (11 sites), fluoride (11 sites), gross alpha (9 sites), lead (1 site), radium (1 site), and uranium (2 sites). At 29 sites, concentrations of at least one constituent exceeded an aesthetics-based SMCL. Aesthetics-based SMCL exceedances included chloride (4 sites), fluoride (20 sites), iron (3 sites), manganese (4 sites), pH-field (2 sites), sulfate (2 sites), and total dissolved solids or TDS (22 sites).

Analytical results indicated that groundwater in the BIS is generally slightly alkaline, fresh, and moderately hard to very hard based on pH, TDS and hardness analyses. Most groundwater sample sites were either of mixed-bicarbonate or calcium-bicarbonate water chemistry. Nitrate concentrations were generally low with no samples exceeding health-based standards. Among trace elements, only arsenic, boron, copper, fluoride, and zinc were detected at more than 20 percent of sample sites. Mercury was not detected in any sample submitted to the Arizona State Health Department Laboratory which has a Minimum Report Level of 0.0005 mg/L.

Patterns were found among groundwater sub-basins, aquifers, and recharge sources (ANOVA with Tukey test using log-transformed data, $p \leq 0.05$). Temperature, TDS, sodium, chloride, sulfate, fluoride, boron, iron and gross beta were higher in the down-gradient Big Sandy sub-basin than in the up-gradient Trout Creek sub-basin. Temperature, TDS, sodium, chloride, sulfate, fluoride, boron, and radon were higher in basin-fill or artesian aquifers than in sedimentary rock. Temperature, pH-lab, sodium, sulfate, and fluoride are higher at depleted recharge sites than at enriched recharge sites; the opposite pattern occurs with calcium, magnesium, hardness, and nitrate.

These patterns suggest that groundwater in the basin generally follows a flow path evolving from calcium-bicarbonate chemistry, indicative of recently recharged groundwater, in sedimentary rock in the Trout Creek sub-basin to a more saline, mixed-bicarbonate chemistry with higher concentrations of constituents such as sodium, chloride, sulfate, fluoride and boron that are indicative of groundwater with a longer residence time (Robertson, 1991).

Detrital Valley Basin - The Detrital Valley groundwater basin (DET), located between Kingman and Hoover Dam in northwestern Arizona, is a north-south trending, semiarid basin traversed by U.S. Highway 93. Lightly populated with retirement and recreation-oriented communities, the construction of a Hoover Dam bypass route for U.S. Highway 93 will likely bring many new residents who commute to Las Vegas. The DET is drained by the ephemeral Detrital Wash which debouches into Lake Mead at Bonelli Bay. The DET, with groundwater depth up to 800 feet below land surface near the center of the valley, is reminiscent of basins in Nevada. Groundwater from the *alluvial aquifer* is the principle water source. Where sufficiently fractured and faulted, mountain *hard rock* provides limited supplies at shallower depths to groundwater. Near Lake Mead, a *Lake Mead aquifer* recharged by Colorado River water is the main supply.

In 2002, a baseline groundwater quality study of the DET was conducted by the Arizona Department of Environmental Quality. The purpose of this study was to create a comprehensive groundwater quality baseline assessment. For this study, 28 groundwater sites were sampled for inorganic constituents as well as isotopes of hydrogen and oxygen, samples were also collected at selected sites for radon gas (9 sites) and radiochemistry (9 sites) analyses. In addition, surface water isotope samples were collected from Lake Mead and Detrital Wash. One weakness of the groundwater study was the few sites available for sampling in the northern third of the basin.

Of the 28 sites sampled, 13 (46 percent) met all drinking water quality standards. Nine sites (32 percent) had concentrations of at least one constituent that exceeded an MCL. Constituents that exceeded MCLs included arsenic (0 sites under current standards, 3 sites under standards effective in 2006), gross alpha (3 sites), and nitrate (3 sites). Ten sites (36 percent) had concentrations of at least one constituent that exceeded an aesthetics-based SMCL. Constituents that exceeded SMCLs included chloride (1 site), fluoride (2 sites), iron (2 sites), manganese (3 sites), sulfate (7 sites), and total dissolved solids or TDS (11 sites).

Groundwater in the DET generally meets drinking water standards and is suitable for domestic, municipal, irrigation, and stock purposes. Groundwater in the DET is generally *fresh*, *slightly alkaline*, and *moderately* to *very hard* based on TDS, pH, and hardness concentrations (Heath, 1989). Groundwater is most commonly a *mixed-mixed* chemistry though it varies widely in the basin. Boron, chromium, fluoride, and zinc were the only trace elements detected at more than 25 percent of sites.

Groundwater quality constituent concentrations varied significantly among aquifers within the DET. Bicarbonate, calcium, and hardness were higher in *hard rock* than in the

alluvial aquifer. In contrast, temperature, nitrate, and chromium were higher in the *alluvial aquifer* than in *hard rock.* The *Lake Mead aquifer* had higher levels of oxygen and hydrogen isotopes, sodium, sulfate, and boron (ANOVA test in conjunction with Tukey test, $p \leq 0.05$). Many groundwater quality constituent concentrations varied significantly with groundwater depth. Most constituents, including TDS, bicarbonate, calcium, magnesium, hardness, chloride, and sulfate decreased with groundwater depth. In contrast, temperature, pH-field, nitrate, and chromium increased with groundwater depth (regression, $p \leq 0.05$).

Hydrogen and oxygen isotope data form a *Local Meteoric Water Line* with a slope of 5.15 that is within the range normally found in arid environments (Coplen, et al., 1999). The most *depleted*, or isotopically lightest sites are near (and include) Lake Mead and consist of recent recharge from the Colorado River. A tight cluster of 16 *depleted* sites, consisting mainly of deep alluvial wells, may represent the oldest water in the basin that was recharged during a more humid time period than the present. Stretching from this cluster to the most *enriched* site (runoff in Detrital Wash) is an evaporation trajectory of 10 shallow wells that produce water that may include recharge from recent precipitation.

Douglas Basin - ADEQ completed a baseline groundwater quality study of the Douglas Groundwater Basin (DGB) in 1995-96. A total of 51 groundwater samples were collected for the study, whose design included 29 grid-based, stratified random samples and 21 targeted samples. All groundwater samples were analyzed for Safe Drinking Water (SDW) inorganic constituents, 12 samples were analyzed for SDW Volatile Organic Compounds (VOCs), 7 samples were analyzed for Groundwater Protection List (GWPL) pesticides, and 6 samples were analyzed for radionuclides. Laboratory results revealed no detections of any GWPL pesticides while the only SDW VOC detected was chloroform in 1 sample. Radionuclide samples did not exceed MCLs for any parameter. With inorganic parameters, levels of arsenic, beryllium, and nitrate each exceeded their respective health-based Primary MCLs in 1 sample apiece. Aesthetics-based SMCLs were exceeded in 16 samples: 8 times by fluoride and total dissolved solids (TDS), twice by pH and sulfate, and once by chloride, iron, and manganese. These results suggest that regional groundwater quality conditions generally support drinking water uses, but because of aesthetic factors, some residents may prefer to use treated water for domestic purposes.

Piper trilinear diagrams reveal that of the two major aquifers in the DGB, bedrock aquifer samples tend to exhibit a calcium-bicarbonate chemistry; alluvial aquifer samples also typically exhibit a calcium-bicarbonate chemistry though sodium-bicarbonate, sodium-sulfate, and calcium-sulfate varieties are also present in this aquifer. Statistical analyses found that many significant differences exist in inorganic groundwater quality parameter levels between aquifers while fewer differences existed between groundwater management areas, and between various divisions (East-West, North-South) of the DGB. A strong positive correlation existed between the levels of most major ions and nitrate; in contrast, fluoride and pH tend to be negatively correlated with other groundwater quality parameters while trace elements have few significant correlations. Many parameter levels also significantly increased or decreased with increasing groundwater depth below land surface in the DGB.

Comparing parameter levels from targeted samples with 95% confidence intervals established for the DGB indicated several potential impacts. Nitrate (as N) appears to be elevated in the Elfrida area perhaps from agricultural practices and/or septic systems. Near the City of Douglas, high sodium and pH levels in combination with low calcium and magnesium levels appear to indicate groundwater is being subjected to natural softening by cation exchange. Elevated sulfate levels in the Mule Gulch area might be the result of mine tailings in the area. Finally, a geothermal anomaly appears to exist east of the Bisbee-Douglas Airport resulting in TDS levels reaching 14,000 mg/L and elevated levels of temperature, arsenic, and other parameters.

A time-trend analysis was conducted using groundwater quality data collected by ADWR from 7 wells in 1987. The results indicated while many of the 12 parameters appeared to have higher levels in 1995-96 than 1987, only nitrate and potassium were significantly higher.

Hualapai Valley Basin - The Hualapai Valley groundwater basin (HUA) trends north-northwest and is roughly 60 miles long and varying from 15 to 25 miles wide in northwestern Arizona. The basin covers 1,820 square miles in Mohave County stretching from Hualapai Peak just south of the City of Kingman to Lake Mead to the north (Remick, 1981). The basin is composed of lands federally managed by the Bureau of Land Management, the National Park Service (as part of the Lake Mead National Recreation Area), private, State Trust and Hualapai Indian Nation lands. Land use is mainly rangeland and recreation, with private lands near Kingman, increasingly developed for residential housing.

There are no perennial streams in the HUA basin (ADWR, 1994). The southern portion of the basin is drained by an ephemeral watercourse, Truxton Wash, which flows north and debouches after heavy precipitation into the normally dry Red Lake Playa. The other major ephemeral watercourse, Hualapai Wash, runs north of Red Lake Playa after heavy precipitation and debouches into Lake Mead (ADWR, 1994). Although the Colorado River, impounded in Lake Mead, forms the northern boundary of the basin, it is not a significant water supply within the HUA basin (Anning, Flynn and Truini, 2006).

Groundwater is the major source of water in the HUA (Remick, 1981). It occurs in both the extensive older alluvium deposits found in Hualapai Valley and, to a lesser degree, the fractured rock and thin alluvium deposits of the Hualapai, Peacock, Music, and Cerbat Mountains (Gillespie and Bentley, 1971). Historically, low-yield wells and springs located in or near mountain areas provided the main source of water for the minimal needs of the local economy that was based on ranching. Now, deep, high-yield alluvial wells, often exceeding 1,000 feet in depth, are the main supply source for major water users in the basin including the City of Kingman and outlying housing developments (Cella Barr Associates, 1990).

In 2000, ADEQ conducted a baseline groundwater quality study of the HUA, sampling 26 sites for inorganic constituents. Also collected at selected sites were volatile organic compounds (VOCs)(21 samples), radiochemistry (16 samples) and radon (8 samples).

Groundwater sites consisted of 20 relatively shallow, domestic or stock wells and/or springs in bedrock mountain areas and 6 deep wells in the valley alluvium.

Of the 26 sites sampled, 9 sites (35 percent) had concentrations of at least one constituent that exceeded a health-based MCL. MCL exceedances included arsenic (3 sites), fluoride (2 sites), gross alpha (3 sites), nitrate (3 sites), radium 226/228 (1 site), and uranium (2 sites). At 17 sites (65 percent), concentrations of at least one constituent exceeded an aesthetics-based SMCL. SMCL exceedances included chloride (2 sites), fluoride (11 sites), iron (2 sites), manganese (3 sites), pH-field (2 sites), sulfate (2 sites), and total dissolved solids or TDS (11 sites). There was one VOC detection of toluene (at 4.7 µg/L) in one of the 21 VOC samples collected.

Analytical results indicate that groundwater in the HUA is generally *slightly alkaline*, *fresh*, and *hard* to *very hard* based on pH values and TDS and hardness concentrations. The chemistry of groundwater samples varied widely with mixed-mixed and mixed-bicarbonate the most common compositions. Among trace elements, only boron, fluoride, selenium and zinc were detected at more than 20 percent of sample sites. Nitrate (as N) concentrations were sometimes elevated, with 11 sites (42 percent) having concentrations that may be from human activities (Madison and Brunett, 1984).

Statistically-significant patterns in water-quality data were found among groundwater sources (ANOVA, $p \leq 0.05$). Temperature (field-measured), pH (field-measured), and fluoride were significantly higher at sites in the alluvium than at sites in hard rock. In contrast, calcium, magnesium and hardness were significantly higher at sites in hard rock than in alluvium. TDS ($p = 0.11$) and bicarbonate ($p = 0.08$) were also higher at sites in hard rock than in alluvium but failed to meet the statistical confidence level (ANOVA, $p \leq 0.05$). The limited sampling conducted in wells tapping the older alluvium—the aquifer that holds the majority of water reserves in the HUA—revealed generally acceptable groundwater quality with fluoride generally the only constituent of concern. Fluoride exceeded the MCL in one well and SMCL in four other wells; otherwise pH-field and TDS were the only aesthetic standards exceeded in one well apiece. The elevated fluoride concentrations are believed to occur naturally and are controlled by pH values that also increase downgradient through silicate hydrolysis reactions (Robertson, 1991).

Lake Mohave Basin - Containing approximately 1,050 square miles, the Lake Mohave groundwater basin (MHV) stretches along the Colorado River from Hoover Dam south to the community of Topock in northwestern Arizona (ADWR, 1994). A granite outcrop where Davis Dam on the Colorado River is located divides the MHV into North and South basins. The North basin consists largely of rugged, undeveloped lands that are part of the Lake Mead National Recreation area. The South basin consists of uplands managed by the Bureau of Land Management and Mohave Valley which is a combination of private, State Trust, and Fort Mohave Indian Reservation lands. The South basin is a populated, highly developed area. Physically, the MHV is characterized by three distinct geologic features: Colorado River floodplain deposits, piedmont alluvial deposits, and consolidated bedrock of the Black Mountains (Darr, 1990).

In 2003, ADEQ conducted a baseline groundwater quality study of the MHV, a basin that was the focus of four previous department groundwater studies since the late 1980s that sampled over 150 wells to investigate links between septic systems and nitrate (Darr, 1990; Tuve and Giannelli, 1995; Tuve, 1999). For the 2003 study, 43 groundwater sites were sampled for inorganic constituents and isotopes of oxygen and hydrogen. Samples were also collected at selected sites for radon (31 sites), perchlorate (18 sites), and radiochemistry (15 sites) analyses.

Of the 43 sites sampled, 15 sites had concentrations of at least one constituent that exceeded MCLs. Health-based MCL exceedances included arsenic (2 sites under the current standard, 14 sites under the standard effective in 2006), fluoride (1 site) and nitrate (3 sites). At 31 sites, concentrations of at least one constituent exceeded an aesthetics-based SMCL. Aesthetics-based SMCL exceedances included chloride (19 sites), fluoride (8 sites), iron (7 sites), manganese (13 sites), sulfate (24 sites), and total dissolved solids or TDS (30 sites). Perchlorate was not detected at any site.

Because of few sources, sampling in the North basin was limited to 10 sites, including four thermal springs along the Colorado River. Hydrogen and oxygen isotope values revealed four sites recharged by local precipitation; other sites by an indeterminate recharge source (Guay et al., 2004). Sites other than thermal springs generally met health based standards.

Groundwater sites in the South basin appeared to consist of 9 sites recharged by pre-dam Colorado River water, 10 sites recharged by post-dam Colorado River water, 12 sites recharged by local precipitation, and 2 sites whose source is the marine-related Bouse Formation (Guay et al., 2004; Robertson, 1991). Their water chemistry varies: Colorado River recharge is higher in chloride and sulfate, local recharge contains more bicarbonate, and the Bouse Formation is sodium-chloride.

Patterns were found among recharge sources (ANOVA with Tukey test, $p \leq 0.05$). Total dissolved solids (TDS), sodium, chloride, and sulfate were higher at sites recharged by pre/post dam-Colorado River water or tapping the Bouse Formation than at sites recharged by local precipitation. Similarly, calcium, magnesium, and hardness were higher at sites recharged by pre/post-dam Colorado River water than at sites recharged by local precipitation. Arsenic, boron and fluoride were higher at sites tapping the Bouse Formation than at sites recharged by pre/post dam-Colorado River water or local precipitation. Temperature, pH, nitrate, and chromium were higher at sites recharged by local precipitation than from pre/post dam Colorado River water. Finally, total Kjeldahl nitrogen, ammonia, total phosphorus, iron, and manganese were higher at sites recharged by post-dam Colorado River water than at sites recharged by local precipitation, which may indicate that reducing conditions driven by the oxygen demand presented by decomposing soil organic carbon occur along the Colorado River in Mohave Valley (Robertson, 1991).

In the South basin, groundwater recharged by local precipitation is the preferred domestic source because of its lower salinity and fewer aesthetic water quality standard exceedances. However, sites sometimes exceeded health-based water quality standards

for arsenic, which are probably naturally occurring because of long groundwater residence time (Robertson, 1991). Groundwater recharged by the Colorado River had fewer health-based water quality standards but was higher in salinity with numerous aesthetics standard exceedances including TDS, sulfate, and chloride. These concentration increases from fresher river water are probably the result of the dissolution of halite and gypsum (Robertson, 1991). Sites tapping the Bouse Formation were saline and had both health and aesthetics-based standard exceedances.

Lower San Pedro Basin – The Lower San Pedro groundwater basin (LSP) baseline groundwater quality study was conducted by ADEQ in 2000. Located in southeastern Arizona, this semiarid basin is drained by the San Pedro and Gila Rivers. The LSP is a rural landscape with scattered towns and two extensive copper mining and processing operations. Groundwater from three aquifers (*floodplain*, *unconfined basin-fill*, and *confined basin-fill* or *artesian*) and fractured mountain hard rock is the principle source of water supply. For this study, 63 groundwater sites were sampled for inorganic constituents. In addition, fewer sites were also sampled for Volatile Organic Compounds (25), radiochemistry (19), radon (19), and pesticide (2) analyses.

Eighteen (18) percent of sample sites had concentrations of at least one constituent that exceeded a health-based MCL. Constituents that exceeded MCLs included antimony (2 sites), arsenic (1 site under current standards, 12 sites under standards effective in 2006), fluoride (8 sites), nitrate (1 site), and gross alpha (2 sites). In addition, 49 percent of sample sites had concentrations of at least one constituent that exceeded an aesthetics-based SMCL. Constituents that exceeded SMCLs included chloride (2 sites), fluoride (16 sites), iron (4 sites), manganese (9 sites), pH (4 sites), sulfate (11 sites), and total dissolved solids (24 sites). At one site, Volatile Organic Compounds that are common by-products of chlorination were detected. No pesticides or pesticide degradation by-products were detected.

Artesian conditions can exist when *confined basin-fill aquifers*, which are generally found along the central portion of the basin's axis, are intercepted (Jones, 1980). Artesian water in the LSP is suitable for domestic and irrigation purposes at its southern boundary near Redington. Farther north, however the water quality deteriorates. Gypsum deposit dissolution and the associated cation exchange in the Mammoth-Dudleyville corridor create groundwater with elevated sulfate and sodium concentrations. The *artesian aquifer* also has a *chemically closed hydrologic system* that favors alkaline pH values and depleted calcium concentrations, which also contribute to the elevated concentrations that can exceed water quality standards. The elevated sodium and other salt concentrations also make these *confined basin-fill aquifer* waters unsuitable for irrigation north of Redington.

The *floodplain aquifer* is the most productive in the basin and supplies water for most irrigation and municipal uses. This aquifer forms a long corridor following the major waterways and receives most of its recharge from surface water flows (ADWR, 1994). As such, this aquifer is considered to be a *chemically open hydrologic system*. However, leakage from the lower *confined basin-fill aquifer* upwards into the *floodplain aquifer* is thought to be largely responsible for the variable salinity and fluoride concentrations that

are particularly elevated near Mammoth (Page, 1963). The elevated salinity, sodium, chloride, and potassium concentrations found in the most downgradient portions of the *floodplain aquifer* appear to be related to the high concentrations of these constituents in the Gila River. Elevated sulfate concentrations found along the *floodplain aquifer* between Mammoth and Winkelman may be from leakage from the *confined basin-fill aquifer* and the elevated concentrations carried north by the San Pedro River. The source of sulfates for both aquifers appears to be a combination of nearby gypsum deposits and mine tailing dumps, though the contribution of each would require an intensive targeted study to determine.

Groundwater collected from the *unconfined basin-fill aquifer* and from hard rock areas was the most dilute and had the fewest water quality standard exceedances. Unfortunately, these areas also have a somewhat limited groundwater production potential. Differences in water quality between these aquifers and the *floodplain aquifer* appear to be related to a more dilute recharge source (mountain precipitation and runoff) as well as minimal leakage from the *confined basin-fill aquifer*. Potential water quality problems appear largely confined to fault zones producing water from great depths and granitic rock areas which may have elevated radiochemistry concentrations (Heindl, 1952).

McMullen Valley Basin - In 2008-2009, the Arizona Department of Environmental Quality (ADEQ) conducted a baseline groundwater quality study of the McMullen Valley basin located in west-central Arizona. The basin consists of the drainage of the ephemeral Centennial Wash within McMullen Valley and the surrounding mountains.[6] Groundwater is predominantly used for irrigation near the communities of Aguila, Wenden and Salome.[7] The City of Phoenix has purchased farms near Salome to obtain the water rights for potential transfer to Maricopa County for municipal use.[7]

The main source of groundwater in the basin is the Regional aquifer. [24] Heavy pumping near Aguila and Salome has produced a groundwater divide near the La Paz-Maricopa County line creating Eastern and Western Regional aquifers.[25] In terms of spatial extent and groundwater storage these are the largest aquifers in the basin. [25] Low hills east of Aguila that minimize groundwater movement divide the Eastern Regional aquifer from the Forepaugh aquifer.[43] A subsurface extension of the Harquahala Mountains that limits groundwater movement separates the Western Regional aquifer from the Southern Regional aquifer located in Harrisburg Valley.[25] Another subsurface geologic feature separates the Harcuvar aquifer from the Southern and Western Regional aquifers lying to the east. [24] Groundwater movement between the Western Regional aquifer and the overlaying Perched aquifer is restricted by the Lake-bed Unit, a layer of fine-grained sediments. [24] These deposits, however, are absent in an area one mile northeast of Salome where groundwater flowing from the Perched aquifer into the Western Regional aquifer is termed the Mixed aquifer. [24]

To characterize regional groundwater quality, samples were collected from 124 wells. The wells supply water for irrigation, domestic, municipal and stock uses throughout the basin. Inorganic constituents and oxygen and deuterium isotopes were collected from all wells. At selected wells, radon (79 sites), radiochemistry (50 sites) and pesticide (2 sites)

samples were also collected. In addition to the 124 wells, 12 additional wells were sampled for field parameters and nitrate.

Primary maximum contaminant levels (MCLs) for inorganic constituents were exceeded at 54 of the 124 sites (44 percent). These enforceable standards define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system and are based on a lifetime daily consumption of two liters. [38] Constituents exceeding Primary MCLs include arsenic (24 sites), fluoride (27 sites), nitrate (25 sites), and selenium (2 sites). Primary MCLs for radionuclides were exceeded at 9 of the 50 sites (18 percent) including gross alpha (9 sites) and uranium (4 sites). Elevated concentrations of arsenic and fluoride likely occur naturally. Elevated nitrate concentrations appear to be caused by nitrogen-laden recharge resulting from irrigation applications and wastewater from septic systems. Gross alpha and uranium exceedances are likely naturally occurring though may be impacted by anthropomorphic activities.[42] Secondary MCLs were exceeded at 87 of 124 sites (70 percent). These are unenforceable aesthetics guidelines that define the maximum constituent concentration that can be present in drinking water without an unpleasant taste, color, or odor.[38] Constituents above Secondary MCLs include chloride (13 sites), fluoride (69 sites), manganese (2 sites), pH (19 sites), sulfate (8 sites), and TDS (31 sites).

The basin's most important groundwater quality issue is the absence of the Lake-bed Unit northeast of Salome. [24] Nearby wells commonly exceed water quality standards and guidelines; nitrate concentrations were elevated up to seven times the 10 mg/L health-based water quality standard. This is the result of percolating irrigation water containing salts and nitrate recharging the Perched aquifer. With a higher static water level than the Regional aquifer, groundwater drains downward from the Perched aquifer into the Western Regional aquifer. This impacted area is referred to in this report as the Mixed aquifer. [24] TDS, sodium, chloride, sulfate, and nitrate were significantly higher in the Perched and Mixed aquifers than in all the other aquifers (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

Both the Eastern and Western Regional aquifers had water quality issues. In the Eastern Regional aquifer, southeast of Aguila, some sample sites exceeded standards for fluoride and, to a lesser degree, arsenic. Similarly, in the Western Regional aquifer near Wenden, sample sites also exceeded standards for fluoride and, to a lesser degree, arsenic. The Eastern Regional aquifer exhibited significantly lower concentrations of TDS, sodium, and boron than in the Western Regional aquifer; the opposite pattern occurs with well depth and groundwater depth. (Kruskal-Wallis with Tukey test, $p \leq 0.05$) These differences may result from poor quality irrigation recharge minimally impacting the Eastern Regional aquifer because of the great depths needed to percolate to groundwater. Almost all the sites sampled in the Forepaugh aquifer exceeded water quality standards for fluoride and arsenic. Fluoride concentrations commonly were up to three times the health-based standard. Few water quality standards were exceeded in the Southern Regional and Harcuvar aquifers; both appear to consist of more recent recharge.

Meadview Basin - The Meadview groundwater basin (MEA), known unofficially as "Where Lake Mead Meets the Grand Canyon," comprises approximately 190 square miles in northwestern Arizona (ADWR, 1994). This small basin is sometimes considered a sub-basin of the Hualapai groundwater basin (Remick, 1981). Lightly populated, most land within the MEA is managed by the Bureau of Land Management or the National Park Service as part of the Lake Mead National Recreation area. Most residents live in the retirement and recreation-oriented community of Meadview that was founded in the early 1960s. Meadview is supplied with water by the Joshua Valley Utility Company (ADWR, 1994).

The basin is drained by Grapevine Wash, an ephemeral waterway that debouches into Lake Mead. A short perennial reach in the wash is caused by discharge from Grapevine Spring (ADWR, 1994). The Muddy Creek Formation is the main aquifer in the basin and can be divided into three units: an upper limestone unit, a middle sandstone/siltstone unit, and a basal conglomerate (Laney, 1979). Although each unit is capable of producing water, most wells draw from the basal conglomerate because of its high hydraulic conductivity (ADWR, 1994). Where sufficiently fractured and faulted, mountain bedrock at the margins also provides limited supplies.

A baseline groundwater quality study of the MEA was conducted by ADEQ from 2000-2003. For the study, 8 groundwater sites were sampled for inorganic constituents. Samples were also collected at selected sites for isotopes of oxygen and hydrogen (6 sites), radon gas (2 sites), radiochemistry (2 sites), and volatile organic compounds (VOCs) (1 site) analyses.

To characterize this small basin, 8 sites were sampled. Three sites met all drinking water quality standards. Concentrations of at least one constituent exceeded a health-based MCL at 3 different sites. Health-based MCL exceedances included arsenic (0 sites under current standards, 1 site under standards effective in 2006), gross alpha (2 sites) and uranium (1 site). At 4 sites, concentrations of at least one constituent exceeded an aesthetics-based SMCL. Aesthetics-based SMCL exceedances included fluoride (3 sites) and total dissolved solids (TDS) (2 sites).

Based on sample results, groundwater chemistry is typically a calcium/mixed-bicarbonate/mixed type. Groundwater is considered *fresh* (TDS less than 1,000 mg/L), *slightly alkaline* (greater than 7 standard units pH), and *moderately* to *very hard* (greater than 150 mg/L) (Heath, 1989). Nitrate (as N) concentrations frequently exceeded 3 mg/L, which is often an indication that human activities have impacted groundwater quality. However, similar patterns in other nearby basins have shown this is more likely the result of natural soil organic matter because of deep groundwater depths and nitrogen isotope results (Towne, 2003). Fluoride, boron, chromium, and zinc were trace elements detected at more than 33 percent of sample sites. Antimony, arsenic, barium, beryllium, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely detected. Isotope results (available for six of eight sites) matched those from sites in the nearby Detrital Valley basin that were from deep wells and/or springs (Towne, 2003). These sites are thought to represent the oldest water in

the basin, recharged during a colder climate. This groundwater age corresponds to the low precipitation and recharge rates occurring in the Meadview basin (ADWR, 1994).

Groundwater movement in the basin is from south to north (Remick, 1981). Bicarbonate and calcium concentrations were significantly higher in samples influenced by granitic geology in the south than in the alluvium/sedimentary rock further north; the opposite pattern occurs with chloride and nitrate concentrations (ANOVA test, $p \leq 0.05$). This illustrates a groundwater flow path with calcium-bicarbonate (often indicative of recharge zones) of the highland areas gradually evolving into more of a mixed chemistry as it moves downgradient to the north. As frequently occurs, sample sites impacted by granite often exceeded health-based water quality standards for gross alpha and uranium (Lowry and Lowry, 1988). Aesthetics-based SMCL exceedances for fluoride and TDS also occurred. In contrast, sample sites further north in alluvium/sedimentary rock usually met drinking water quality standards with the exception of arsenic, fluoride, and TDS at one site apiece. The arsenic exceedance of 0.01 mg/L (or 10 µg/L) occurred at Grapevine Spring. This arsenic MCL concentration was effective in 2006 and also the minimum reporting limit for the state laboratory used in the study (USEPA, 1993).

Pinal AMA Basin - In 2005-06, ADEQ conducted a baseline groundwater quality study of the Pinal Active Management Area (AMA) located between Phoenix and Tucson in south-central Arizona. To characterize regional groundwater quality, samples were collected from 86 sites located on non-tribal lands. Roughly two-thirds of the sampled sites were irrigation wells using turbine pumps with the remainder mostly domestic wells using submersible pumps. All sites were sampled for inorganic constituents and oxygen and deuterium isotopes. At selected sites, samples were also collected for radon (41), radiochemistry (21) and organics (semi-volatile compounds, chlorinated pesticides, and organo-phosphorus pesticides) (14). Among Pinal AMA's five sub-basins, the majority of groundwater samples were collected in Eloy (50 sites) and Maricopa-Stanfield (27 sites) with the remainder in Aguirre Valley (5 sites) and Vekol Valley (4 sites).

Analytical results indicate that of the 86 sites sampled, 60 sites (70 percent) had concentrations of at least one constituent that exceeded a health-based MCL. MCL exceedances included arsenic (33 sites), fluoride (7 sites), gross alpha (5 sites), nitrate (23 sites), and uranium (2 sites). These results appear to be naturally occurring with the exception of nitrate whose concentrations are impacted by fertilizer and both human and animal wastewater. At 59 sites (69 percent), concentrations of at least one constituent exceeded an aesthetics-based SMCL. SMCL exceedances included chloride (25 sites), fluoride (19 sites), iron (2 sites), pH-field (8 sites), sulfate (26 sites), and total dissolved solids or TDS (50 sites). There were no detections of organic compounds in the 14 organic samples. Both irrigation wells and drinking water wells had similar frequencies of drinking water quality standard exceedances.

Groundwater in the Pinal AMA basin was found to be generally *slightly alkaline*, *fresh*, and *hard*-to-*very hard* as indicated by pH values and TDS and hardness concentrations. Groundwater chemistry varied but tended to be calcium-sulfate/chloride in the upper water zone and sodium-bicarbonate in the lower water zone (Hammett, 1992).

Statistically-significant patterns were found among groundwater sub-basins, land uses, irrigation districts and groundwater zones (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). Of the water quality patterns found, the most numerous are those involving irrigation districts and water zones.

Analytical results were compared among samples collected in three irrigation and drainage districts: the Central Arizona (CAIDD), Maricopa-Stanfield (MSIDD) and San Carlos (SCIDD). Groundwater depth, temperature, pH-field and pH-lab were higher in the CAIDD and MSIDD than in SCIDD. TDS, SC-field, SC-lab, hardness, calcium, magnesium, potassium, chloride, sulfate, TKN and boron were higher in the SCIDD than in CAIDD and MSIDD. Seven constituents had unique patterns: sodium, bicarbonate, fluoride, arsenic, radon, oxygen and deuterium.

Analytical results were compared among samples collected in three water zones within the Eloy and Maricopa-Stanfield sub-basins: lower main water zone, upper main water zone and local water zones. Well depth, groundwater depth, temperature, pH-field and pH-lab were higher in the lower main water zone than in upper and local water zones. TDS, SC-field, SC-lab, hardness, calcium, magnesium, sodium, chloride, sulfate and nitrate were higher in the upper and local water zones than in the lower main water zones. Potassium, TKN and boron were higher in the upper main water zone than in the lower main water zone.

Several factors contribute to these patterns, including evaporate deposits, such as gypsum, salt and gypsiferous mudstone but their specific impacts are difficult to quantify Hammett, 1992). The greatest impact however, appears to be the effect of salts and calcite concentrated by evaporation during irrigation and then recharged to the upper main or local water zones (Coes et al., 2000; Cordy and Bouwer, 1999). Since water from the Gila River is the main source of irrigation for the SCIDD, its importation maintains relatively shallow groundwater levels in this irrigation district. Thus, there is little lag time before the highly saline recharge from irrigation applications percolates to the aquifer and impacts groundwater quality in the SCIDD (Cordy and Bouwer, 1999). In contrast, before 1987 the CAIDD and the MSIDD used groundwater as the sole source of irrigation water (ADWR, 1998). This has led to declining groundwater depths in these districts, but has probably protected the groundwater from the full impacts of saline recharge from irrigation applications because of the increased distance necessary for this water to percolate to the aquifer.

Prescott AMA Basin - A regional groundwater quality study of the Prescott Active Management Area (AMA) was conducted by ADEQ to determine the suitability of groundwater for drinking-water purposes, appraise current (1997-1998) baseline conditions, and examine spatial and temporal groundwater-quality patterns. Sampling was conducted at 58 sites; 41 randomly selected and 17 from the ADEQ index well network. Groundwater samples were collected for Safe Drinking Water (SDW) inorganic analysis from all sites, for SDW radiochemistry analysis from 10 sites, and for Groundwater Protection List (GWPL) pesticide analysis from 2 sites.

The results found that 6 of 58 sites had parameters exceeding an MCL. Health-based MCL exceedances included arsenic (four sites), fluoride (three sites), barium, gross alpha, and nitrate (one site apiece). Aesthetics-based SMCLs were exceeded at 9 of the 58 sites. SMCL exceedances included TDS (six sites), fluoride (four sites), iron, manganese, and sulfate (two sites apiece). There were no detections of the 152 pesticides or degradation products on the GWPL. Although MCLs or SMCLs were exceeded at 11 of 58 sites, they were geographically scattered and do not appear to indicate extensive areas of groundwater unsuitable for domestic use. Based on these results, regional groundwater quality conditions generally support drinking-water uses.

Fluoride and arsenic, the most common health-based water quality exceedances, appear to be the result of naturally occurring conditions. Elevated levels of these parameters tend to occur at sites which are chemically very dissimilar from the prevalent calcium-bicarbonate water chemistry (Jenkins and Myers, 1988). These sites are characterized by moderately-alkaline groundwater largely depleted of calcium. Fluoride levels in the AMA appear to have multiple controls. Previous research suggests that depleted calcium levels influence higher fluoride levels (> 5 mg/L) through precipitation of the mineral fluorite (Robertson, 1986). Relatively high levels of fluoride (> 7 mg/L) found at two sites appear to be related to the corresponding low calcium levels (< 9 mg/L) that constitute less than 5 percent of the total cation concentration. At lower fluoride levels, hydroxyl ion exchange or sorption-desorption reactions may provide controls (Robertson, 1986). Levels of fluoride and arsenic are positively correlated ($p=0.01$) in this study as well as in previous studies (Robertson, 1986). Arsenic levels may be related to the alkaline, oxidizing environment which is created by elevated pH levels enhanced by weathering of the alluvium (Hem, 1970). Basin-fill sediments in Arizona are rich in trace elements which, under favorable conditions such as elevated pH levels along with a change in redox potential, may be mobilized and contribute to elevated levels in groundwater (Robertson, 1991). Other mechanisms such as exchange on clays or oxyhydroxides have been cited as influencing arsenic levels (Robertson, 2000). Previous studies have suggested that silicate hydrolysis is occurring which increases levels of parameters such as sodium, pH, arsenic, and chromium (Jenkins and Myers, 1988).

Prescott AMA nitrate (as N) levels were generally below natural background levels of 3.0 mg/L, but elevated levels did occur, even exceeding health-based MCLs at a site near the Dewey-Humboldt area. High nitrate levels in this area have been reported by other sources and may be influenced by wastewater from older septic systems and/or agricultural systems (Corkhill, 2000; Dodder, 1998). Septic and alternative wastewater system impacts to groundwater are often best indicated by nitrate and chloride levels, parameters which are positively correlated ($p=0.01$) in the study area (Bedient, Rifai and Newell, 1994). Nitrate levels should continue to be monitored because of increasing population growth and reliance on septic and alternative wastewater-disposal methods in the study area. The MCL for gross alpha was exceeded at a site in the Granite Dells, an area previously cited as having elevated radiochemistry levels (ADWR, 1988). Some SMCL exceedances involving TDS, iron, manganese, and sulfate appear to be due to site-specific conditions such as historic mining activity in the Black Hills and Bradshaw Mountains.

Groundwater quality parameters varied by sub-basin, aquifer, and groundwater depth in the study area. The following statistically significant ($p \leq 0.05$) groundwater quality parameter trends were observed:

- Bicarbonate, sulfate, total alkalinity, and TDS had higher levels in the Upper Agua Fria sub-basin than in the Little Chino sub-basin; the opposite pattern occurs with fluoride levels.

- Bicarbonate, calcium, hardness, magnesium, sodium, total alkalinity, and TDS had higher levels in the hard rock aquifer than in the regional aquifer; the opposite pattern occurs with temperature and pH values.

- Barium, bicarbonate, calcium, electrical conductivity, hardness, magnesium, manganese, total alkalinity, TDS, and total Kjeldahl nitrogen levels decreased with increasing groundwater depth. In contrast, pH, temperature, and zinc levels increased with increasing groundwater depth.

Significant ($p \leq 0.05$) groundwater depth differences between each sub-basin and aquifer suggest that for parameter levels vertical variation is less important than spatial variation. Thus, groundwater depth patterns may be influenced by spatial patterns. Other sources indicate groundwater parameter levels tend to be a function more of flow path evolution than of vertical mixing (Robertson, 1991).

A limited groundwater quality comparison was conducted between the two main water-bearing units in the Little Chino sub-basin regional aquifer. The results suggest that the levels of many parameters may be higher in the Upper Alluvial unit, which is tapped by numerous small-capacity domestic wells, than in the Lower Volcanic unit, which is the source for most large capacity irrigation and municipal wells. This finding is supported by earlier studies (Schwalen, 1967). The groundwater quality difference may be due to recharge to the Lower Volcanic unit that occurs along the basin margins, thus allowing for less evaporation and associated concentration of salts than recharge associated with the Upper Alluvial unit (Corkhill, 2000).

A time-trend analysis was conducted using groundwater-quality data collected from 17 wells over a 7-year period. Of the 12 parameters examined, levels of chloride, SC-field, fluoride, hardness, magnesium, nitrate, sodium, sulfate, total alkalinity, TDS, and zinc did not significantly change between 1991-93 and 1997-98. Calcium levels were the only constituent that varied significantly ($p \leq 0.05$), increasing between the time periods. The calcium level variation may be due to major flooding and the associated groundwater recharge that occurred in 1993 or to potentially different analytical methods used by the Arizona Department of Health Services laboratory during the two sampling periods (Corkhill, 2000; Roberts, 1997).

Sacramento Valley Basin - A regional groundwater quality study of the Sacramento Valley groundwater basin (SVGB) was conducted by ADEQ to determine the suitability of groundwater for drinking water purposes, appraise 1999 baseline conditions, and

examine spatial groundwater quality patterns. The SVGB is located in Mohave County in northwestern Arizona. Groundwater is the main water source in this semiarid basin. Sampling was conducted at 48 sites: 40 random sites and 8 targeted sites. Groundwater samples were collected for Safe Drinking Water (SDW) inorganic constituents, SDW Volatile Organic Compounds (VOCs), perchlorate, and isotopes of hydrogen, oxygen, and nitrogen. At 40 sites, samples were collected for SDW radiochemistry analysis.

Interpretation of results from laboratory analyses of collected groundwater samples indicates that 20 of the 48 sites met all drinking water quality standards. MCLs were exceeded at 22 of 48 sites. MCL exceedances included gross alpha (18 sites), nitrate (6 sites), fluoride (4 sites), radium-226+228 (4 sites), and antimony (2 sites). In addition, 17 sites exceeded the proposed Primary MCL for uranium. Aesthetics-based SMCLs were exceeded at 28 of 48 sites. SMCL exceedances included total dissolved solids (TDS) (24 sites), fluoride (16 sites), chloride (7 sites), sulfate (7 sites), manganese (3 sites), and iron (2 sites). Arizona Aquifer Water Quality standards had exceedances that were identical to Primary MCL exceedances. No VOCs, including methyl tertiary-butyl Ether (MTBE), were detected at any site. Perchlorate, a man-made inorganic salt used in the manufacture of explosives and very mobile in groundwater, was detected at four sites.

Despite these numerous water quality exceedances many of the SVGB groundwater sites, including those in the central valley and in the Black Mountains in the western basin periphery, meet drinking water standards. Water quality standard exceedances were identified in three principal basin areas.

- In the vicinity of the town of Chloride, exceedances of gross alpha, radium-226+228, TDS, nitrate, chloride, antimony, sulfate, and manganese occurred. These exceedances appear to be due to a combination of the area's granitic geology, historic mining activity, and septic systems (Rosner, 1998).

- In the central and southern Hualapai Mountains, exceedances of gross alpha, radium-226+228, fluoride, TDS, chloride, and sulfate occurred. The radiochemistry exceedances appear to be related to the area's granitic geology (Lowry and Lowry, 1988).

- In the vicinity of the town of Topock, exceedances of fluoride, TDS, and chloride occurred. These exceedances appear to be due to dissolution reactions that increase constituent concentrations as groundwater migrates downgradient within the basin (Robertson, 1991).

Groundwater in the basin is generally *slightly alkaline*, *hard* to *very hard*, and *fresh* based upon pH, hardness, and TDS levels (Hem, 1985). Half of the 48 sites had a calcium-bicarbonate chemistry which is typical of recharge areas in Arizona (Robertson, 1991). Sixteen sites had a calcium-sulfate chemistry, six samples had a sodium-bicarbonate chemistry, and the two most downgradient sites had a sodium-sulfate chemistry. Nitrate concentrations at 20 sites were greater than 3.0 mg/l (as nitrogen) which may indicate

impacts from human activities (Madison and Brunett, 1984). Trace elements such as aluminum, antimony, barium, beryllium, cadmium, iron, lead, manganese, mercury, silver, and thallium were rarely detected; only arsenic, boron, chromium, copper, fluoride, selenium, and zinc were detected at more than 10 percent of the sites.

Data from randomly-selected sample sites examined using various statistical methods found groundwater quality constituents varied by aquifer, geology, geographic location, and with groundwater depth. The following significant ($p \leq 0.05$) trends were observed. Concentrations of many constituents were higher in the hard rock aquifer compared to the alluvial aquifer, a pattern similar to that found in other Arizona groundwater basins (Robertson, 1991). Additional patterns were revealed when the hard rock aquifer was further subdivided into granitic, metamorphic, volcanic, and sedimentary rocks. Groundwater associated with granitic rock frequently had higher constituent concentrations than groundwater associated with volcanic rock and alluvial fill. These findings support previous studies in the SVGB that found more mineralized groundwater in or near mountain areas compared to the central valley (Gillespie and Bentley, 1971; Rascona, 1991). Groundwater movement in the basin is from north to south. A chemical flowpath evolution was observed along this flowpath. Concentrations of constituents such as calcium, magnesium, bicarbonate, and hardness tend to decrease downgradient while sodium, chloride, fluoride, and boron tend to increase. Statistical tests support these observations. Concentrations of sodium and some trace elements were higher in the southern, downgradient portion of the basin than in the upgradient northern portion. These constituents probably are increasing due to dissolution reactions (Robertson, 1991). In addition, a positive correlation existed among levels of calcium, magnesium, bicarbonate, sulfate, and hardness. In contrast, a positive correlation existed among levels of sodium, chloride, sulfate, boron, and fluoride.

Many constituent concentrations tend to decrease significantly ($p \leq 0.05$) with groundwater depth below land surface (bls) though parameters such as pH and temperature increased with increasing groundwater depth bls. A *critical level*, ranging between 50 and 200 feet bls, was established for many constituent concentrations. At groundwater depths greater than the *critical level*, concentrations remain generally constant; in contrast, concentrations are highly variable at more shallow depths.

A groundwater quality time-trend analysis was conducted utilizing data collected by the U.S. Geological Survey in 1979, the Arizona Department of Water Resources in 1990, and ADEQ in 1999. Constituent concentrations were largely found to be stable over a period stretching up to 20 years. This suggests that constituents are largely controlled by natural factors and are not prone to vary significantly over time.

This study is the first application of stable isotopes in characterizing regional groundwater by ADEQ and was partially intended to test the usefulness of this technology. Based upon deuterium and oxygen isotope data, groundwater in the basin appears to have undergone a consequential amount of evaporation prior to recharge which is characteristic of arid regions. Future sampling for these two isotopes appears to be of greatest value for regional studies in basins having a major perennial river and where there is a need to distinguish water recently recharged from river infiltration and

paleo-water representing a non-renewable resource. In contrast, there appears to be fewer potential uses for regional nitrogen isotope sampling. Data interpretation for this study suggests that it is not possible to determine the source of nitrate groundwater contamination simply by measuring nitrogen isotopes without sampling sites which specifically measure the nitrogen isotope signature of each potential source of nitrogen.

Safford Basin: Gila Valley Sub-Basin - In 2004, ADEQ conducted a baseline groundwater quality study of the Gila Valley sub-basin of the Safford groundwater basin located in eastern Arizona. The sub-basin includes the drainage of the Gila River from the Peloncillo Mountains down gradient to near the San Carlos Tribal Lands and the drainage of the San Simon River downstream from a ridge near the railroad siding of Tanque (Towne, 2004). The sub-basin includes the communities of Safford, Thatcher, Pima and Fort Thomas and consists primarily of federal lands (U.S. Forest Service and Bureau of Land Management), State Trust and private land.

To characterize regional groundwater quality, samples were collected from 67 wells and springs using a randomly stratified design. All sites were sampled for oxygen and deuterium isotopes. At selected sites, samples were collected for inorganic constituents (65 sites), radon (30 sites), radiochemistry (20 sites) and pesticides (4 sites). Nine isotope samples were collected from surface water sources to help determine groundwater recharge sources. Analytical results indicate that of the 65 sites sampled, only 11 sites (17 percent) met all health and aesthetics-based drinking water quality standards. Health-based MCLs were exceeded at 30 of 65 sites (46 percent). Constituents exceeding MCLs included arsenic (21 sites), fluoride (20 sites), gross alpha (3 site), nitrate (4 sites), and uranium (2 sites). The EPA proposed 300 picocuries per liter (pCi/L) drinking water quality standard for radon was also exceeded at 19 sites (USEPA, 2009). These water quality exceedances, with the exception of nitrate, appear to be the result of natural sources. Fluoride exceedances often occur at sites that are depleted in calcium allowing for large concentrations if a source for fluoride ions is available for dissolution (Robertson, 1991). Elevated arsenic concentrations may be related to an oxidizing environment, aquifer residence time, lithology and clay mineralogy (Robertson, 1991; Spencer, 2002). Aesthetics-based SMCLs were exceeded at 54 of 65 sites (83 percent). Constituents above SMCLs included chloride (29 sites), fluoride (35 sites), manganese (4 sites), pH (11 sites), sulfate (29 sites), and TDS (43 sites).

Groundwater is characterized as predominantly of either *sodium-bicarbonate* or *sodium-mixed* chemistry, varied from *fresh* to *moderately saline*, had *soft* to *very hard* water, and had few occurrences of trace elements other than arsenic, boron and fluoride. Analyses of oxygen and deuterium isotope samples revealed two general recharge groups: Gila River (18 sites) and local precipitation (47 sites). Local precipitation recharge was further subdivided into four categories: recent (2 sites), newer (12 sites), older (29 sites), and Mt. Graham springs (4 sites). These recharge sources roughly correlate to the following alluvial units: Gila River recharge (younger alluvium), local precipitation (older alluvium), recent local precipitation (summer monsoon recharge long tributaries to the Gila River), newer local precipitation (clay-silt sub-unit), older local precipitation (evaporate and/or basal conglomerate sub-unit), and Mt. Graham springs (winter precipitation recharge in the high altitude Pinaleno Mountains).

Statistically-significant patterns were found among the two main recharge sources (Kruskal-Wallis test, $p \leq 0.05$). TDS, major ions, nitrate and boron were higher in Gila River recharge than local recharge; the opposite pattern occurred with pH. Older local precipitation sites had significantly higher temperature, TDS, sodium, potassium, chloride, sulfate, arsenic, boron, and fluoride concentrations than newer local precipitation sites (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). These patterns indicate the best strategy for developing public water supplies in the Gila Valley sub-basin from a water quality perspective appears to be drilling shallow wells in the older alluvium along the mountain front up from the Gila River.

In 1995, ADEQ conducted an extensive study of the Gila Valley sub-basin data sampling 81 targeted wells (Wallin, 1999). Despite different sampling strategies, the frequency of water quality exceedances for each study was remarkably similar. Examination of the 1995 data revealed deficiencies with sampling protocol and data validation, but the collected information was still considered suitable for making general groundwater quality comparisons between the studies. Using well characteristics and isotope data from the 2004 study, the 1995 sites were classified as either younger or older alluvium (ADWR, 2009). Using the data from the younger alluvium, 49 sites sampled in 1995 were compared with the 18 sites sampled in 2004. Concentrations of TDS, sodium, chloride, sulfate and pH-lab increased significantly in the decade between the studies (Mann-Whitney test, $p \leq 0.05$). Increases in concentrations of these constituents in the younger alluvium appears to be the result of saline water under artesian pressure entering from upward leakages along faults and abandoned wells and from saline irrigation recharge (Black, 1991; Harris and Eastoe, 2009).

Safford Basin: San Simon Sub-Basin - The San Simon sub-basin (SS) of the Safford basin is located in southeastern Arizona. The basin is sparsely populated and consists of mainly of federal and State rangeland with irrigated farmland near the towns of Bowie and San Simon. The SS is drained by the ephemeral San Simon River whose headwaters are the now-dry San Simon Cienega. After heavy precipitation, the river flows north out of the SS and debouches into the Gila River near Solomon. For the purposes of this water quality report, based on water chemistry patterns, groundwater is divided into four generalized, water-bearing units: the alluvial aquifer, upper aquifer, lower aquifer, and mountain bedrock. The unconfined alluvial aquifer occurs south of the cienega and is differentiated from connected alluvial areas to the north in this report because of its superior groundwater quality. North of the cienega are the upper and lower aquifers. Various blue-clay units separate the groundwater perched in the upper aquifer from percolating to the lower aquifer, which occurs under either water table or artesian conditions. Where sufficiently fractured and faulted, mountain bedrock also provides limited supplies. Recent studies have indicated that groundwater occurs in a more complex system than outlined here, but some simplification is needed for regional water quality analysis.

A baseline groundwater quality study of the SS was conducted by ADEQ that consisted of 62 sites sampled in 2002 and an additional 17 sites sampled in 1997. Overall, 77 groundwater sites were sampled for inorganic constituents. Samples were also collected

at selected sites for isotopes of oxygen and hydrogen (62 sites), radon (33 sites), radiochemistry (23 sites), and pesticide (4 sites) analyses.

Of the 77 sites sampled, 28 met all drinking water quality standards. At 25 sites, concentrations of at least one constituent exceeded a health-based MCL. MCL exceedances included arsenic (2 sites under current standards, 17 sites under standards effective in 2006), beryllium (2 sites), fluoride (19 sites), nitrate (3 sites), gross alpha (3 sites) and uranium (1 site). At 49 sites, concentrations of at least one constituent exceeded an aesthetics-based SMCL. SMCL exceedances included chloride (6 sites), fluoride (35 sites), iron (5 sites), manganese (3 sites), pH (7 sites), sulfate (18 sites), and total dissolved solids or TDS (34 sites).

Groundwater composition and quality vary considerably in the sub-basin. Generally, groundwater from the alluvial aquifer and bedrock can be used without treatment for domestic purposes while that obtained from the upper or alluvial aquifer exceeds health or aesthetic standards. The limited groundwater in the bedrock of the Chiricahua, Dos Cabezas, Peloncillo, and Pinaleno Mountains generally meets health-based standards except for gross alpha in the granite rock of the western Dos Cabezas and Pinalenos. Though variable, groundwater chemistry is most commonly calcium-bicarbonate which is associated with recharge areas (Robertson, 1991). Concentrations of sodium, potassium, chloride, sulfate, fluoride, boron, and arsenic are lower in bedrock than in the upper or lower aquifer (ANOVA test in conjunction with Tukey test, $p \leq 0.05$). Groundwater in the alluvial aquifer also meets health-based standards except for fluoride at one site. The alluvial aquifer is the most uniform with most sites having calcium-bicarbonate chemistry. Concentrations of TDS, sodium, chloride, sulfate, boron, and arsenic are lower in the alluvial aquifer than in the upper or lower aquifer (ANOVA test in conjunction with Tukey test, $p \leq 0.05$). There are few significant water quality differences between sites in the alluvial aquifer and bedrock.

Groundwater in the lower aquifer rarely met health-based standards because of elevated fluoride and arsenic concentrations. The high fluoride concentrations are permitted by very low calcium concentrations which result from a chemically closed system (Robertson, 1991). This closed system also results in sodium-bicarbonate or sulfate groundwater chemistry. Aesthetics-based standards such as TDS, sulfate, and pH were also frequently exceeded. The most depleted or isotopically lightest waters, which may represent the oldest water in the SS, are generally associated with lower aquifer sites. Groundwater in the upper aquifer often did not meet health-based MCLs because of elevated fluoride or nitrate concentrations. Aesthetics-based SMCLs for TDS and sulfate were also frequently exceeded. The least uniform geochemically, upper aquifer sites sometimes reflect major impacts from saline irrigation recharge and/or leakage from the lower aquifer. Concentrations of calcium, magnesium, hardness, and nitrate were higher in the upper aquifer than in the lower aquifer (ANOVA test in conjunction with Tukey test, $p \leq 0.05$).

San Rafael Basin - The San Rafael groundwater basin (SRF) baseline groundwater quality study was conducted by ADEQ in 2002. Located between Sierra Vista and Nogales along the Mexican border in southeastern Arizona, this semiarid basin is

relatively untouched by modern development. It contains some of the most pristine desert grasslands in the Southwest. The basin consists of the San Rafael Valley and the surrounding slopes of the Patagonia and Huachuca Mountains and the Canelo Hills. The local economy was originally based on mining and livestock grazing, but mining operations have long been inactive (Hadley and Sheridan, 1995).

The SRF is noted as the headwaters of the Santa Cruz River. This watercourse, perennial in stretches, flows into Mexico and later reenters the U.S. near Nogales, Arizona. Groundwater from the *alluvial aquifer* is the principle water source though, where sufficiently fractured and faulted, mountain *hard rock* provides limited supplies (Murphy and Hedley, 1984). For this study, 20 groundwater sites were sampled for inorganic constituents as well as oxygen and hydrogen isotopes. In addition, samples were also collected at selected sites for radiochemistry (5), radon gas (5), and Volatile Organic Compounds (2) analyses.

Two of the 20 sampled sites (10 percent) had concentrations of at least one constituent that exceeded a health-based MCL. Constituents that exceeded MCLs included antimony (1 site), lead (1 site), gross alpha (1 site), and uranium (1 site). In addition, 3 of the 20 sampled sites (15 percent) had concentrations of at least one constituent that exceeded an aesthetics-based SMCL. Constituents that exceeded SMCLs included iron (1 site), manganese (2 sites), sulfate (2 sites), and total dissolved solids or TDS (2 sites). No Volatile Organic Compounds were detected.

Interpretation of the analytical results of the groundwater quality samples indicates that groundwater in the SRF generally meets drinking water standards and is suitable for domestic, municipal, irrigation, and stock purposes. Samples collected from two sites in the Patagonia Mountains contained all the health-based standard exceedances and the aesthetics-based guideline exceedances (except one) that occurred in the SRF. The elevated sulfate, TDS, and trace element levels found at these sites suggest impacts from the historic mining conducted in the area (Henderson, 1984). The elevated radionuclide concentrations found at one of these sites also suggest additional impacts from the granitic geology found in the area (Lowry and Lowry, 1988).

Groundwater in the SRF is generally *fresh*, *slightly alkaline*, and *hard* based on TDS, pH, and hardness concentrations (Heath, 1989). The majority of sites had a *calcium-bicarbonate* chemistry. The two previously mentioned sites in the Patagonia Mountains exhibited *calcium-sulfate* chemistry. Nutrient concentrations were low with the exception of one site near the center of the basin whose nitrate (as N) concentration approached the MCL. Barium, fluoride, and zinc were the only trace elements detected at more than ten percent of sites. Antimony, arsenic, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely, if ever, detected. Groundwater quality constituent concentrations were compared among aquifers, watersheds, and geologic types; few significant differences were found in any of the groupings (Kruskal-Wallis test in conjunction with the Tukey test, $p \leq 0.05$).

Deuterium and oxygen isotope data formed a *Local Meteoric Water Line* whose slope of 4.6 conformed to the range of slopes (3 to 6) normally found in arid environments (Coplen et al., 1999). The most *depleted*, or isotopically lighter, sites tended to be in the highest mountains and may be from recent local precipitation less subject to evaporation. In contrast, the most *enriched*, or isotopically heaviest, sites tended to be at lower elevations within the central part of the basin. The levels of these two groups were found to be significantly different (Kruskal-Wallis test, $p \leq 0.01$).

Upper San Pedro Basin – Thirty-nine ground-water samples were collected and analyzed in 1996-1997 by the USGS and ADEQ to assess ground-water quality in the Sierra Vista subbasin (the Upper San Pedro basin) in southern Arizona. The MCLs and Arizona Aquifer Water Quality standard for fluoride and the SMCL contaminant levels for fluoride, iron, manganese, pH, sulfate, and total dissolved solids were exceeded in samples collected for this study.

On the basis of statistical tests, significant variations were identified between ground-water quality and well location, well depth and aquifer type. Significant differences were not identified between ground-water quality data and geology, land use, or ground-water quality data collected during 1950-65. Temperature and pH values increased and calcium concentrations decreased with increased well depth. Sodium, potassium, and fluoride concentrations in samples from the northern part of the subbasin were higher than concentrations in samples from the southern part of the subbasin. Sodium and chloride concentrations in samples from bedrock areas were higher than concentrations in samples from unconfined parts of the basin-fill aquifer; sodium and fluoride concentrations in samples from confined parts of the basin-fill aquifer in the St. David-Pomerene area were higher than concentrations in samples from unconfined parts of the basin-fill aquifer. Geochemical reactions in the basin-fill deposits are responsible for the concentrations of constituents that exceeded MCLs, SMCLs, State Aquifer Water Quality standards, and the statistically significant variations of ground-water quality data in relation to well location and aquifer type.

Quality-control samples collected and analyzed by the U.S. Geological Survey and the Arizona Department of Environmental Quality generally verified that combining the ground-water quality data collected by the two agencies for regional assessment was acceptable. Statistically significant differences, however, were identified between quality-control samples collected and analyzed by the two agencies for alkalinity, specific conductance, magnesium, and potassium concentrations. Consideration of this variability was taken into account when analyzing the data from this study.

Tucson AMA Basin: Upper Santa Cruz Sub-Basin – Fifty-eight ground-water samples were collected and analyzed in 1998 by the USGS and ADEQ to assess ground-water quality and to identify factors affecting ground-water quality in the Upper Santa Cruz Basin. In addition, pre-existing ground-water quality data for six wells were analyzed to determine changes in the ground-water quality of the basin over time.

Twenty-nine percent of the ground-water samples collected had concentrations of at least one constituent that exceeded an MCL. MCLs and State Aquifer Water Quality

standards were exceeded for arsenic, fluoride, and nitrite plus nitrate. SMCLs were exceeded for fluoride, iron, manganese, pH, sulfate, and dissolved solids.

Ground-water quality in the basin is affected by natural factors and human activities. The natural factors that have the most effect on ground-water quality in the basin are depth in the aquifer and distance from the major faults. Ground-water temperatures and pH significantly increased with well depth ($p \leq 0.05$). Concentrations of dissolved solids, alkalinity, calcium, potassium, chloride, and sulfate were significantly higher in samples collected from wells less than 2 kilometers from major faults than in samples from wells greater than 2 kilometers from major faults ($p \leq 0.05$). Previous studies have attributed this relation to the upward migration through faults of ground water from gypsiferous mudstones. Ground-water quality was not significantly different among the various basin-fill units; between parts of the basin fill that differ in thickness, lateral extent, and composition north and south of an inferred fault; or among areas that differ in distance from stream alluvium ($p \leq 0.05$).

Human activities have a substantial effect on ground-water quality in the basin. Ground water that contained recent (post-1953) recharge from urban areas had significantly higher concentration of nitrite plus nitrate than ground water that did not contain recent recharge from the land surface ($p \leq 0.05$). Ground water that contained recent recharge from present agricultural areas had significantly higher concentrations of nitrite plus nitrate, calcium, and potassium than ground water that did not contain recent recharge from the land surface ($p \leq 0.05$). Ground water that contained recent recharge from present agricultural areas also had significantly higher concentrations of calcium, potassium, alkalinity, and dissolved solids than ground water that contained recent recharge from urban areas ($p \leq 0.05$).

Virgin River Basin - ADEQ completed a baseline groundwater quality study of the Virgin River Groundwater Basin (VRGB) in 1997. Located in the arid northwest corner of Arizona, the VRGB consists mainly of undeveloped public lands punctuated by small areas of private land, some of which contain densely-settled residences utilizing septic systems for wastewater treatment. A total of 38 groundwater samples were collected for the study including 33 stratified random samples from four aquifers: Beaver Dam, Littlefield, Virgin River alluvial, and Virgin River basin. All groundwater samples were analyzed for Safe Drinking Water (SDW) inorganic constituents, 10 samples were analyzed for radionuclides, and 3 samples were analyzed for Groundwater Protection List (GWPL) pesticides. Laboratory results revealed no detections of GWPL pesticides, while only one radionuclide sample exceeded the MCL for gross alpha. Inorganic parameter levels of the VRGB samples did not exceed any health-based MCLs, though aesthetics-based SMCLs for chloride, iron, manganese, field pH, sulfate, and total dissolved solids were exceeded, especially in the Littlefield and Virgin River alluvial aquifers. These results suggest that regional groundwater quality conditions generally support drinking water uses; however, some residents may prefer to use treated water for domestic purposes because of aesthetic reasons.

Piper trilinear diagrams revealed each aquifer in the VRGB had characteristic water chemistry's: Beaver Dam aquifer had bicarbonate-calcium water, Littlefield and Virgin

River alluvial aquifers had sulfate-calcium water, and Virgin River basin aquifer had a mixed water chemistry. Statistical analyses indicated that many significant differences exist in groundwater quality parameter levels among aquifers in the VRGB. Generally, inorganic parameters in the Littlefield and Virgin River alluvial aquifers have significantly higher levels than the Beaver Dam and Virgin River basin aquifers.

A strong correlation existed among the levels of most groundwater quality parameters in the VRGB, perhaps indicating a common natural source for most parameters. Exceptions to this trend include nitrate, fluoride, iron, and manganese; parameters which may come from other natural or cultural sources. There is also a significant relationship between decreasing groundwater quality parameter levels and increasing groundwater depth below land surface in the VRGB; however, when examined by individual aquifer few of these statistical relationships are present. Thus, these VRGB depth-dependent parameter levels may be more the result of parameter level differences among aquifers and the accompanying groundwater depth variations than by any actual relationships within aquifers.

The groundwater quality of the Beaver Dam and Littlefield aquifers may be impacted by cultural factors as evidenced by the comparison of upgradient, control samples to the 95% confidence interval established for each aquifer. The presence of poorer-quality groundwater beneath the Beaver Dam aquifer and better-quality groundwater beneath the Virgin River alluvial aquifer was also indicated by results of limited sampling of deeper aquifers.

Willcox Basin - A baseline groundwater quality study of the Willcox Groundwater Basin (WGB) was completed by ADEQ in 1999. Groundwater is the main water supply in this semiarid basin, which is located in Cochise and Graham Counties in southeastern Arizona. The basin is surrounded by topographically higher areas so that most drainage is internal and flows to the Willcox Playa, an alkali flat in the central portion of the basin. For the study, 58 groundwater sites - 46 random sites and 12 targeted sites - were sampled for inorganic constituents. Varying numbers of sites were also sampled for Volatile Organic Compounds (VOCs) (54 sites), radionuclides (44 sites), nitrogen isotopes (7 sites), and pesticides (4 sites).

Thirty-six (36) percent of the sample sites had concentrations of at least one constituent that exceeded a health-based MCL. Constituents exceeding MCLs include antimony (1 site), arsenic (3 sites under current standards, 9 sites under standards due to become effective in 2006), fluoride (8 sites), nitrate (5 sites), gross alpha (8 sites), and radium-226+228 (1 site). Forty (40) percent of the sample sites had concentrations of at least one constituent that exceeded an aesthetics-based SMCL. Constituents exceeding SMCLs include chloride (2 sites), fluoride (13 sites), iron (1 site), manganese (1 site), pH (4 sites), sulfate (4 sites), and total dissolved solids or TDS (11 sites). At one site, VOCs were detected that are common by-products of chlorination (Morrow, 1999). No pesticides or related degradation by-products were detected. Although water quality constituent exceedances occurred throughout the basin, they were largely concentrated in four areas: near the Spike E Hills northeast of the city of Willcox (fluoride, arsenic, and pH); areas of granitic rock (gross alpha); northwest of the Sulphur Hills (nitrate, fluoride,

and sulfate); and immediately west of the Willcox Playa (chloride and sulfate). The study results suggest that, apart from these areas, groundwater appears to be largely suitable for domestic uses.

Groundwater in the WGB is generally *fresh, slightly alkaline*, and varies widely in hardness concentrations. The chemistry is typically *calcium-bicarbonate* except near the Willcox Playa (*sodium-mixed anion*) and northwest of the Sulphur Hills (*calcium-sulfate*). Twenty-five (25) percent of sites had nitrate (as nitrogen) concentrations (> 3 mg/L) which may indicate impacts from human activities (Madison and Brunette, 1984). Analyses were conducted on 18 trace elements; only boron, chromium, fluoride, and zinc were detected at more than 10 percent of sample sites.

Groundwater quality varied significantly by aquifer, geology, geographic location, and with groundwater depth. Constituents such as nitrate, pH, potassium, and temperature were higher in the *alluvial aquifer* than in *hard rock areas*. Sodium and chloride were higher in *young alluvium* near the Willcox Playa than in *old alluvium*. Gross alpha was higher in groundwater associated with *granite rock* than in *old* and *young alluvium*. Bicarbonate, calcium, hardness, and sulfate were higher in the southern portion of the basin than in the northern portion (Kruskal-Wallis test, $p \leq 0.05$). Many constituents such as bicarbonate, calcium, chloride, gross alpha, hardness, sodium, sulfate, TDS, and total Kjeldahl nitrogen decreased with increasing groundwater depth below land surface (bls) (regression analyses, $p \leq 0.05$). TDS and some major ions attained a *critical level* at approximately 110 feet bls. These constituent levels remained generally constant at groundwater depths greater than the *critical level* but were highly variable and sometimes dramatically higher at depths shallower than 110 feet bls.

Although only limited time-trend analyses were conducted for this study, constituents in most areas of the basin appear to be controlled by natural geochemical reactions and would probably not vary significantly in the short term. An exception may occur near Kansas Settlement, a farming community located southeast of the Willcox Playa. Targeted sampling conducted indicates that shallow groundwater quality is probably impacted by a variety of sources, especially irrigation recharge carrying salts and nitrate.

Yuma Basin - ADEQ conducted a baseline groundwater quality study of the Yuma Groundwater Basin (YGB) in 1995. Fifty-five wells were sampled for Safe Drinking Water (SDW) inorganic constituents, with a lesser number of samples collected for the banned-pesticides DBCP and EDB (41 samples), Groundwater Protection List pesticides (21 samples), and radionuclides (7 samples). A stratified random sampling design was used to select 42 wells that are equally distributed in three physiographic areas (Gila Valley, Yuma Mesa, and Yuma Valley) and two groundwater zones (upper, fine-grained and lower, coarse-gravel). Also sampled were 13 wells targeted around land uses and/or an area of high nitrate levels.

Laboratory results revealed no detection of any pesticides. Of the inorganic and radionuclide parameters with health-based MCLs, only nitrate (as N) exceeded the water quality standard in five wells - four of which are located in the eastern South Gila Valley. In this area of high nitrate levels, one nitrate sample exceeded the Primary MCL by a factor of twelve. Of inorganic parameters with aesthetics-based SMCLs, chloride, iron,

manganese, sulfate, and total dissolved solids frequently exceeded water quality standards. This data suggests that regional groundwater quality conditions in the YGB generally support drinking water uses but because of aesthetic factors, residents may prefer to use treated water for some domestic purposes.

YGB groundwater has no dominant water chemistry and is chemically fairly uniform and similar to Colorado River water. Many groundwater quality parameter levels are positively correlated with one another which may indicate a common source of salts and minerals. These findings support the assertion made by previous studies that groundwater in the YGB consists largely of recharged Colorado River water (Olmstead, Loeltz and Irelan, 1973).

Statistical analyses comparing the upper, fine-grained and lower, coarse-gravel groundwater zones indicate no significant differences exist between groundwater quality parameter levels; however, when groundwater quality parameter levels are compared with groundwater depth below land surface (bls), many parameters have decreasing levels significantly related to increasing groundwater depth bls. Numerous statistically-significant differences exist in groundwater quality parameter levels among physiographic areas, with many inorganic parameters having higher levels in Gila Valley than Yuma Mesa and Yuma Valley. These spatial groundwater quality differences may be due to unique histories involving how long an area has been irrigated, depth to groundwater, and especially, the source of irrigation water. The irrigation source in Gila Valley has predominately been groundwater with this resource being constantly recycled and degraded; in contrast, "fresher" Colorado River water has been chiefly applied for agriculture in the Yuma Mesa and Yuma Valley. A time trend analysis conducted on 15 wells sampled by both the U.S. Bureau of Reclamation in 1989-90 and ADEQ in 1995 showed few significant groundwater quality parameter level differences indicating that groundwater quality has been relatively unchanged during this time period.

References

Anning, D.W., M. E. Flynn, and M. Truini, 2006. *Hydrogeologic investigation of the Detrital, Hualapai, and Sacramento Valleys of northwestern Arizona.* U.S. Geological Survey Fact Sheet 2006-3008, pp. 4.

Arizona Corporation Commission Website, 2006, www.cc.state.az.us/news/pr11-26-01.htm accessed 5/15/06.

Arizona Department of Environmental Quality, 2002-2003. Arizona Laws Relating to Environmental Quality: St. Paul, Minnesota, West Group Publishing, §49-221-224, p.134-137.

Arizona Department of Water Resources, 2009. ADWR Website: Arizona's Water Supplies and Water Demands, www.azwater.gov/.

Arizona Department of Water Resources, 1998. *Third Management Plan 2000-2010, Pinal Active Management Area.*

Arizona Department of Water Resources, 1994. *Arizona Water Resources Assessment - Volume I & II, Hydrologic Summary.* Hydrology Division.

Arizona Department of Water Resources, 1988. *Prescott Active Management Area Draft Management Plan for the Second Management Period, 1990-2000.* ADWR: Phoenix, Arizona.

Barnett, J.M., J. W. McKlveen, and W. K. Hood, 1990. *Determination of Radon-222 in Ground Water Using Liquid Scintillation Counting - Survey of Carefree-Cave Creek Water Basin in Arizona.* Proceedings of the twenty-Ninth Hanford Symposium in Richland, Washington on Health and the Environment: Indoor Radon and Lung Cancer: Reality or Myth?

Bedient, Philip B., Hanadi S. Rifai, and Charles J. Newell, 1994. *Ground Water Contamination: Transport and Remediation.* Prentice Hall, Inc: Englewood Cliffs, NJ.

Black, K.R., 1991. *Maps showing groundwater conditions in the Gila Valley sub-basin of the Safford basin, Graham and Greenlee Counties, Arizona—1987.* Arizona Department of Water Resources, Hydrologic Map Series Report Number 20, 1 sheet, scale 1:125,000.

Cady, C.V., 1981. *Map showing ground-water conditions in the Big Sandy area, Yavapai and Mohave Counties, Arizona—1980.* Arizona Department of Water Resources, Hydrologic Map Series Report Number 5, 1 sheet, scale 1:250,000.

Cella Barr Associates, 1990. *Geohydrologic study for the Kingman-Red Lake sub-area of The Hualapai basin.* Unpublished consultants report to the City of Kingman, Arizona, CBA #41503-01, pp. 64.

Centers for Disease Control (CDC), 1996. *Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water, La Grange County, Indiana, 1991-1994.* Morbidity and Mortality Weekly Report, v. 45, p. 569-572.

Cleveland, W.S., 1993, *Visualizing Data.* Hobart Press, Summit, NJ.

Coes, A.L., D. J. Gellenbeck, Doug Towne, and M. C. Freark, 2000. *Groundwater qualityin the Upper Santa Cruz basin, Arizona, 1998.* U.S. Geological Survey Water-Resources Investigations Report 00-4117, pp. 55.

Coplen, Tyler B., Andrew L. Herczeg, Chris Barnes, and H. Craig, 1999. *Isotope Engineering–Using Stable Isotopes of the Water Molecule to Solve Practical Problems.* In Environmental Tracers in Subsurface Hydrology, Peter Cook and Andrew Herczeg, eds., Kluwer Academic Publishers: Boston, Massachusetts.

Cordy, G.E., and H. Bouwer, 1999. *Where do the salts go?: the potential effects and management of salt accumulation in south-central Arizona.* U.S. Geological Survey Fact Sheet 170-98, pp. 4.

Corkhill, E.F., 2000. Personal communication from ADWR hydrologist.

Daniel, Debra L., Brian E. Munson, and Charles G.Graf, , 1988. *Groundwater Contamination by Pesticides in Arizona: An Overview.* Proceedings of the Arizona Hydrological Society 1st Annual Symposium. Phoenix.

Darr, C.M., 1990, Groundwater quality in the Bullhead City area, Mohave County, Arizona: Arizona Department of Environmental Quality, pp. 7.

DeSimone, Leslie A., 2008, *Quality of Water from Domestic Wells in Principal Aquifers of the United States, 1991-2004.* U.S. Scientific Investigations Report 2008-5227, pp. 128.

Dodder, Joanna, 1998. *Water Problems Likely Isolated to Each Property, Organization Says.* Prescott Daily Courier October 1, Page A9: Prescott, Arizona.

Duncan, John T., and Jon E. Spencer, 1991. *Investigations of Uranium and Radon in the Greater Phoenix Metropolitan Area, Arizona.* AZGS Open-File Report 91-9.

Fewtrell, Lorna, 2004. *Drinking-water nitrate, methemoglobinemia, and global burden of disease – A discussion.* Environmental Health Perspecitves, v. 112, no. 14, p. 1371-1374.

Fitch, S.T., 2006. *Mercury Total Maximum Daily Load (TMDL) for Alamo Lake,Arizona.* Arizona Department of Environmental Quality, Open File Report 06-07, pp. 54.

Graf, Charles G., 1986, *VOCs in Arizona's Groundwater: A Status Report.* Proceedings of the Focus Conference on Southwestern Groundwater Issues, National Water Well Association, Oct. 20-21, 1986.

Gillespie, J.B., and C. B. Bentley, 1971. *Geohydrology of Hualapai and Sacramento Valleys,Mohave County, Arizona.* U.S. Geological Survey Water-Supply Paper 1899-H, 37 p, two sheets, scale 1:125,000.

Guay, B.E., C. J. Eastoe, R. Bassett, and A. Long, 2004. *Identifying sources of groundwater in the lower Colorado River valley, USA with □^{18}O,□D and ^{3}H-implications for river water accounting.* Hydrogeology Journal, pp. 22.

Hadley, Diana, and Thomas E. Sheridan, 1995. *Land Use History of the San Rafael Valley, Arizona (1540 - 1960).* General Technical Report RM-GTR-269. USDA, Forest Service Rocky Mountain Forest and Range Experiment Station: Fort Collins, Colorado.

Hammett, B.A., 1992. *Maps showing groundwater conditions in the Eloy and Maricopa Stanfield sub-basins of the Pinal Active Management Area, Pinal, Pima, and Maricopa Counties, Arizona—1989.* Arizona Department of Water Resources, Hydrologic Map Series Report Number 23, 3 sheets, scale 1:125,000.

Harris, R.C., and C. J. Eastoe, website materials, www.ose.state.nm.us/PDF/SpecialProjects/RGProjectSalinitymgt/posters/Saffordposter.pdf accessed 8/20/09.

Heath, Ralph C., 1989. *Basic Ground-Water Hydrology.* U.S. Geological Survey Water-Supply Paper 2220.

Heindl, L.A., 1952. *Groundwater in the Gila River Basin and Adjacent Areas, Arizona–A Summary*, Halpenny, L.C., ed. USGS Open File Report: Tucson, Arizona.

Hem, John D., 1970. *Study and Interpretation of the Chemical Characteristics of Natural Water.* USGS Water-Supply Paper 1473: Washington, D.C.

Henderson, Timothy, 1984. *Groundwater: Strategies for State Action.* The EnvironmentalLaw Institute: Washington, D.C.

Hood, Wayne K., 1991. *A Plan to Establish Ambient Groundwater Quality Monitoring Networks in Arizona.* Arizona Department of Environmental Quality, pp. 14.

Hood, W.K., A. A. Myers, and D. L. Totman, 1988. *Statewide Groundwater Quality Monitoring Network Design.* Proceedings of the Conference on Southwestern Groundwater Issues, National Water Well Association, March 23-25, 1988, Albuquerque, New Mexico. p. 205-222.

Jenkins, Robin D., and Abigail A. Myers, 1988. *Groundwater Quality Conditions in the*

Prescott Valley / Dewey Area, Arizona. ADEQ Groundwater Hydrology Section: Phoenix, Arizona.

Jones, S.C., 1980. *Maps Showing Ground-Water Conditions in the Lower San Pedro Basin Area, Pinal, Cochise, Pima, and Graham Counties, Arizona–1979.* USGS Water-Resources Investigations Open-File Report 80-954.

Kaplan, E.L., and O. Meier, 1958. *Nonparametric Estimation from Incomplete Observations.* Journal of the American Statistical Association, Vol. 53, p. 457-481.

Laney, R.L., 1979. *Geohydrologic reconnaissance of Lake Mead Recreation Area – Temple Bar to Grand Wash Cliffs, Arizona.* U.S. Geological Survey Open-File Report 79-688, pp. 71.

Littin, G.R., 1981. *Maps showing groundwater conditions in the Agua Fria area, Yavapai and Maricopa Counties, Arizona—1979.* U.S. Geological Survey Water-Resources Investigations Open-File Report 81-804, 2 sheets, scale 1:125,000.

Lowry, J.D., and S. B. Lowry, 1988. *Radionuclides in drinking waters.* American Water Works Association Journal 80 (July), p. 50-64.

Madison, R.J., and J. O. Brunett, 1984. *Overview of the occurrence of nitrate in ground water of the United States.* In National Water Summary 1984-Water Quality Issues: U.S. Geological Survey Water Supply Paper 2275, p. 93-105.

Metzger, D.G., and O. J. Loeltz, 1973. *Geohydrology of the Needles area, Arizona, California, and Nevada.* U.S. Geological Survey Professional Paper 486-J, pp. 54.

Morrow Jr., William S., 1999. *Volatile Organic Compounds in Ground Water of the Lower Illinois River Basin.* U.S. Geological Survey Water-Resources Investigations Report 99-4229, December 1999.

Murphy, B.A., and J. D. Hedley, 1984. *Maps Showing Groundwater Conditions in the Upper Santa Cruz Basin Area, Pima, Santa Cruz, Pinal, and Cochise Counties, Arizona–1982.* Arizona Department of Water Resources Hydrologic Map Series Report #11, January 1984.

Olade, Moses. 2009. Personal communication with ADEQ Hydrologist on pesticide detections in Arizona.

Olmstead, F.H., O. J. Loeltz, and Burdge Irelan, 1973. *Geohydrology of the Yuma Area, Arizona and California.* USGS Professional Paper 486-H: Washington, D.C.

Page, Harry G., 1963. *Water Regimen of the Inner Valley of the San Pedro River near Mammoth, Arizona (A Pilot Study).* USGS Water-Supply Paper 1699-1: Washington, D.C.

Rascona, S.J., 1991. *Map Showing Groundwater Conditions in the Sacramento Valley Basin Mohave County, Arizona - 1991.* ADWR Hydrologic Map Series Report #21: Phoenix, AZ.

Remick, W.H., 1981. *Map showing ground-water conditions in the Hualapai Basin area, Mohave, Coconino and Yavapai Counties, Arizona—1980.* Arizona Department of Water Resources, Hydrologic Map Series Report Number 4, 1 sheet, scale 1:250,000.

Roberts, Isaac, 1997. Personal communication from ADHS laboratory staff member.

Robertson, F.N., 2000. Personal communication from USGS hydrologist, retired.

Robertson, F.N., 1991. *Geochemistry of ground water in alluvial basins of Arizona and adjacent parts of Nevada, New Mexico, and California.* U.S. Geological Survey Professional Paper 1406-C, pp. 90.

Robertson, F.N., 1986. *Occurrence and Solubility Controls of Trace Elements in Groundwater in Alluvial Basins of Arizona.* Anderson, T.W., and Johnson, A.I., eds., *Regional Aquifer Systems of the United States, Southwest Alluvial Basins of Arizona.* American Water Resources Association Monograph Series No. 7, p. 69-80.

Rosner, Ulrike, 1998. *Heavy Metals in Surface Soils and Streambed Sediments in the Wallapai Mining District, Northwestern Arizona, A Historic Mining District in a Semiarid Region.* Arizona Geological Survey Contributed Report CR-98-A: Tucson, AZ.

Spencer, J. 2002. *Natural occurrence of arsenic in Southwest ground water.* Southwest Hydrology, May/June, p. 14-15.

Schwalen, Harold C., 1967. *Little Chino Valley: Artesian Area and Groundwater Basin.* Agricultural Experiment Station Technical Bulletin #178, University of Arizona: Tucson, AZ.

Toccalino, P.L., and J. E. Norman, 2006. *Health-based screening levels to evaluate U.S. Geological Survey ground water quality data: Risk Analysis.* Vol. 26, no. 5, p. 1339-1348.

Towne, Douglas C., 2004. *Ambient Groundwater Quality of the Safford Basin, Gila Valley Sub-basin. A 1997 Baseline Study.* ADEQ Open File Report 99-4.

Towne, D.C., 2003. *Ambient groundwater quality of the Detrital Valley basin: A 2002 baseline study.* Arizona Department of Environmental Quality Open File Report 03-03, pp. 65.

Tuve, P., 1999. *Groundwater quality study for northern central Mohave Valley, Arizona.* Arizona Department of Environmental Quality Open File Report 99-10, pp. 127.

Tuve, P., and J. Giannelli, 1995. *Groundwater quality study for Bullhead City and northern Mohave Valley, Arizona.* Arizona Department of Environmental Quality Open File Report 95-06, pp. 80.

U.S. Environmental Protection Agency website, www.epa.gov/waterscience/criteria/humanhealth/ accessed 8/20/09.

U.S. Environmental Protection Agency, 1993. *A pocket guide to the requirements for the operators of small water systems: U.S. Environmental Protection Agency Region 9,* 3rd edition, pp. 47.

Wallin, R., 1999. *Groundwater quality in the Upper Gila River basin, Arizona*. Arizona Department of Environmental Quality Open File Report 98-12, pp. 48.

Ward, M.H., S. D. Mark, K. P. Cantor, D. D. Weisenburger, Adolofo Correa-Villase, and S. H. Zahm, 1996. *Drinking water nitrate and risk of non-Hodgkin's lymphoma.* Epidemiology v. 7, no. 5, p. 465-471.

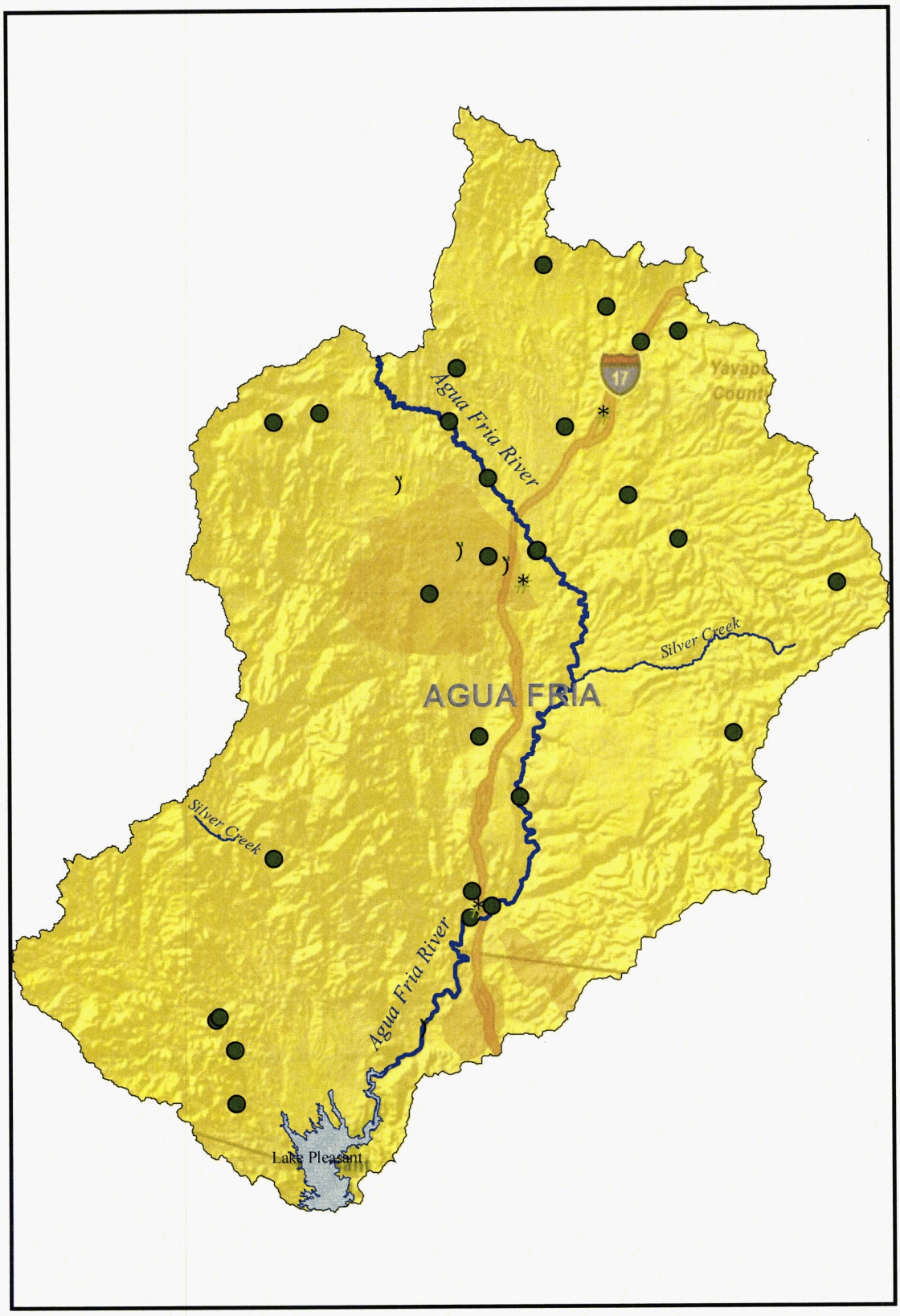
Water Quality Association website, 2006, www.wqa.org accessed 5/15/06.

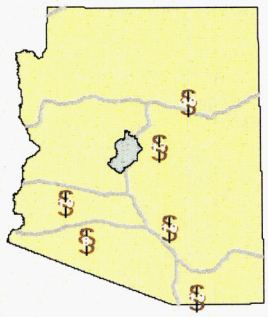
Weyer, Peter, J. R. Cerhan, B. C. Kross, G. R. Hallberg, Jiji Kantamneni, George Breuer, M. P. Jones, Wei Zheng, and C. F. Lynch, 2001, *Municipal drinking water nitrate level and cancer risk in older women.* The Iowa Health Study, Epidemiology, v. 11, p. 327-338.

Wirt, Laurie, J. R. Gray, and P. C. Van Metre, 1989. *Occurrence and movement of radionuclides in the Puerco River basin, Arizona and New Mexico.* USGS Open File Report 89-409, pp. 109.

Appendix A – Maps of Actual and Inferred Nitrate (as Nitrogen) Concentrations in Selected Basin-Fill Aquifers

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Agua Fria Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

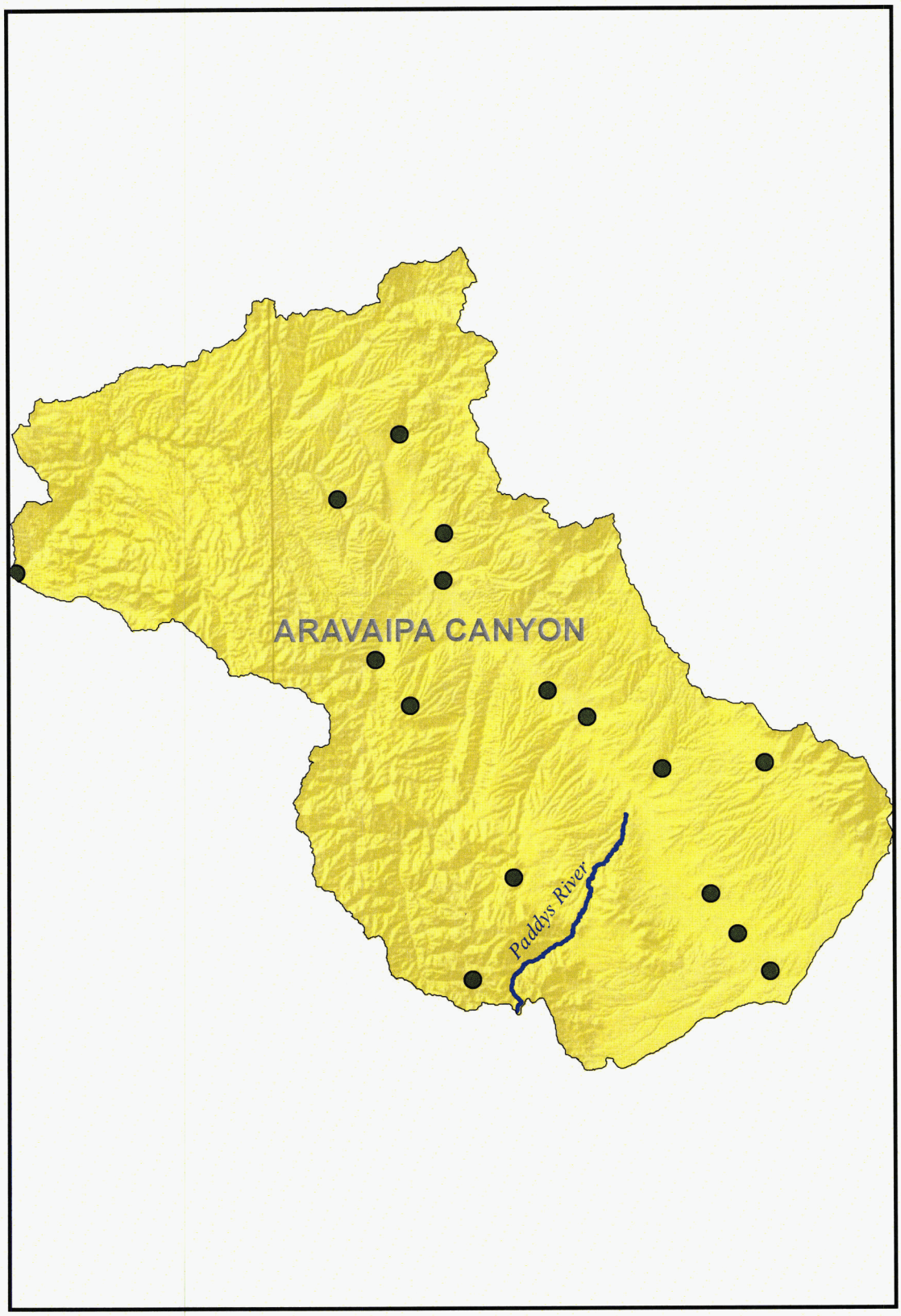
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

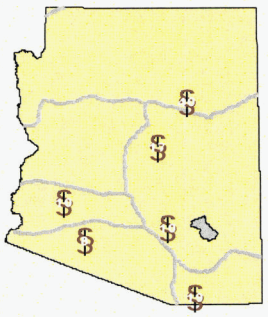
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdc\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Agua Fria Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

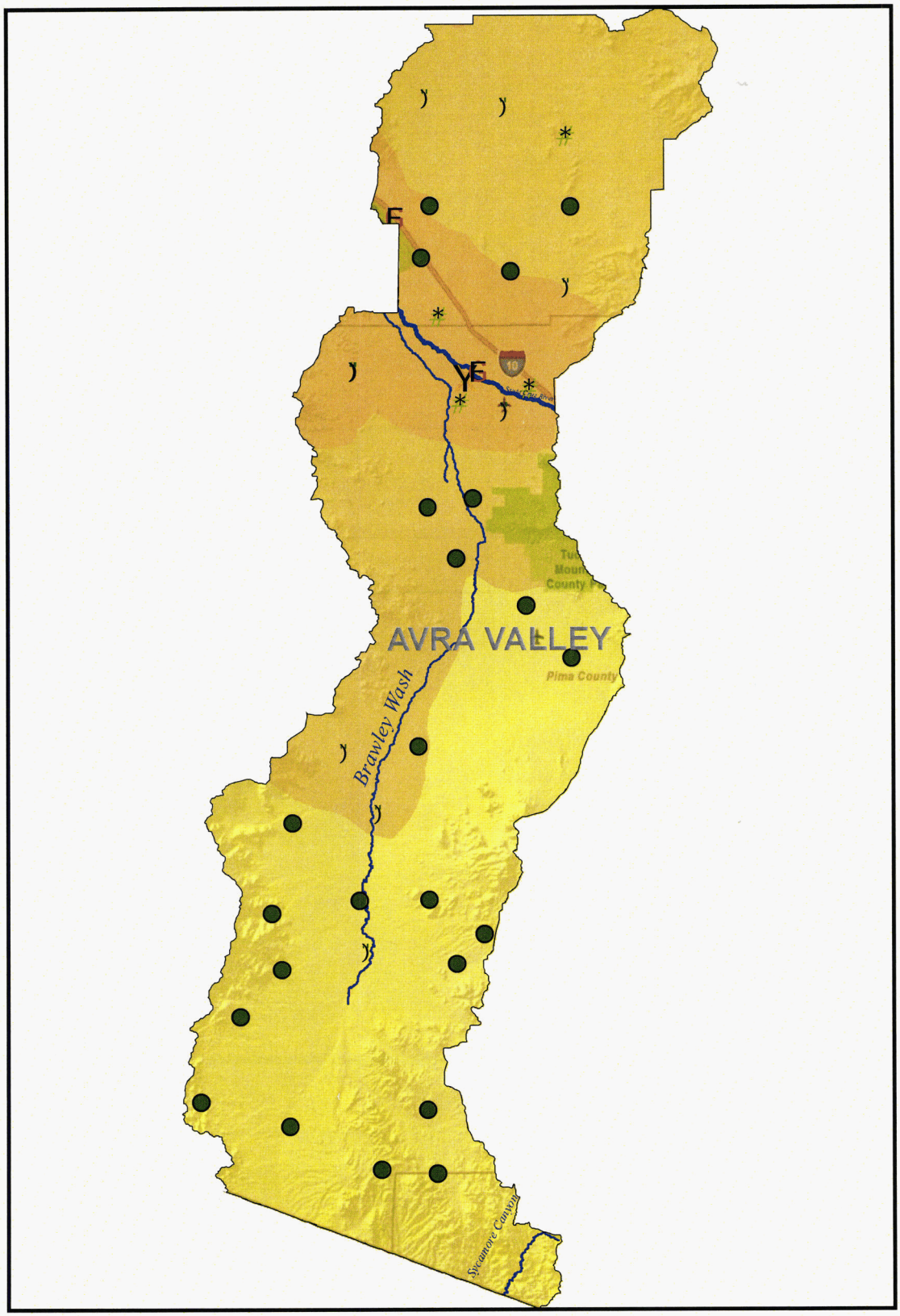
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

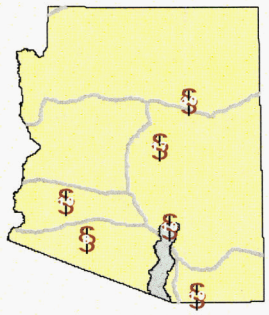
0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Tucson AMA Groundwater Basin, Arizona
Avra Valley Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

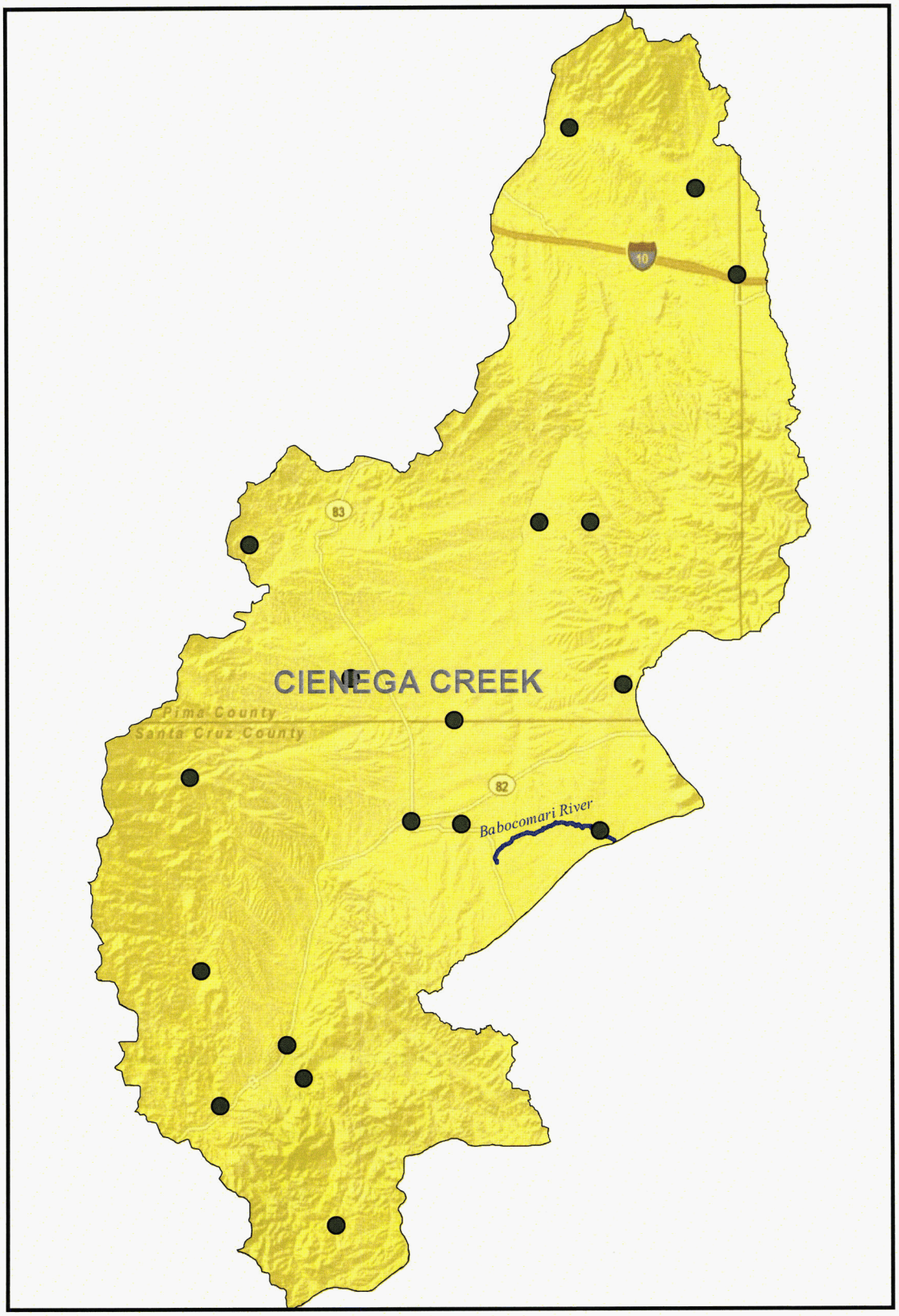
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

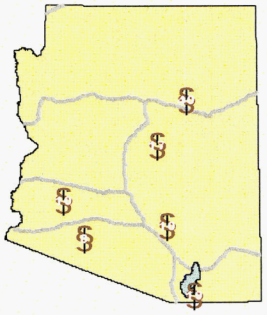
0 8 16
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\adeGW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Cienega Creek Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

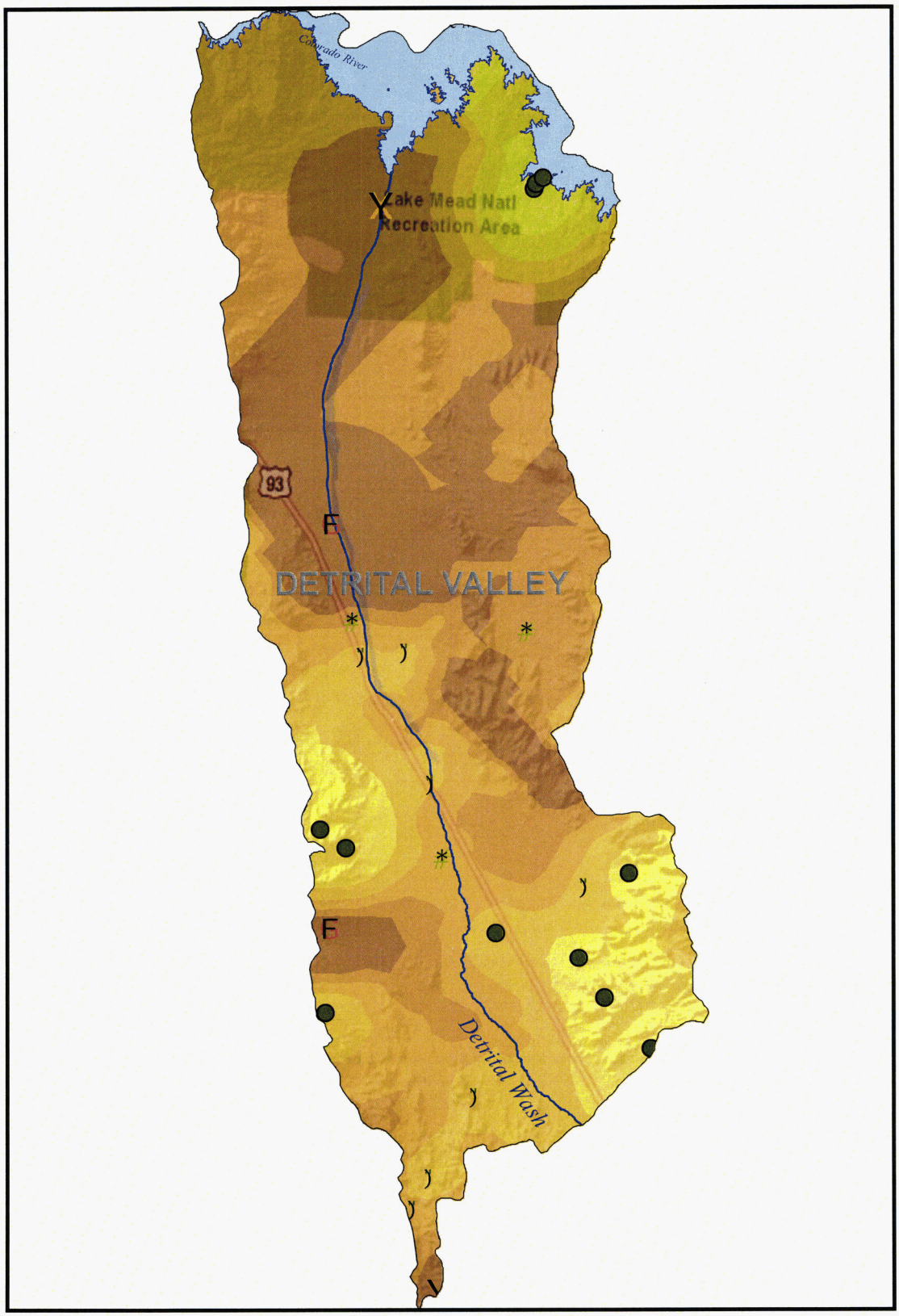
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdo\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Detrital Valley Groundwater Basin, Arizona



Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

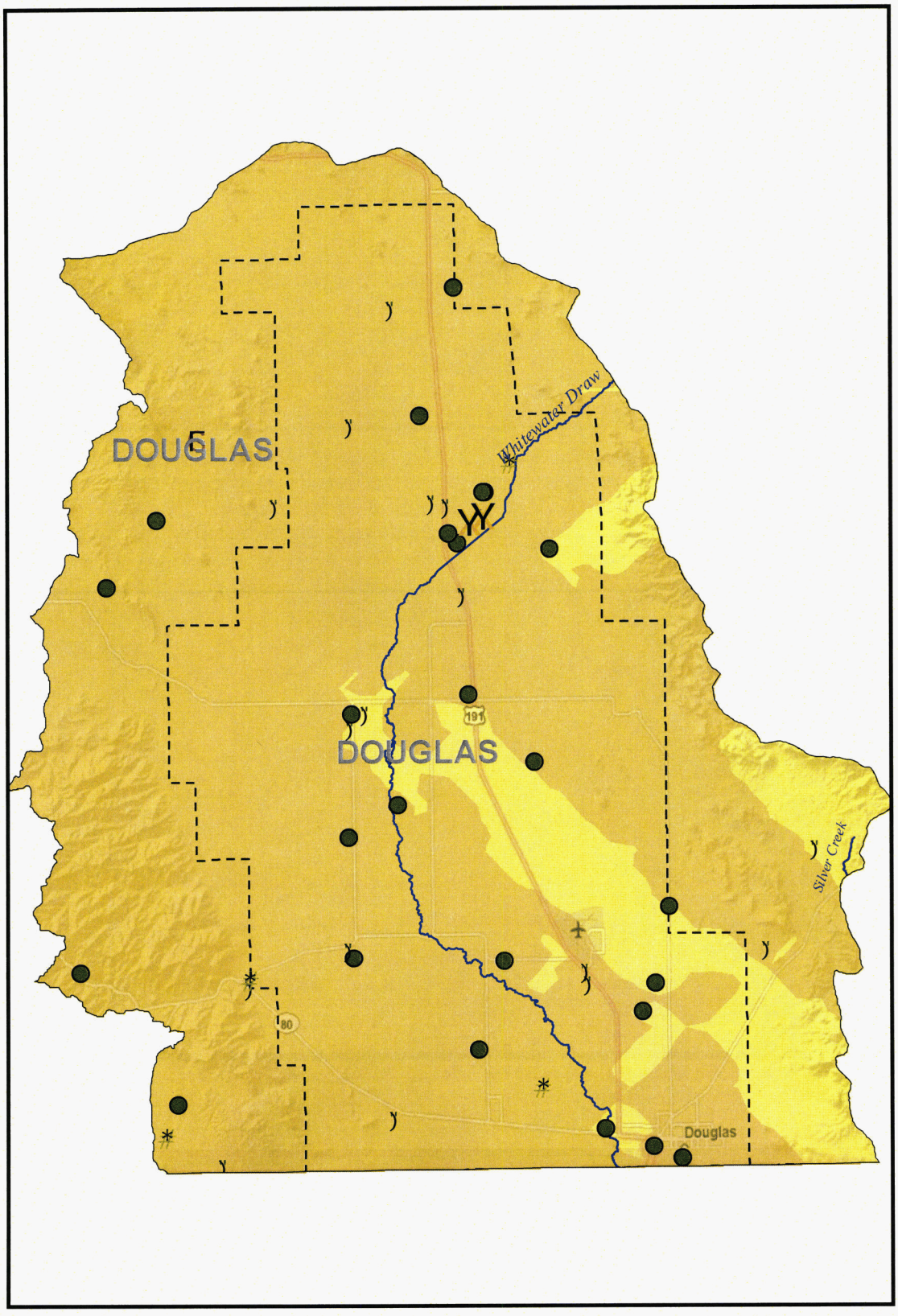
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

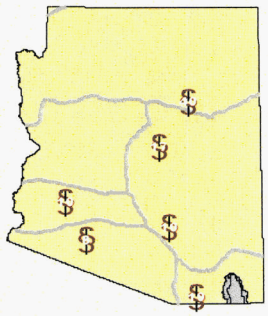
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Douglas Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

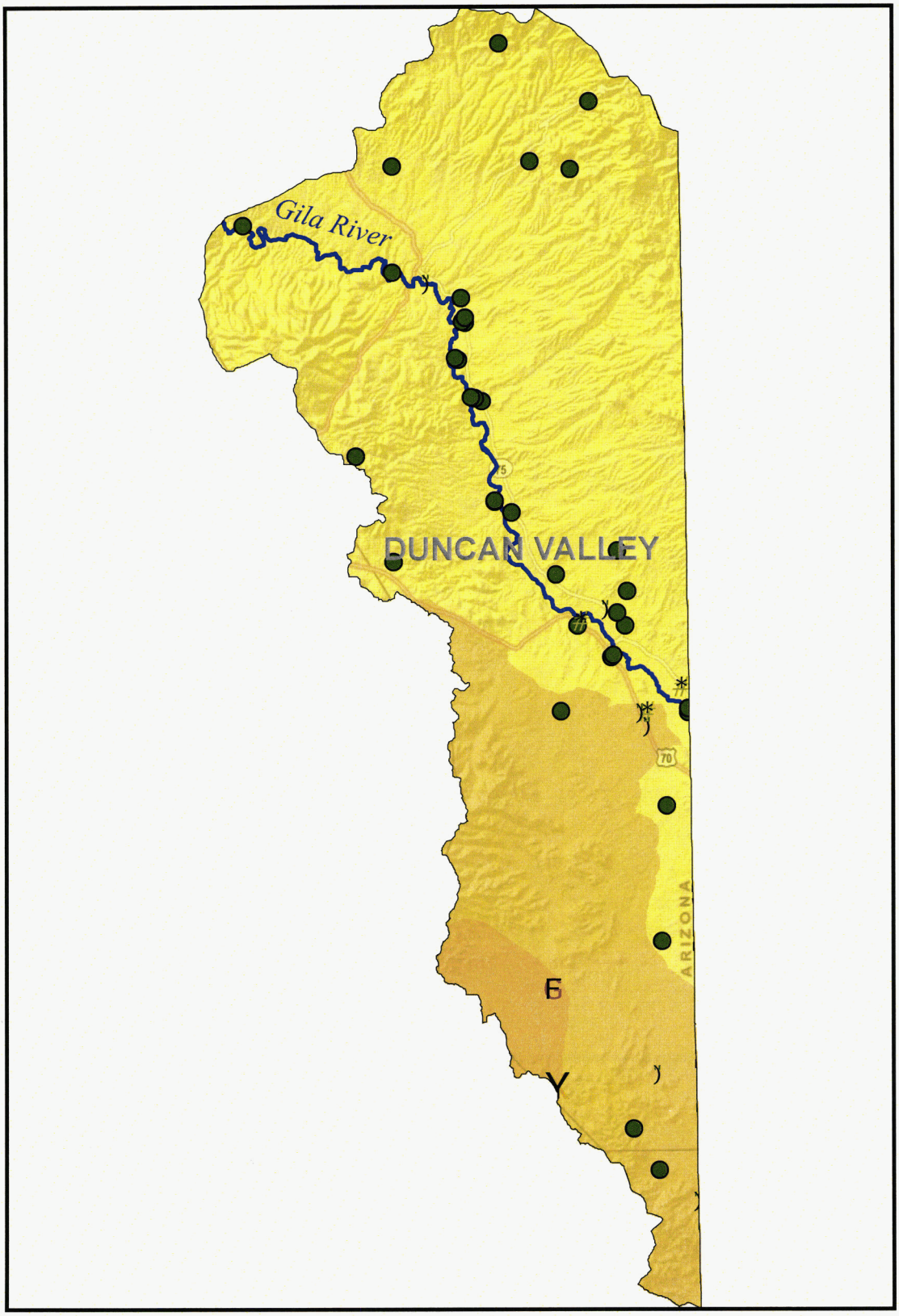
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

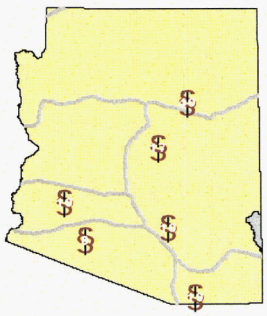
0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\adoGW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Duncan Valley Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

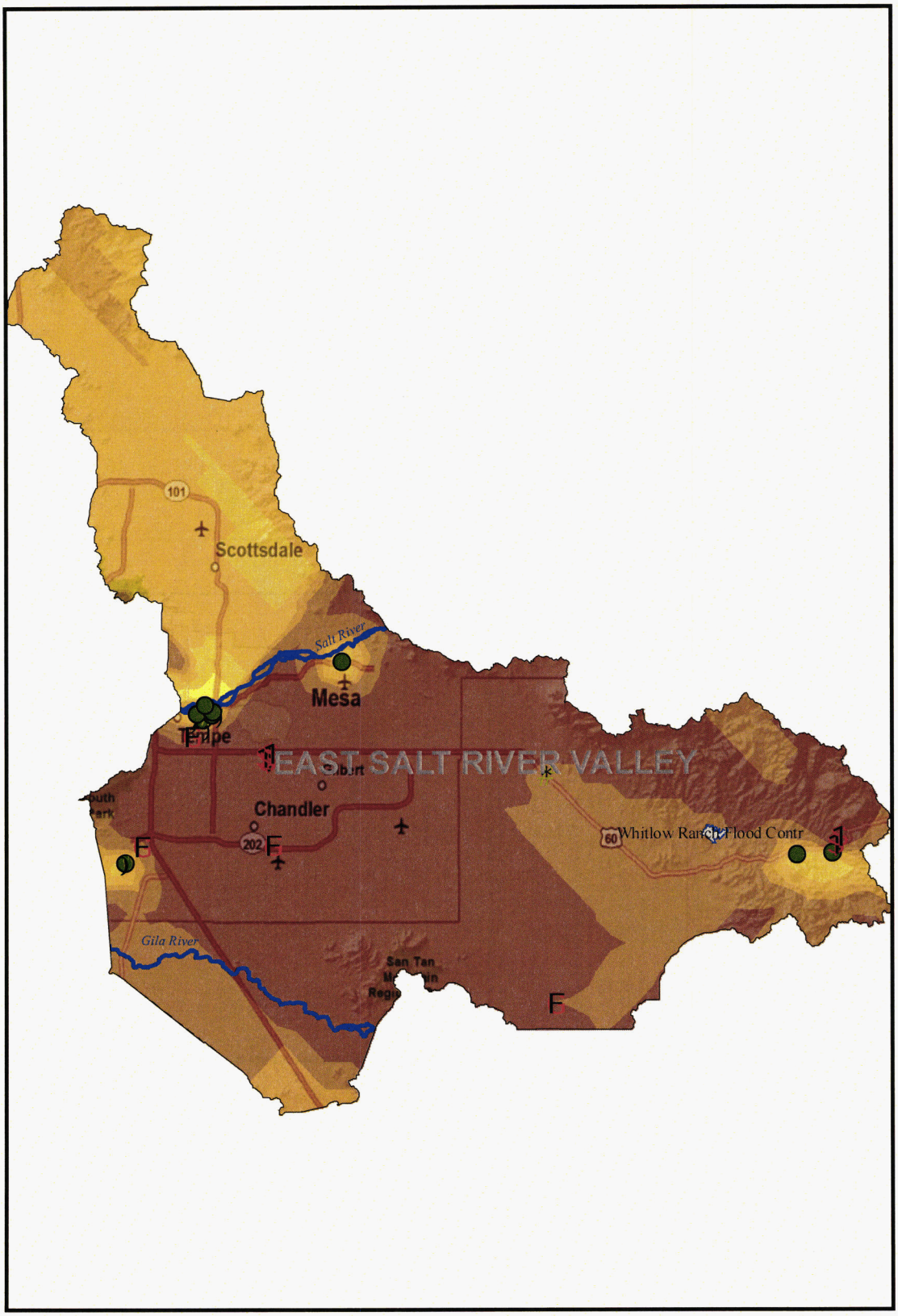
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

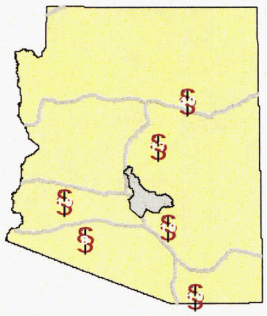
0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdo\GW Geostatistical\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Phoenix AMA Groundwater Basin, Arizona
East Salt River Valley Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

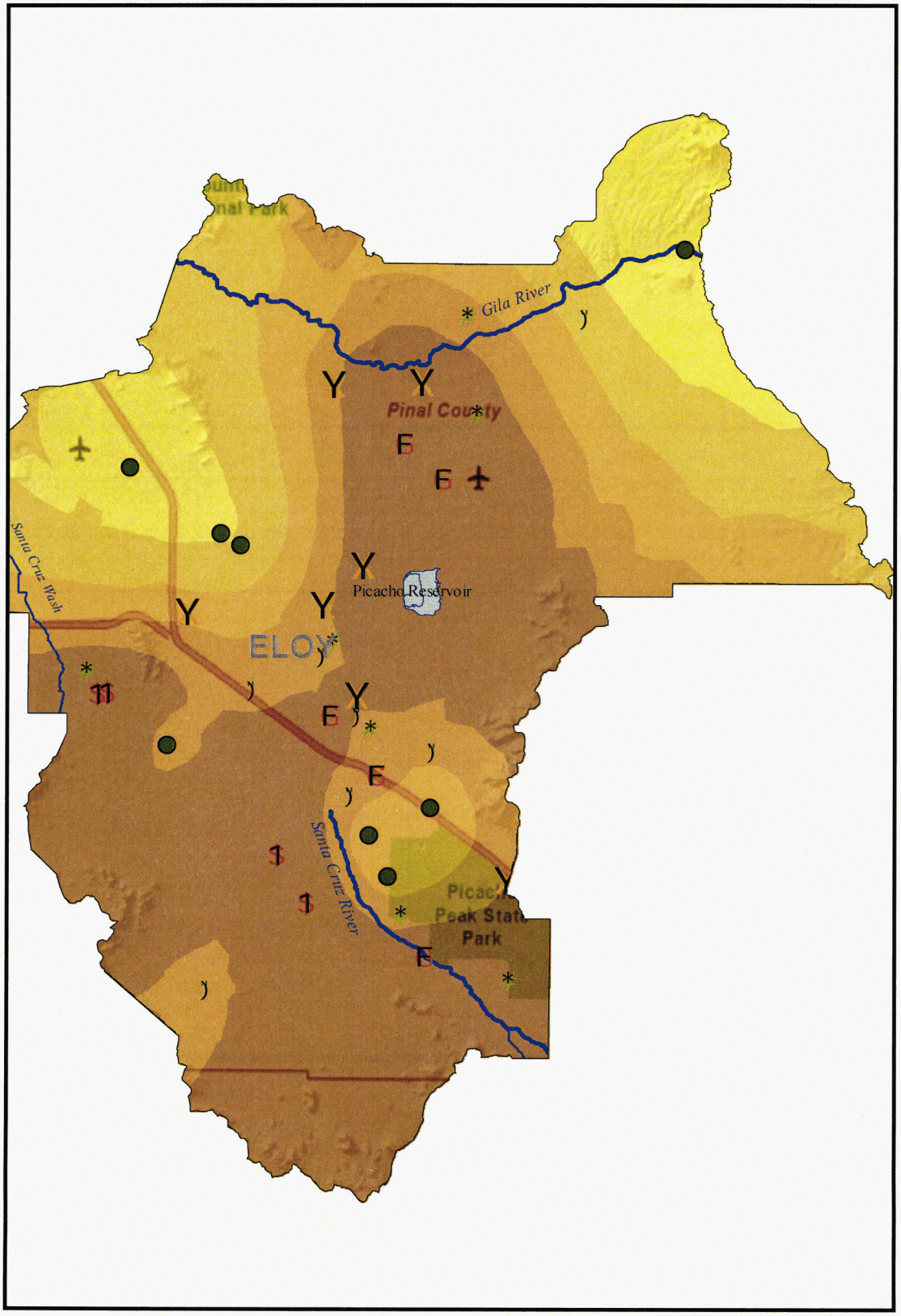
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

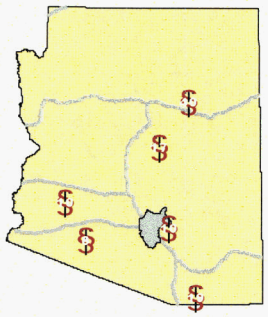
0 7.5 15
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdo\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Pinal AMA Groundwater Basin, Arizona
Eloy Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

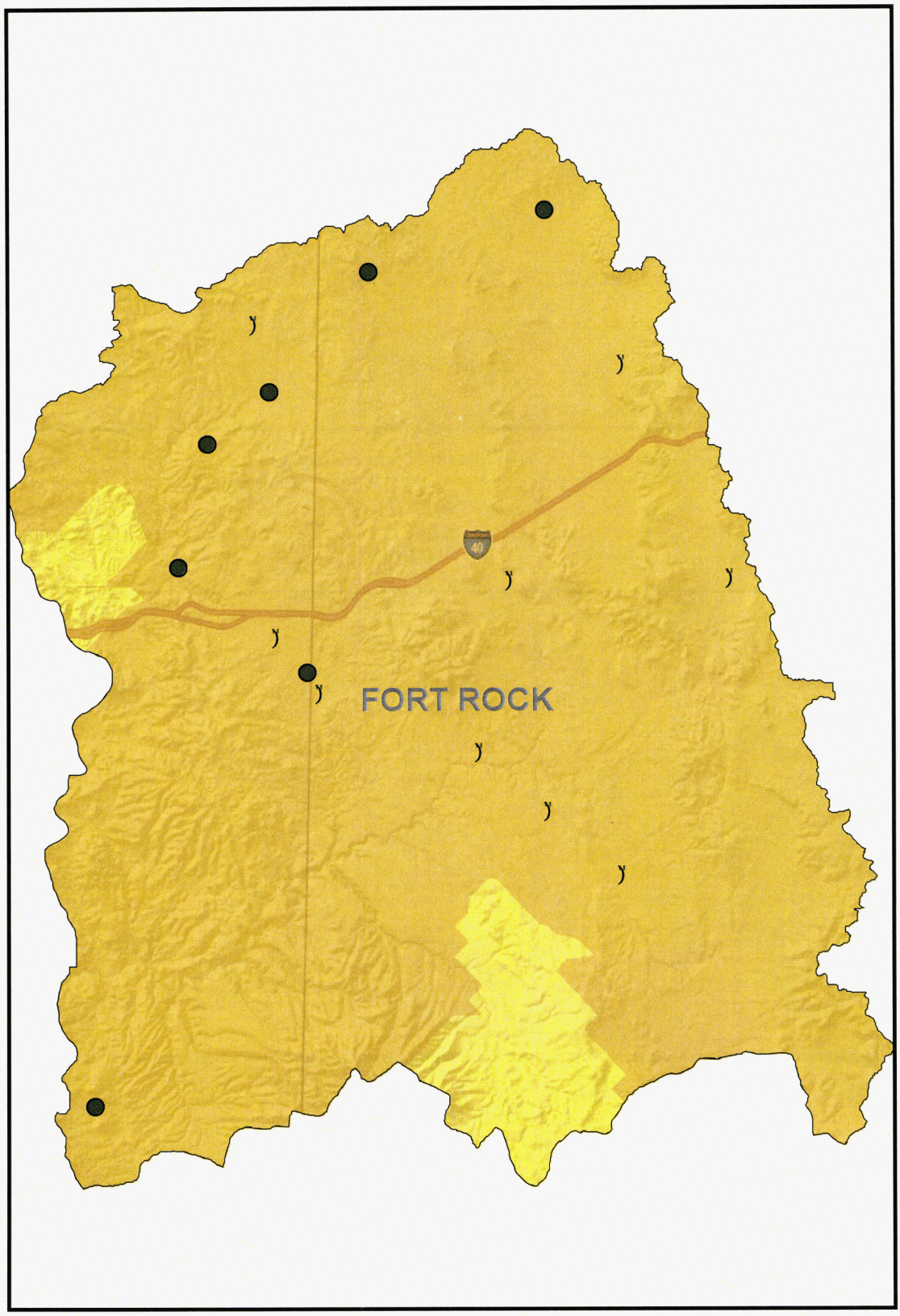
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

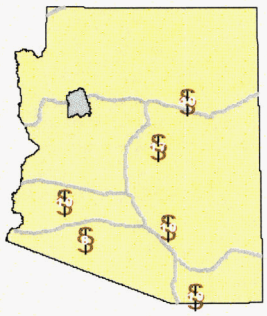
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Big Sandy Groundwater Basin, Arizona Fort Rock Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

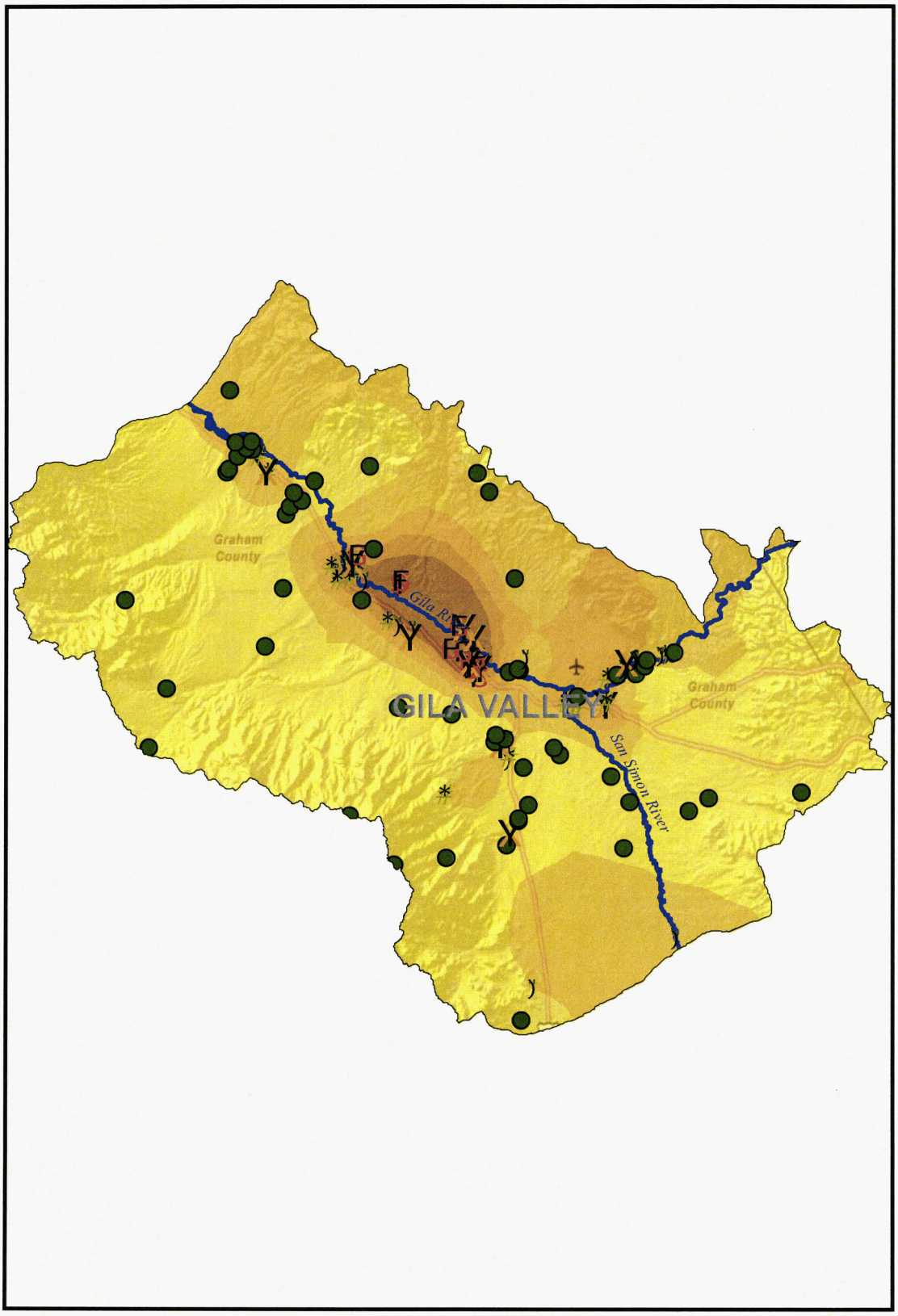
0 4 8

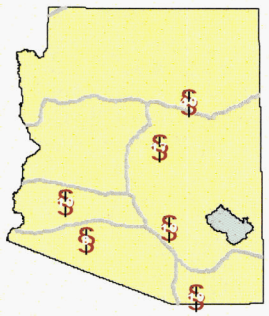
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Safford Groundwater Basin, Arizona
Gila Valley Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

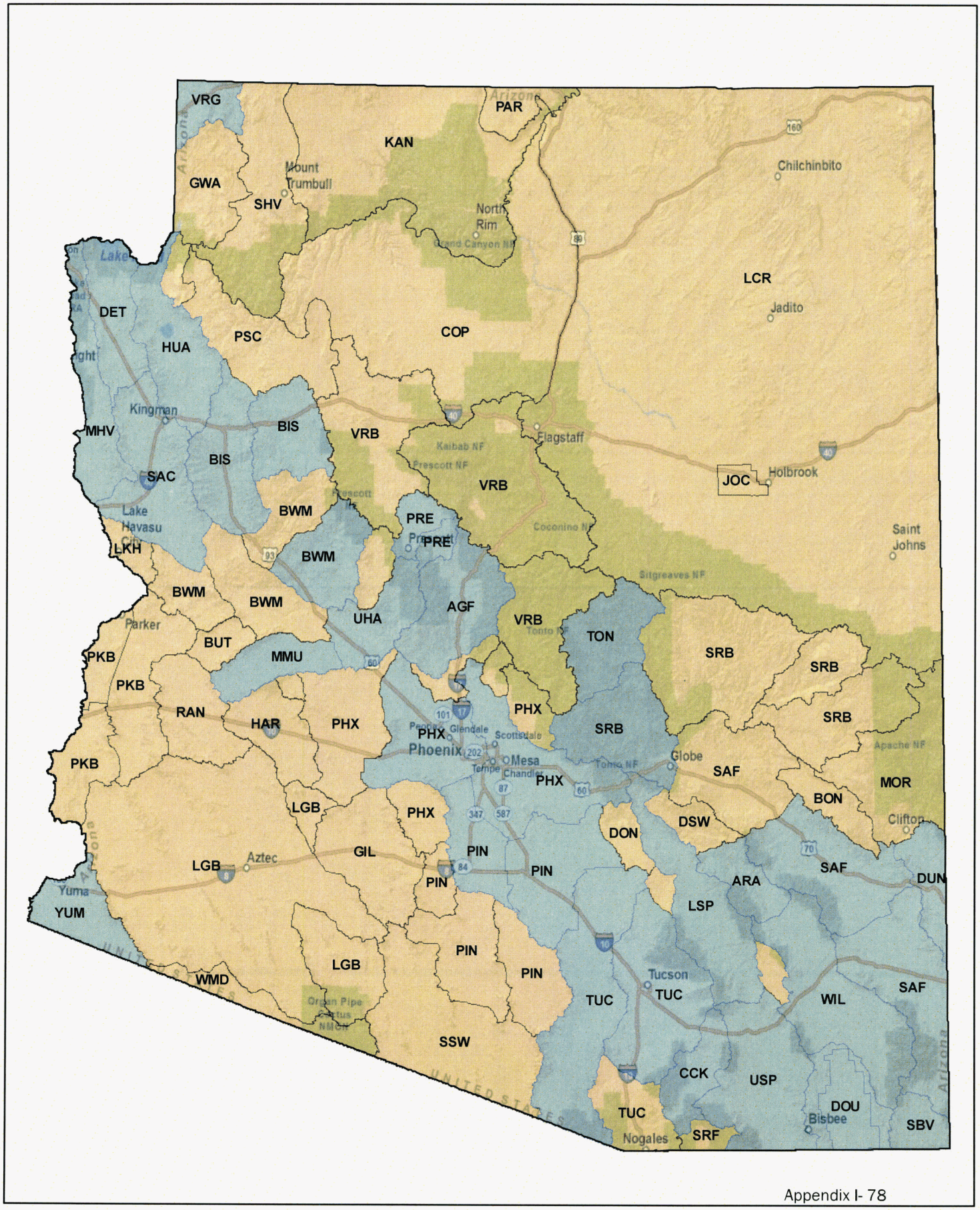
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

0 7.5 15
Miles

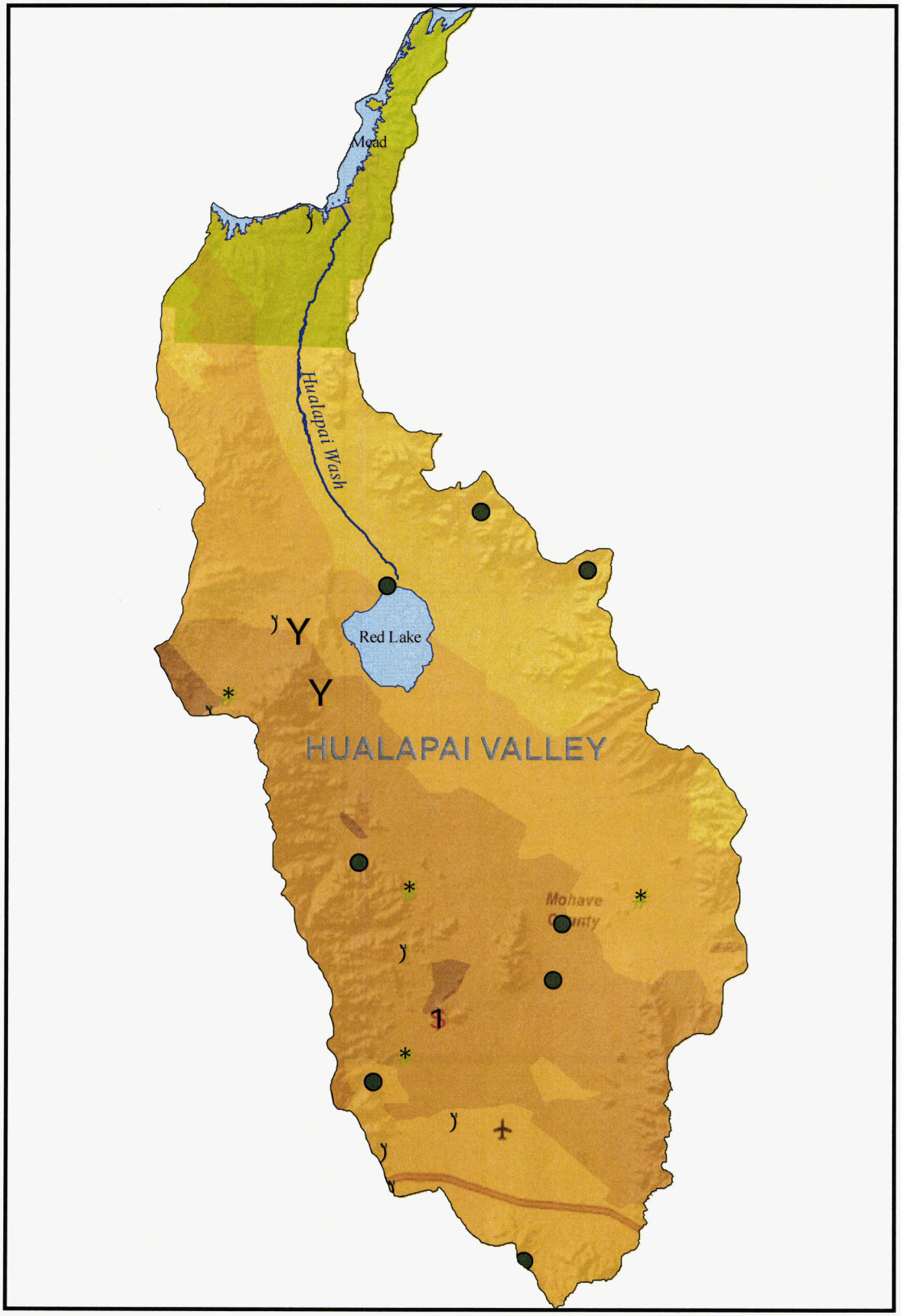
ADEQ Arizona Department of Environmental Quality

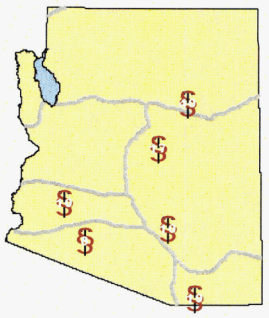
Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Arizona Groundwater Basins Mapped for Actual and Inferred Nitrate Values



Actual and Inferred Nitrate (as Nitrogen) Concentrations in Hualapai Valley Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

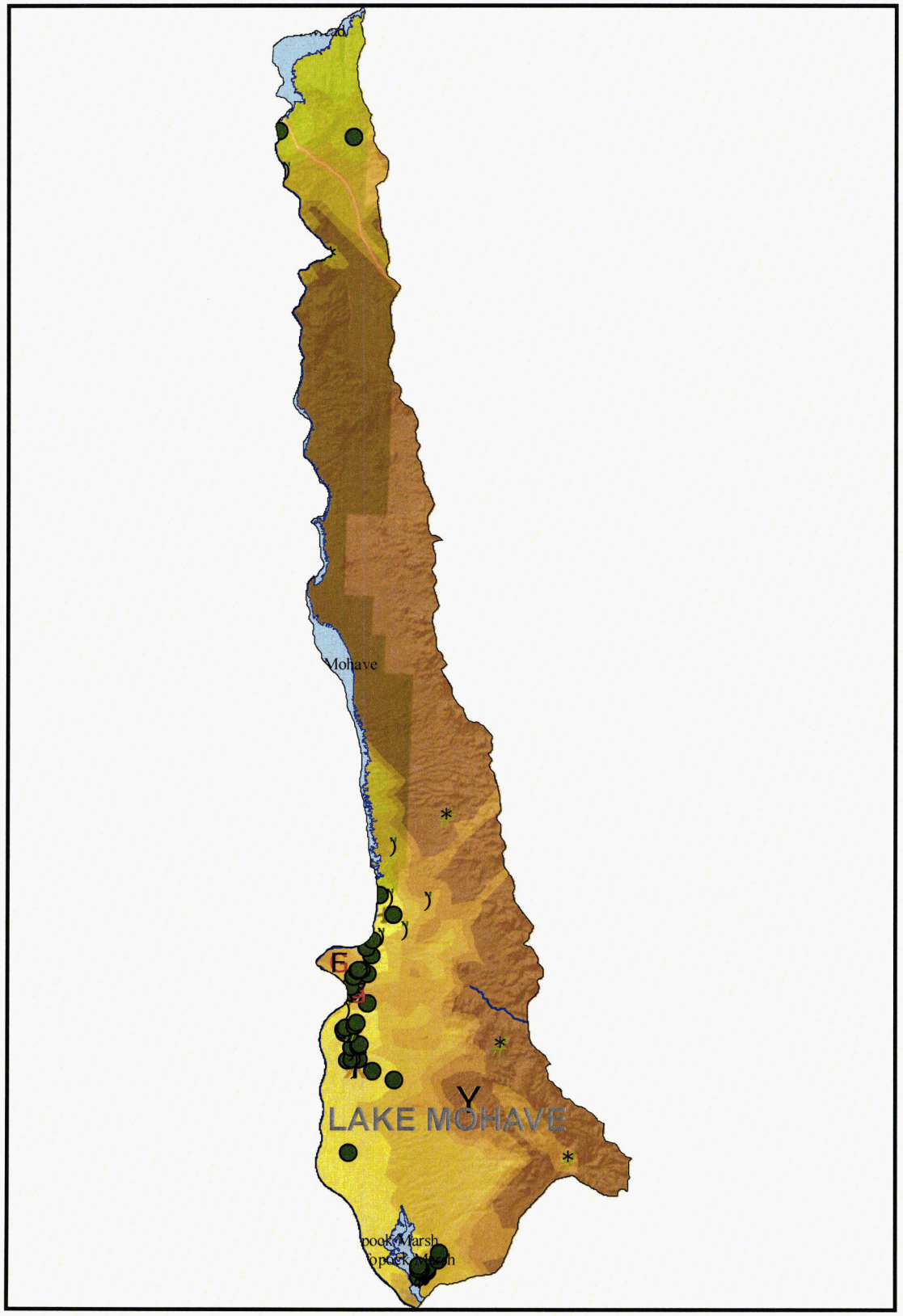
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

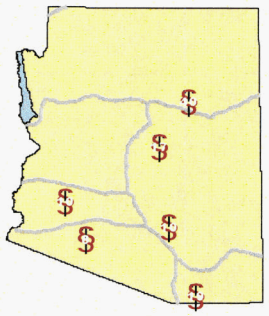
0 6 12
Miles

ADEQ
Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Lake Mohave Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

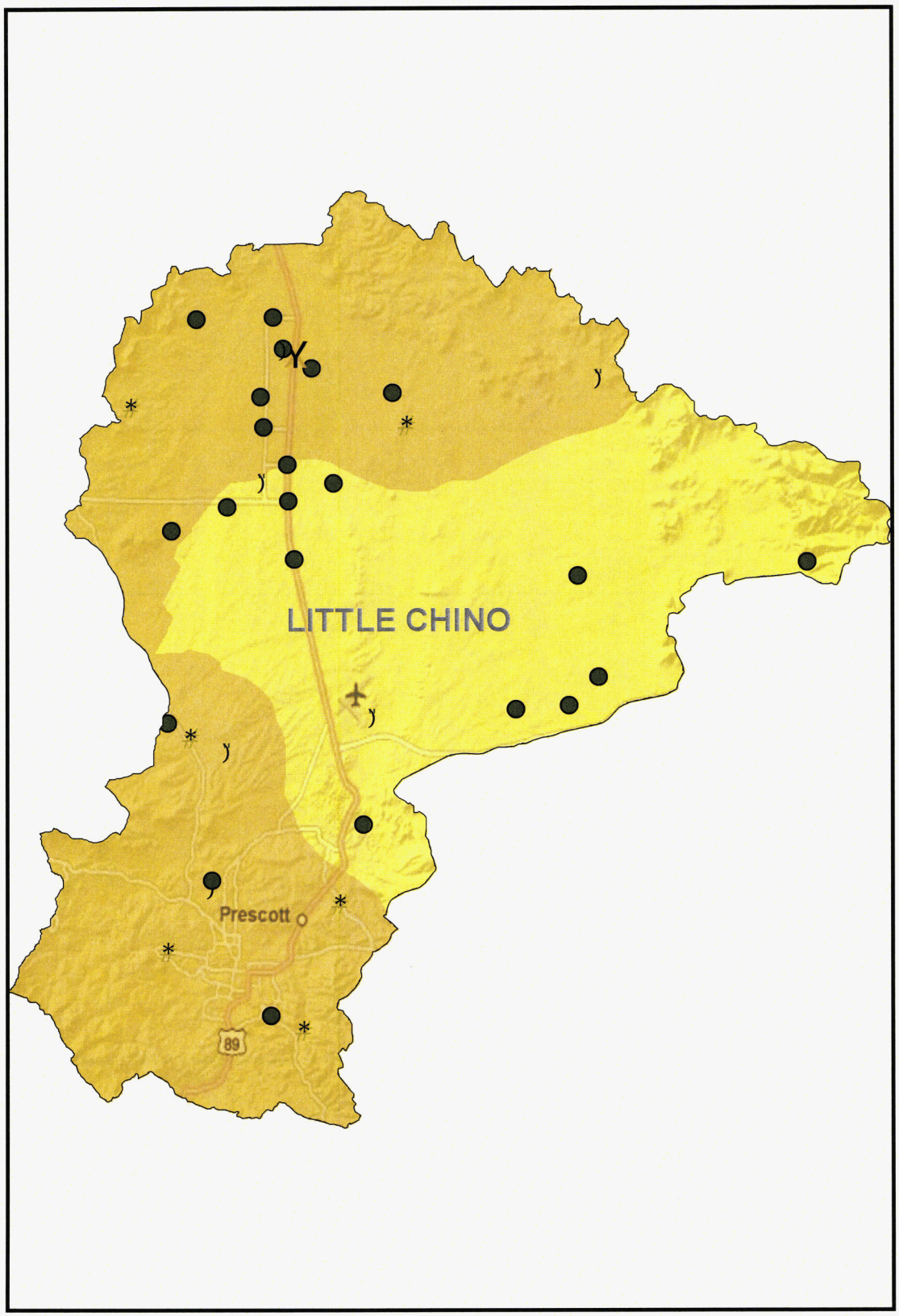
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

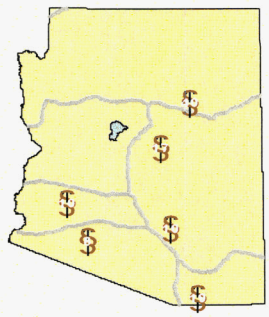
0 8 16
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Prescott AMA Groundwater Basin, Arizona
Little Chino Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

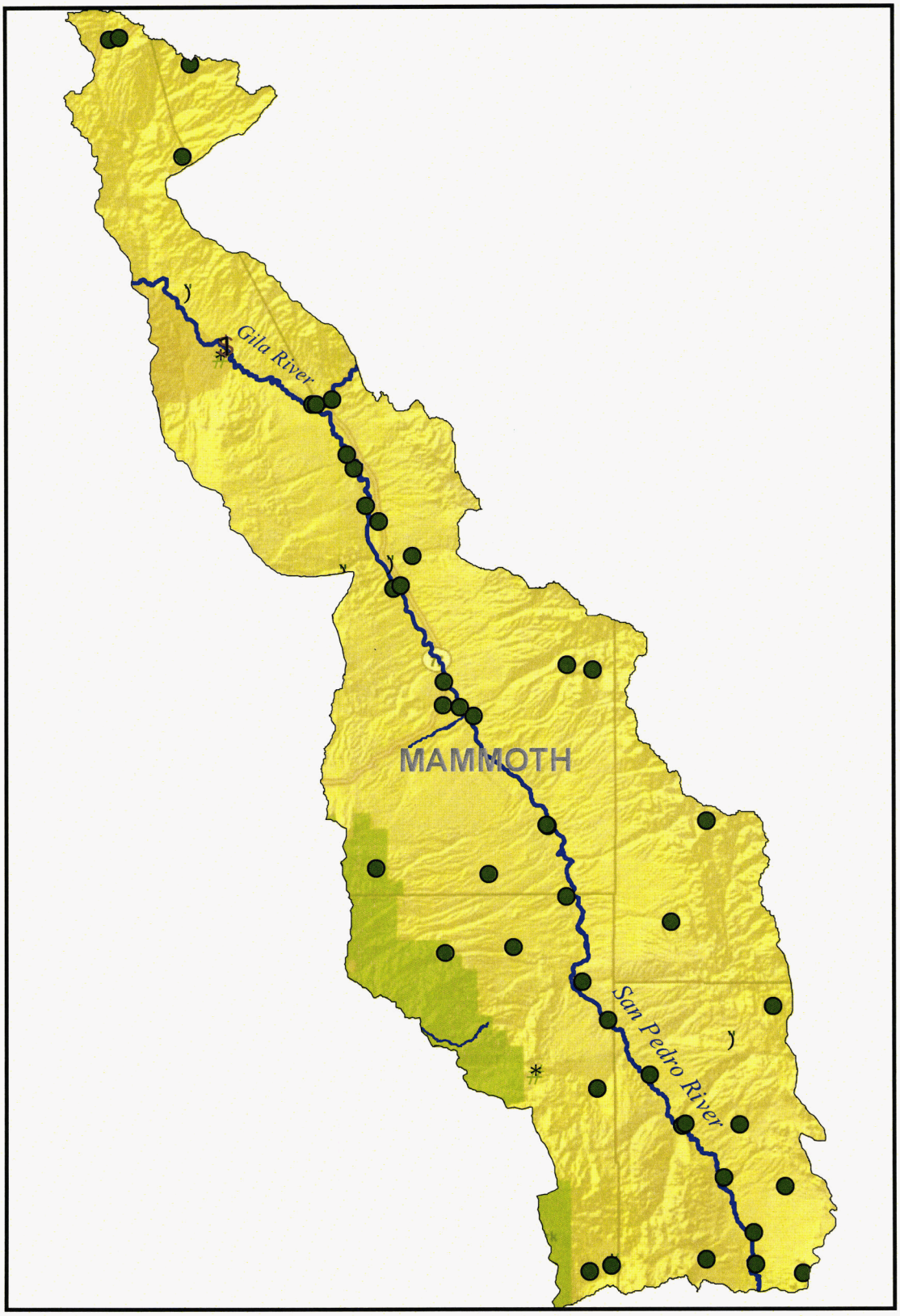
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

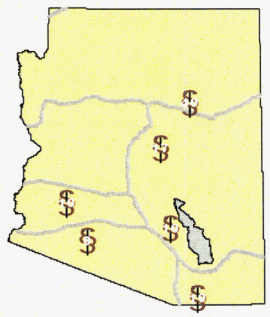
0 3 6
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Lower San Pedro Groundwater Basin, Arizona Mammoth Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

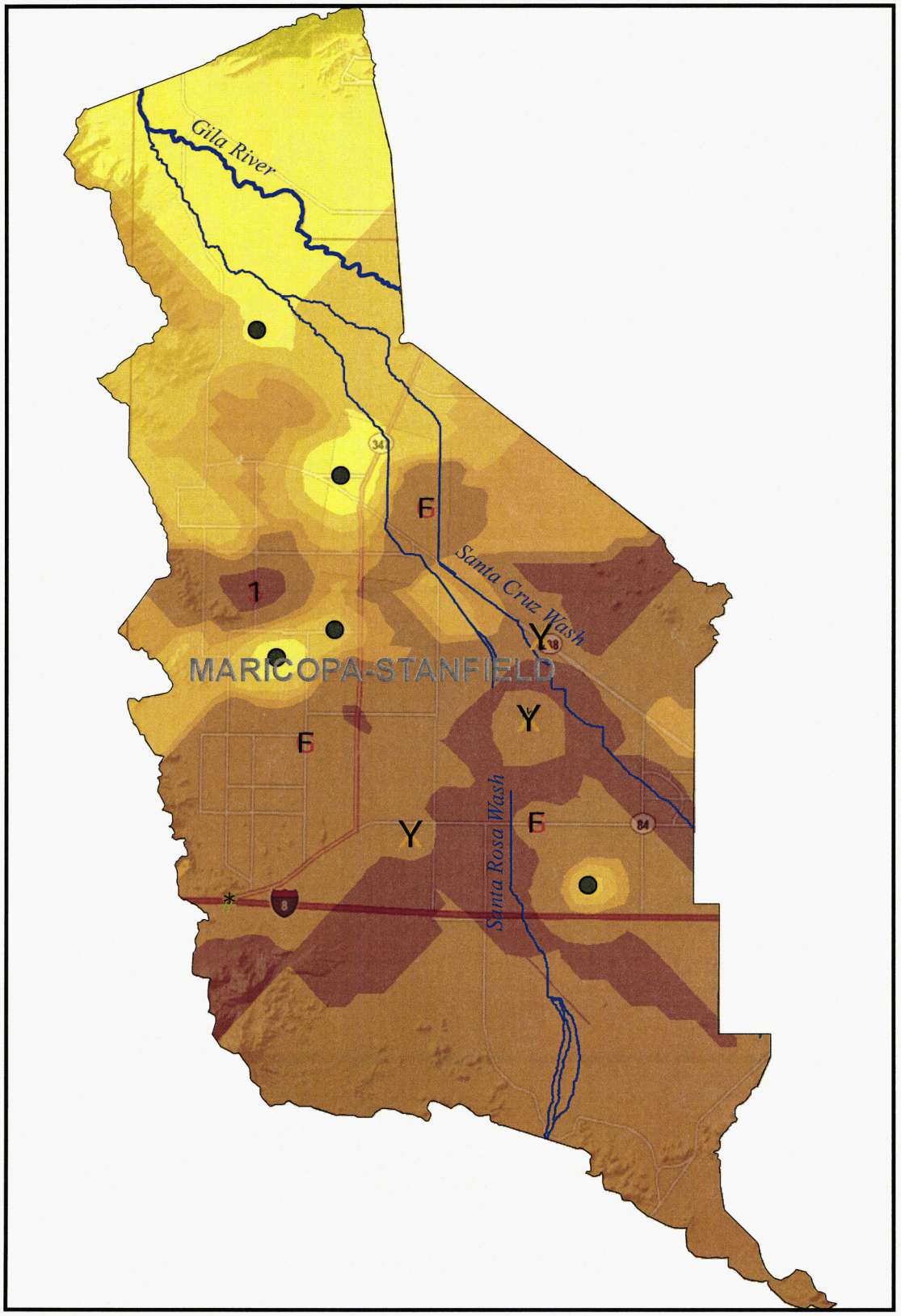
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

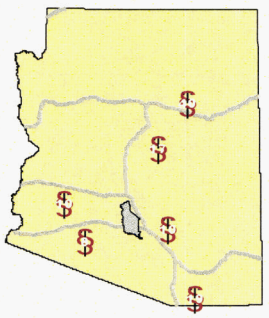
0 7 14
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Pinal AMA Groundwater Basin, Arizona Maricopa-Stanfield Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

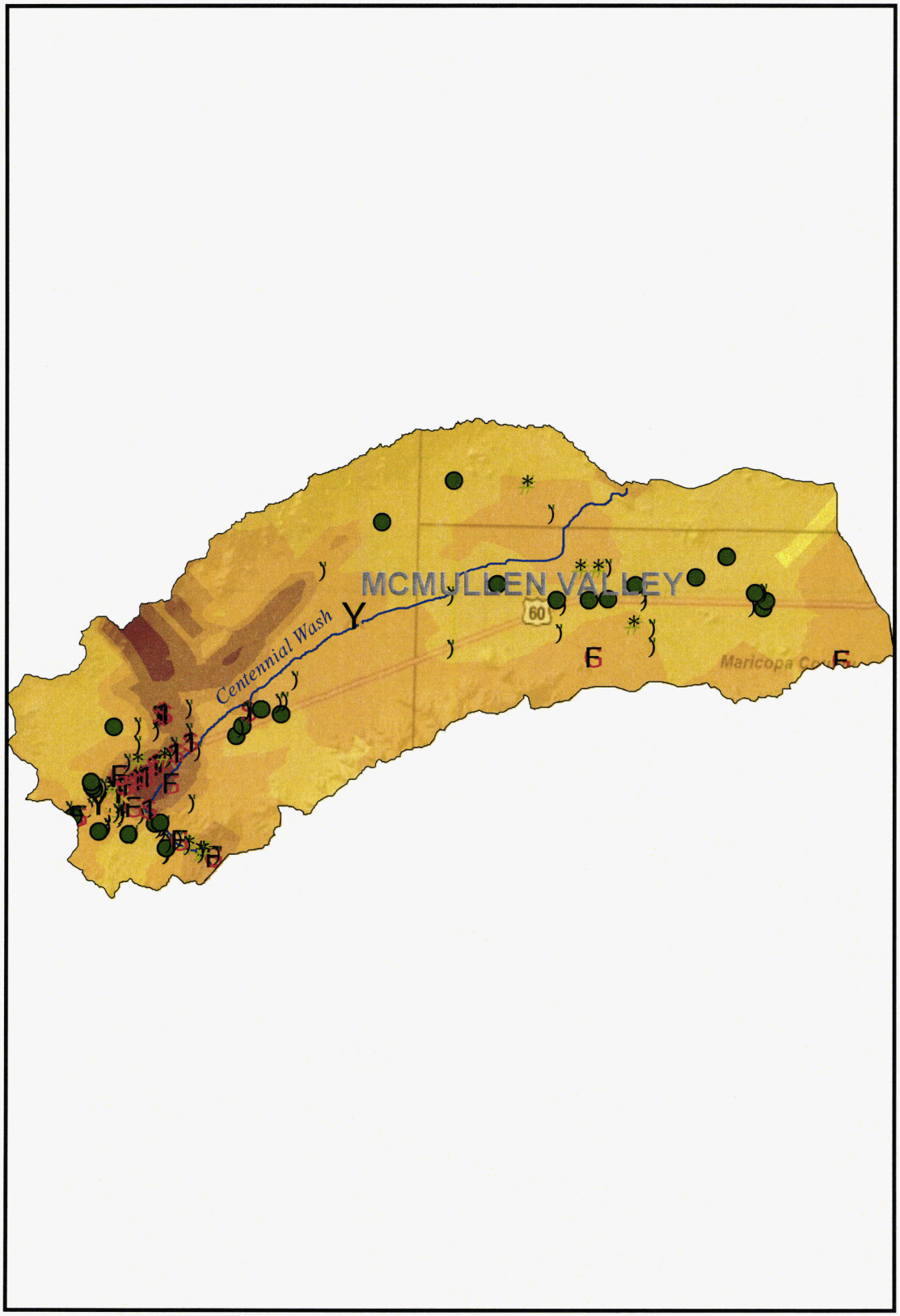
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

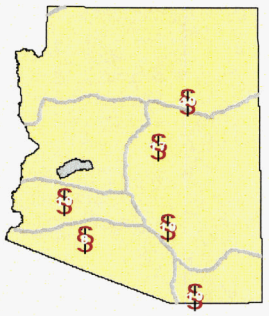
0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in McMullen Valley Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

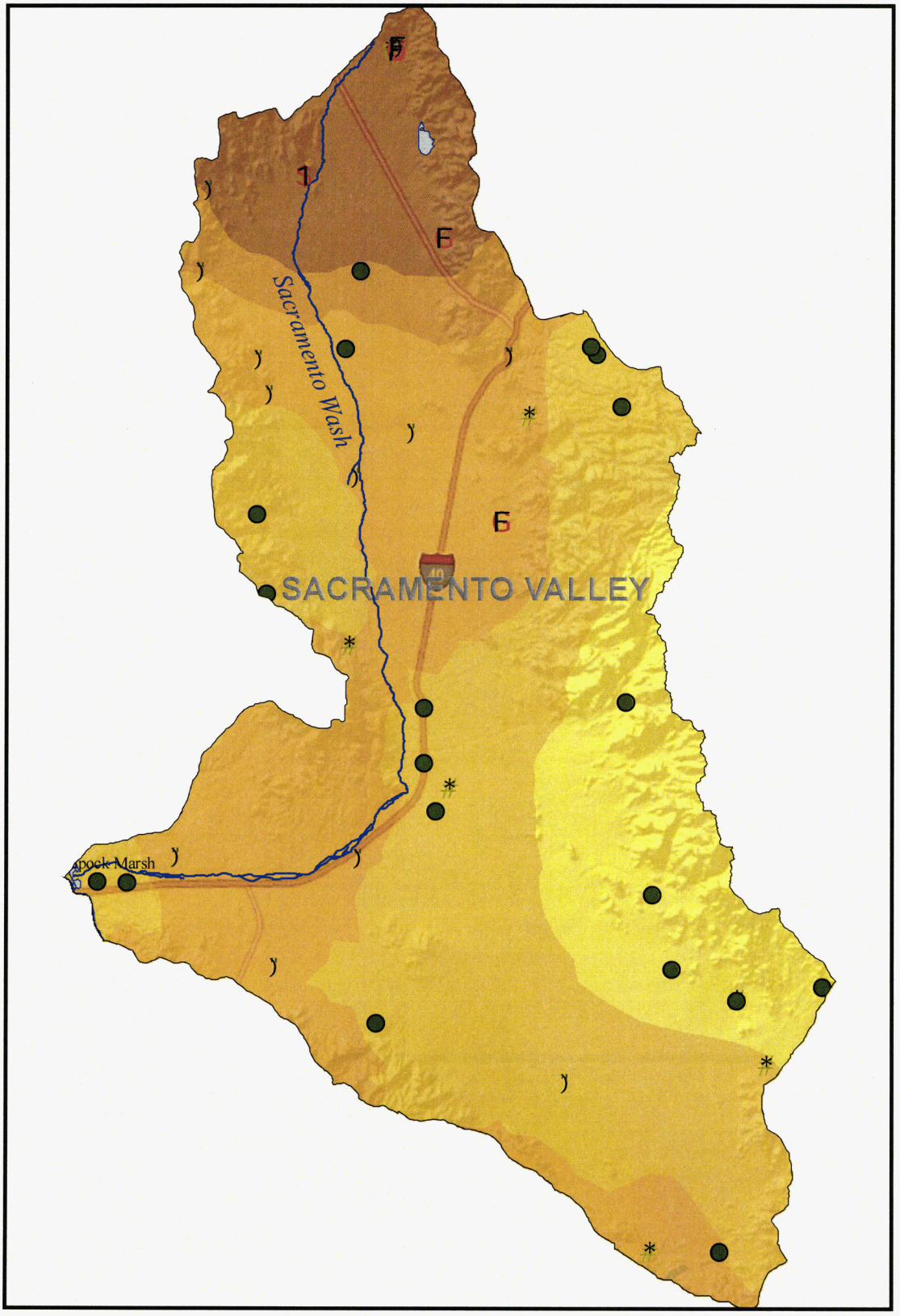
0 6 12

Miles

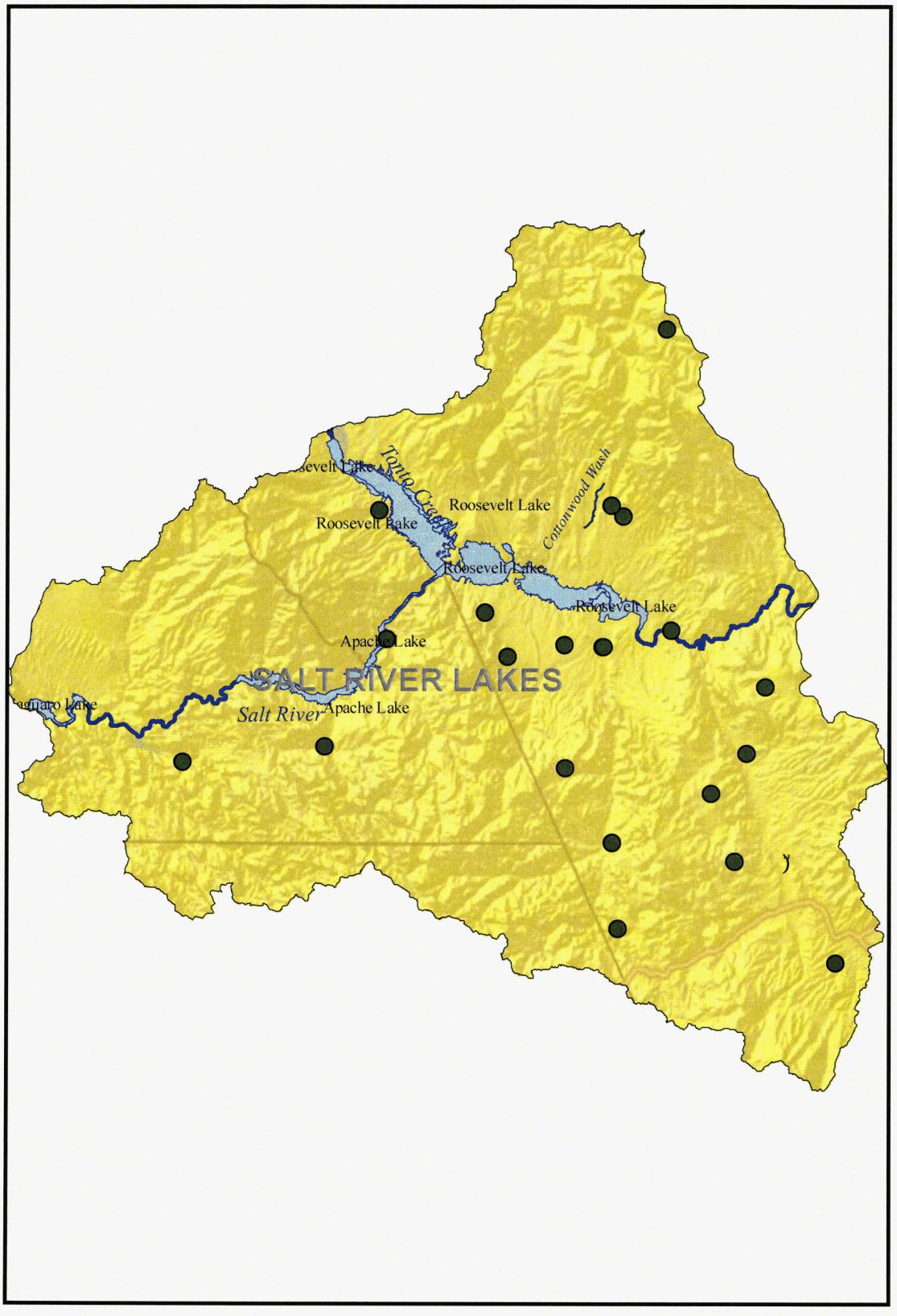
ADEQ Arizona Department of Environmental Quality

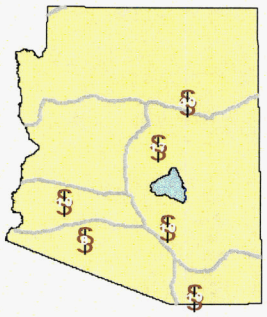
Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Sacramento Valley Groundwater Basin, Arizona



Actual and Inferred Nitrate (as Nitrogen) Concentrations in Salt River Groundwater Basin, Arizona
Salt River Lakes Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

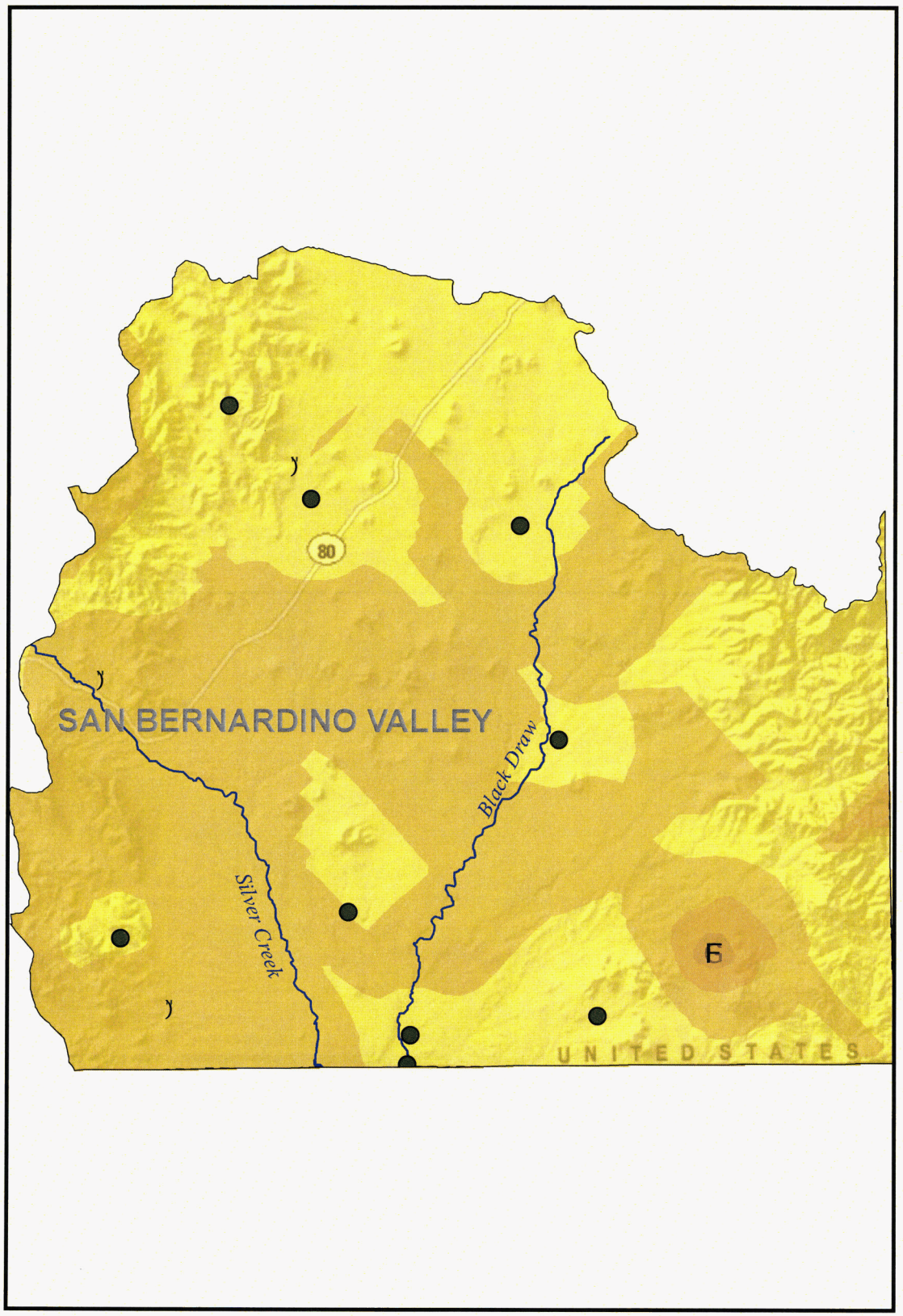
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

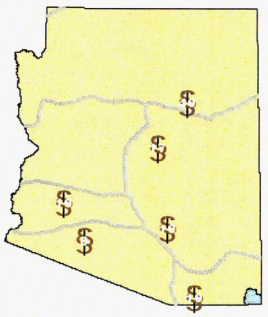
0 6 12
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in San Bernardino Valley Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

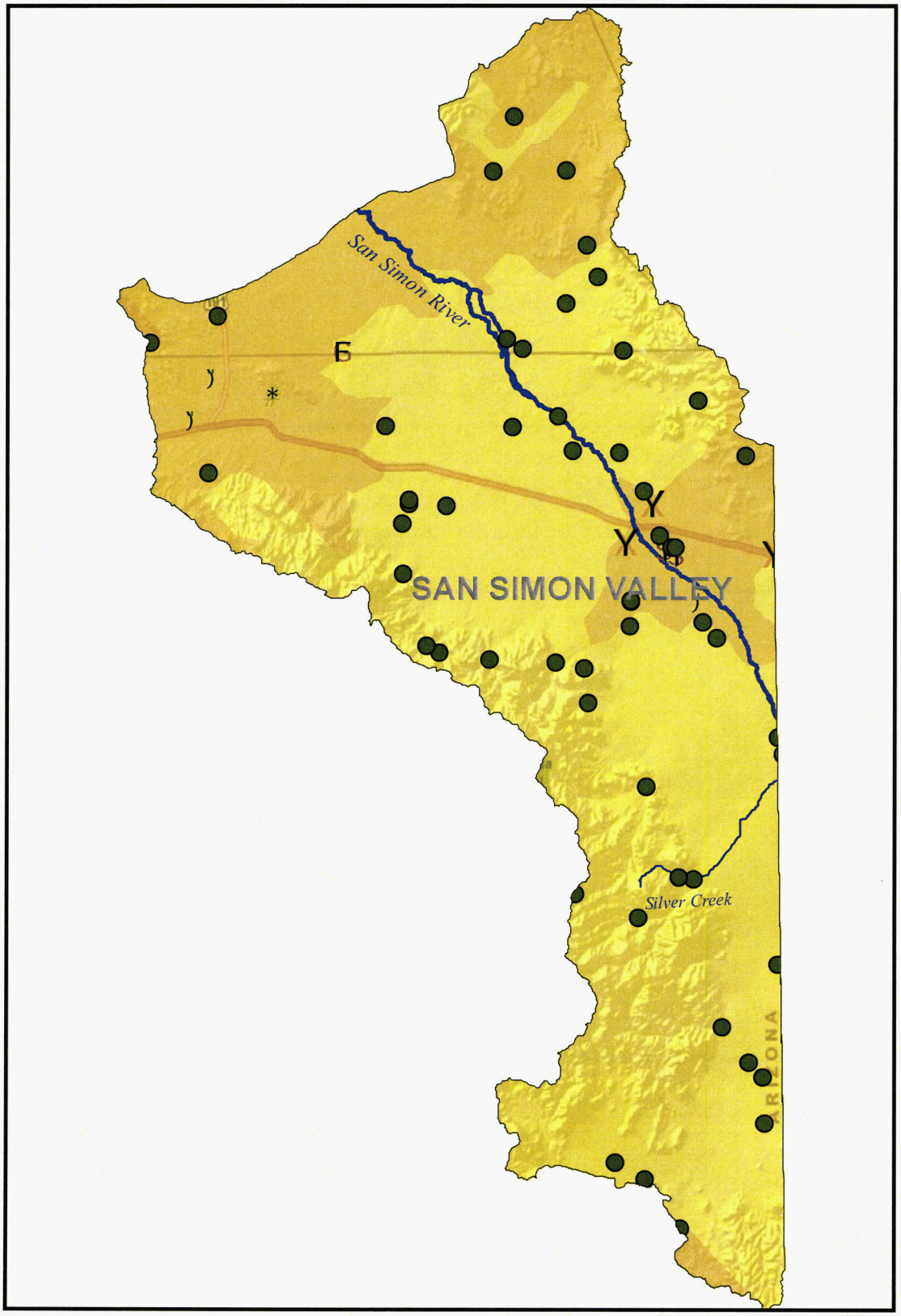
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

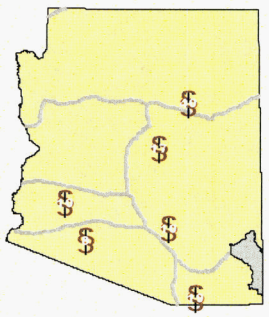
0 3 6
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Safford Groundwater Basin, Arizona
San Simon Valley Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

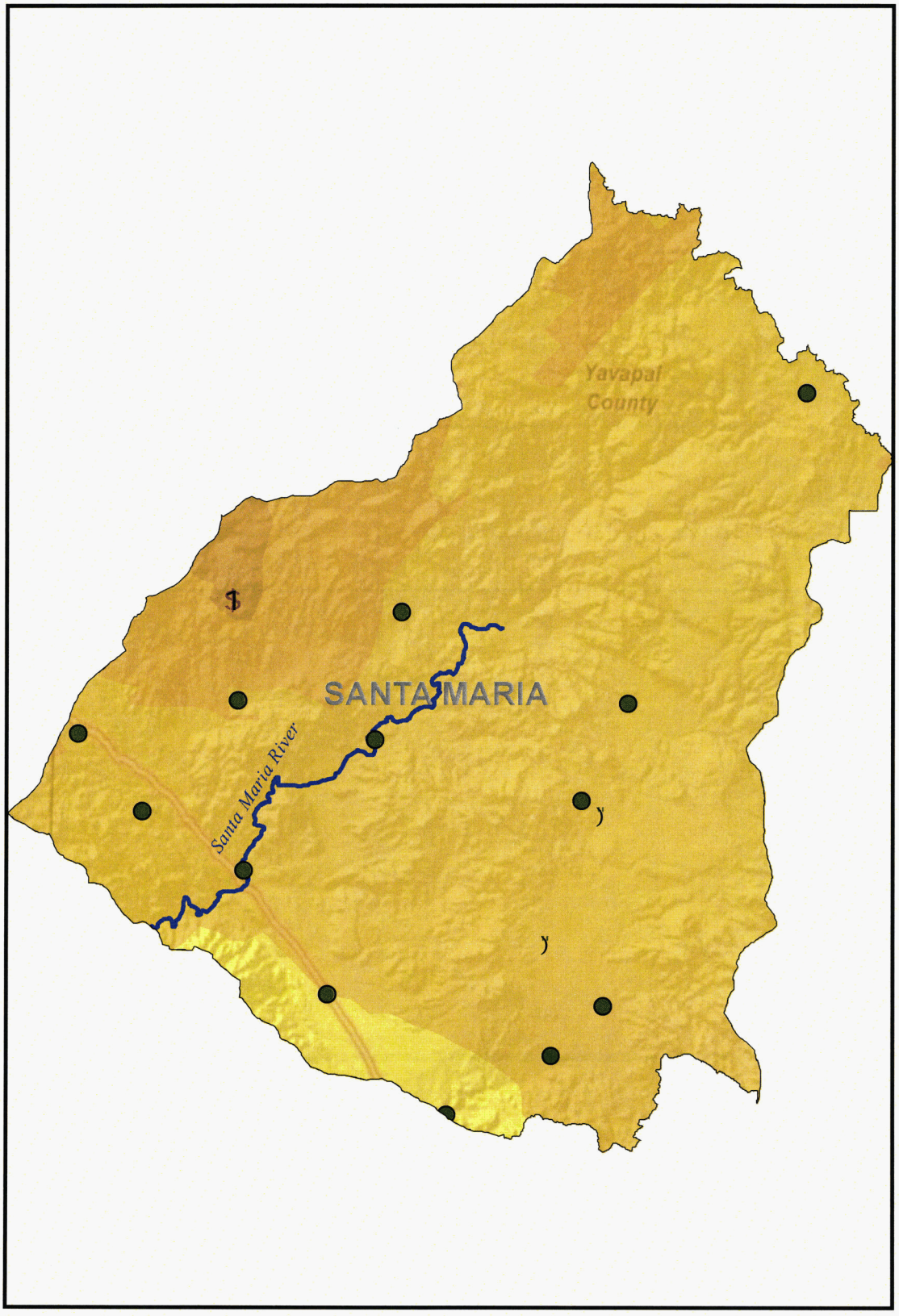
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

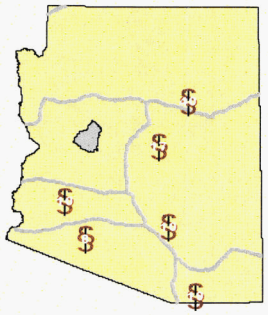
0 7.5 15
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistical\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Bill Williams Groundwater Basin, Arizona
Santa Maria Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

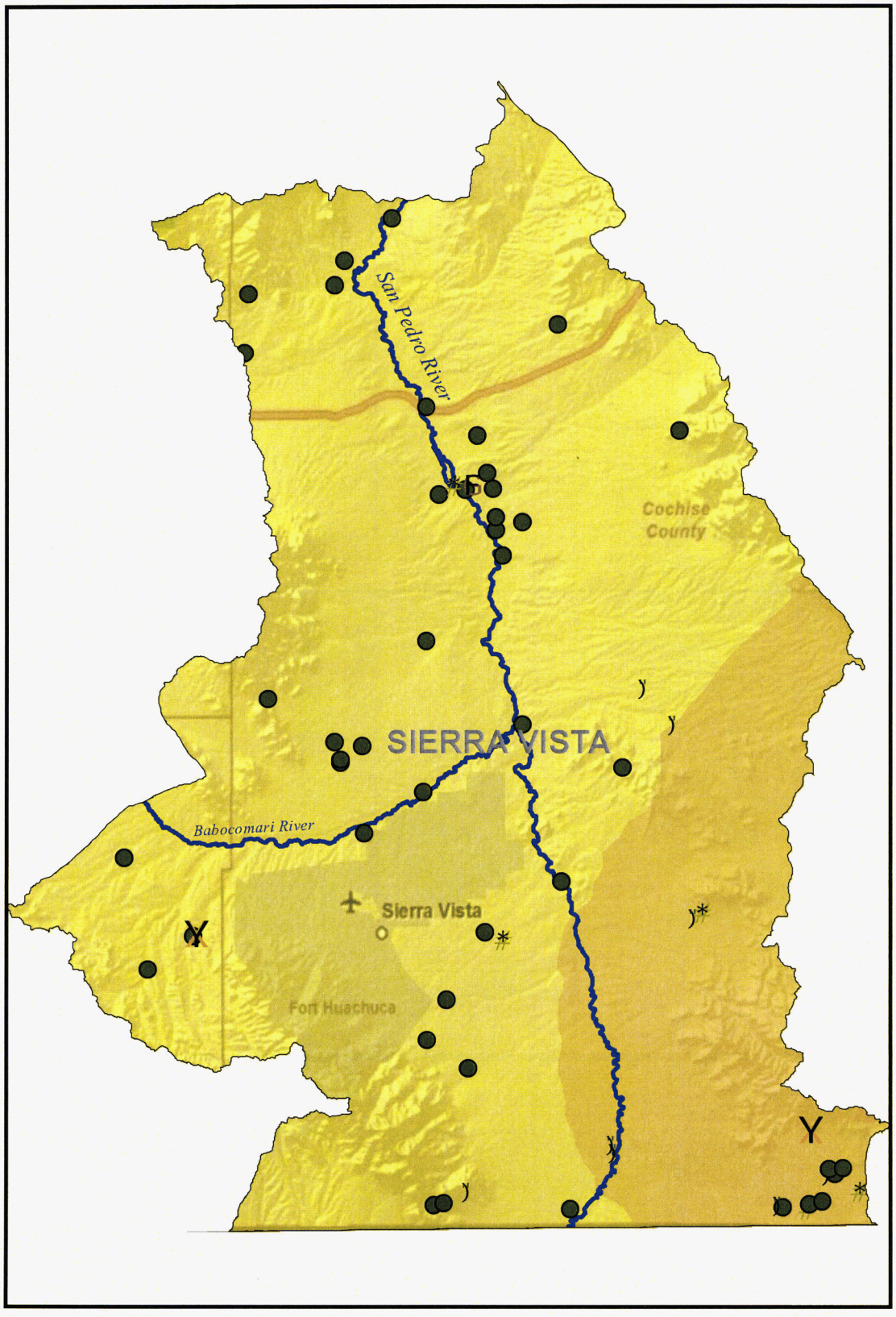
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

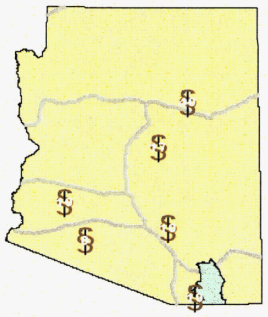
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Upper San Pedro Groundwater Basin, Arizona Sierra Vista Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

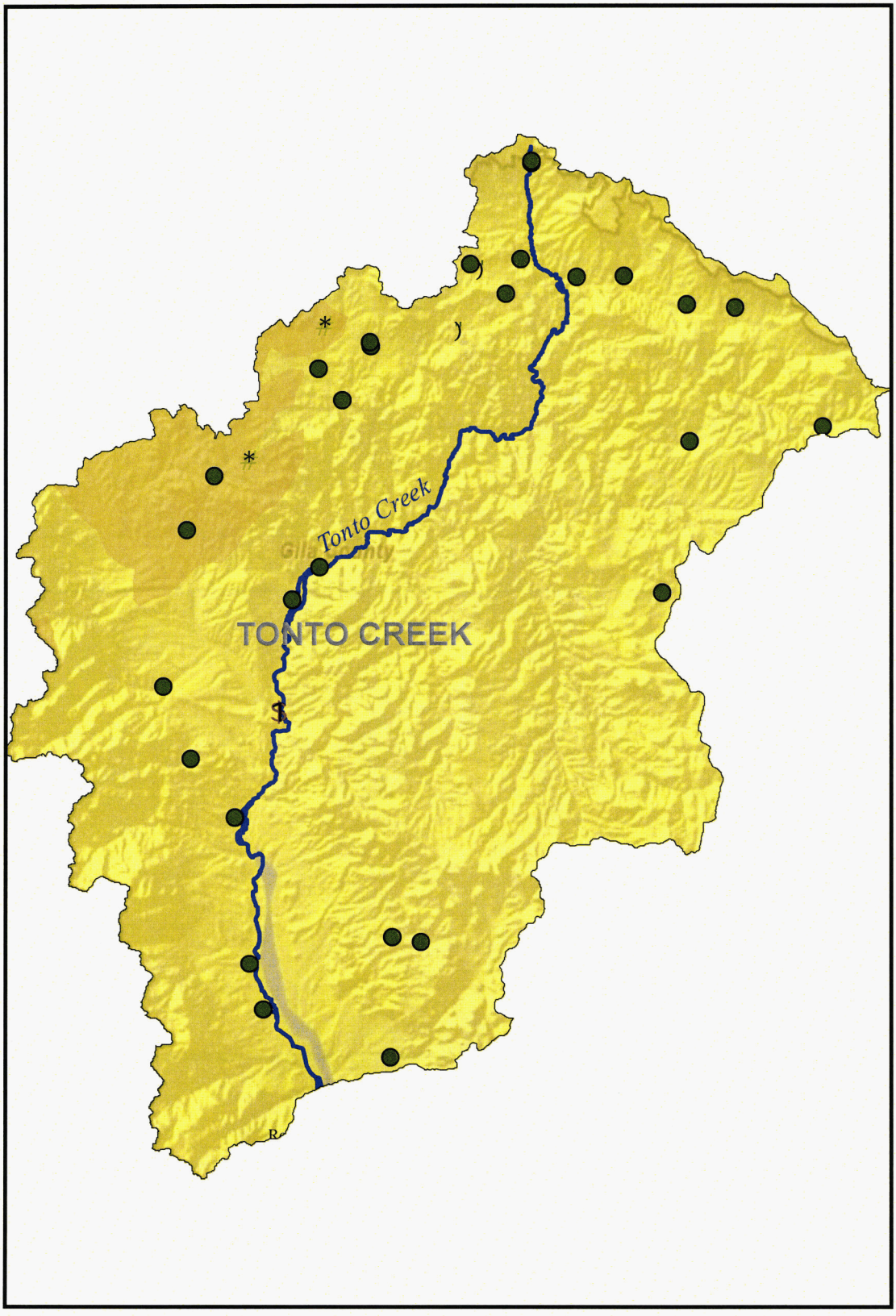
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

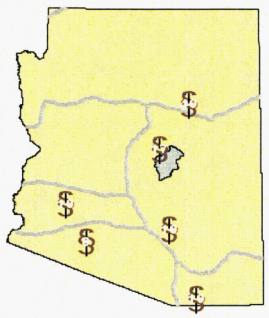
0 6 12
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway, 602-771-4454
S:\common\add\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Tonto Creek Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

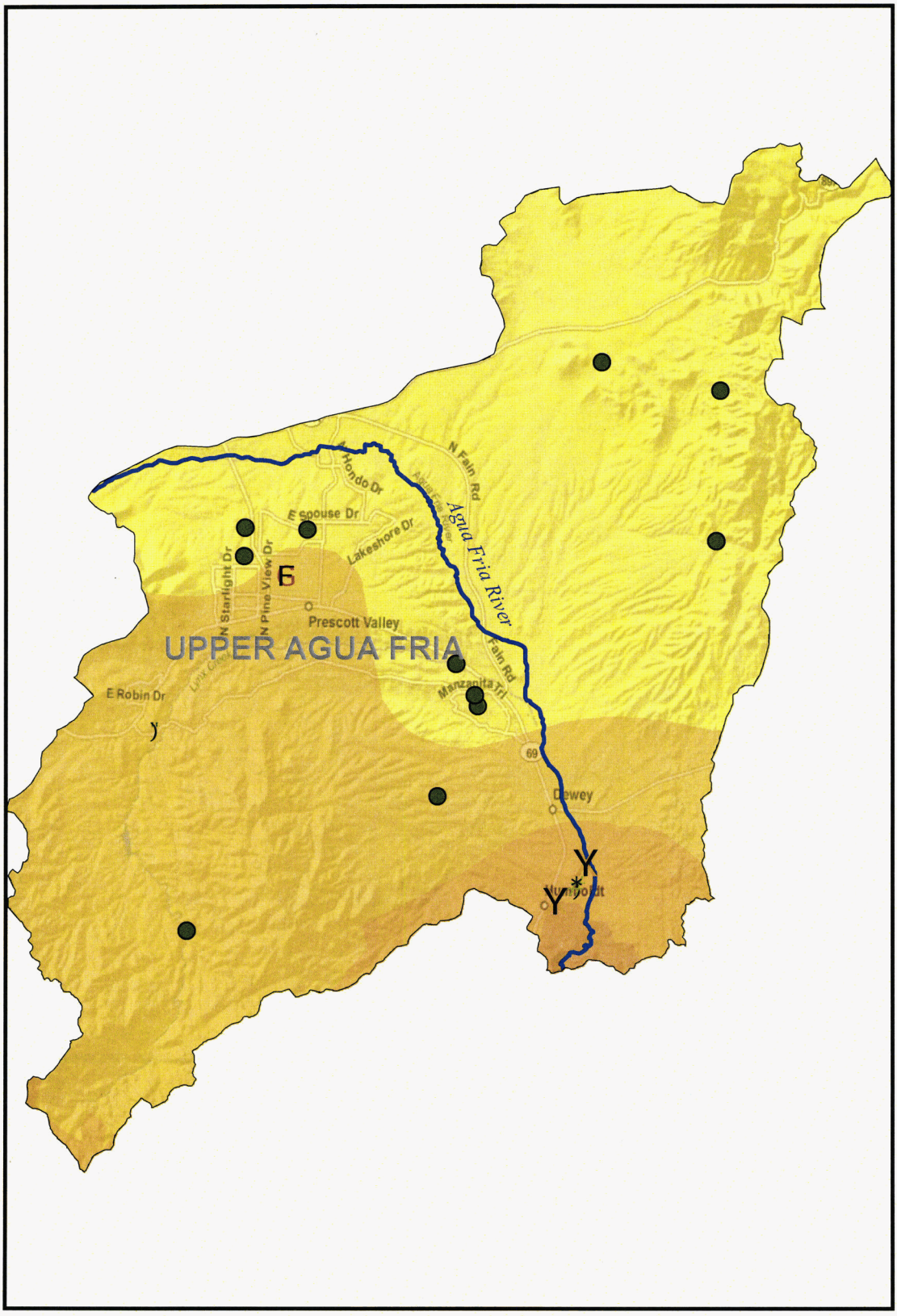
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

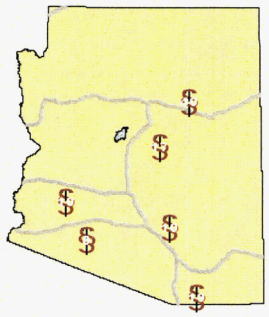
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostats\cs\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Prescott AMA Groundwater Basin, Arizona
Upper Agua Fria Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

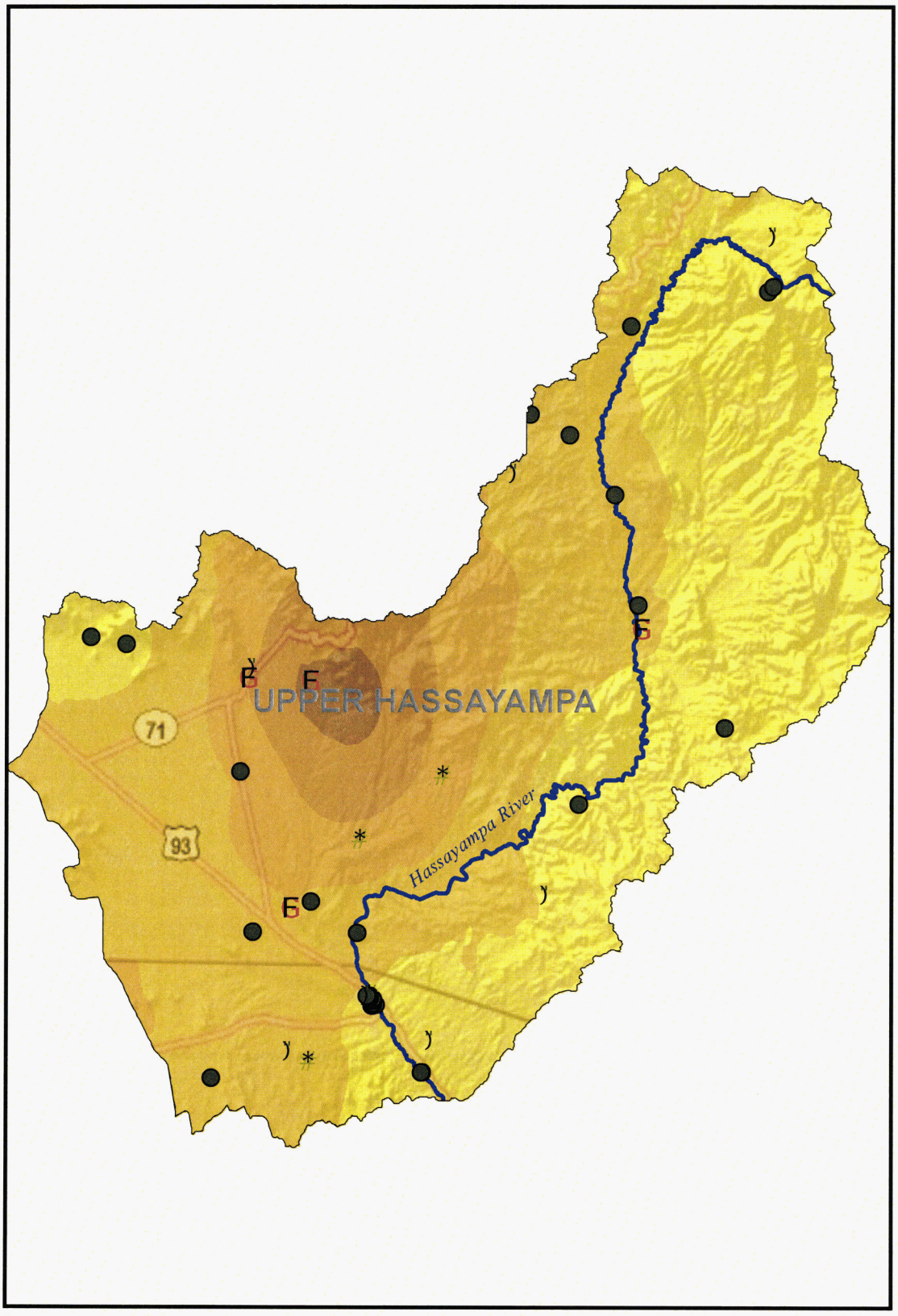
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

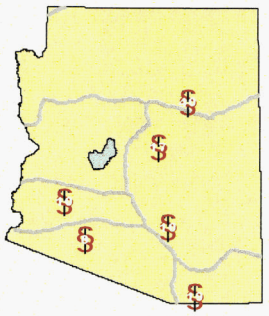
0 2 4
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Upper Hassayampa Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

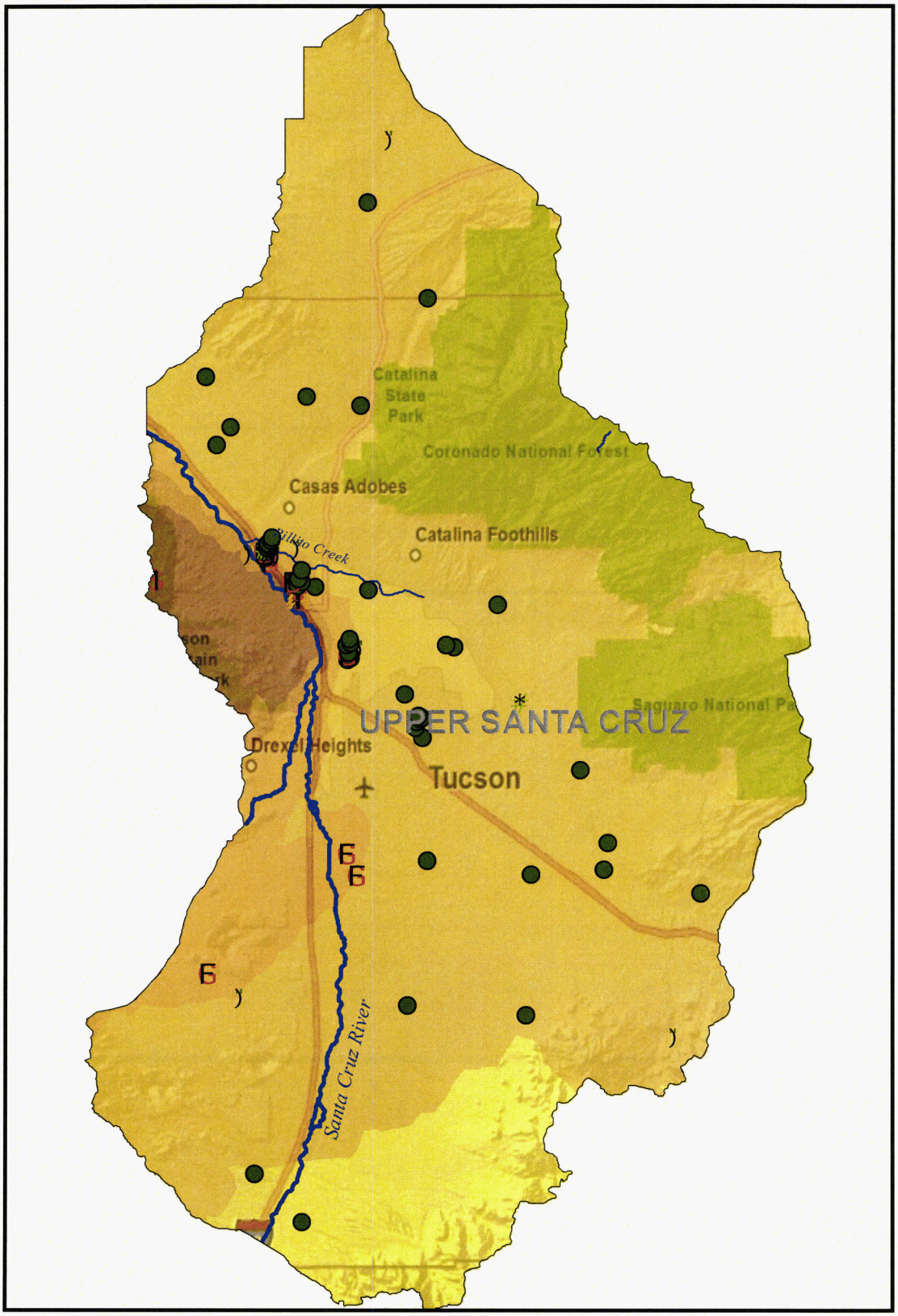
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

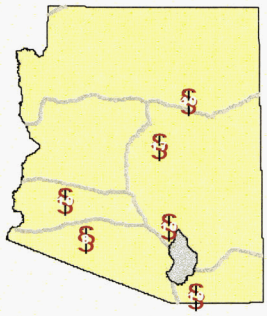
0 4 8
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Tucson AMA Groundwater Basin, Arizona
Upper Santa Cruz Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

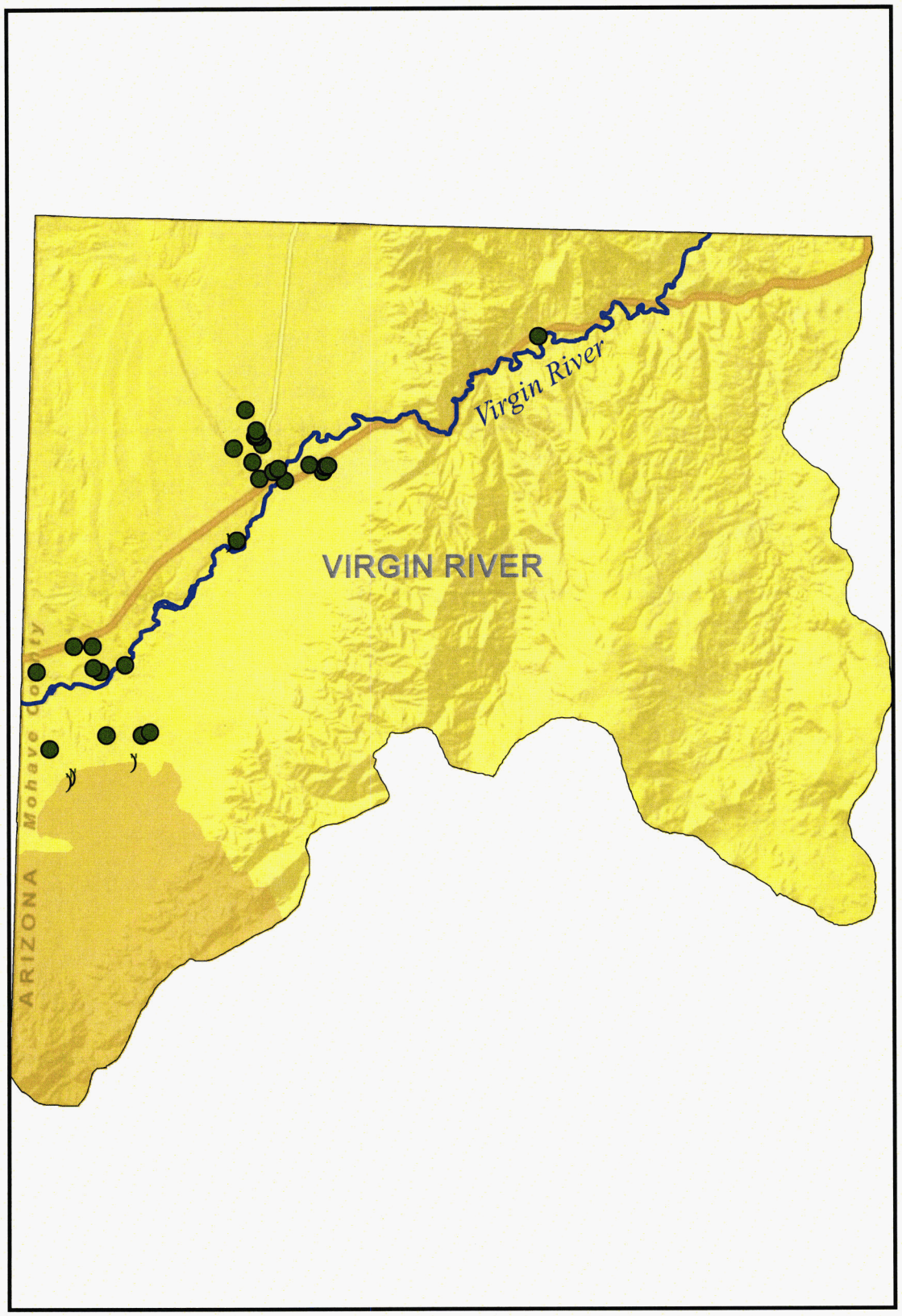
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

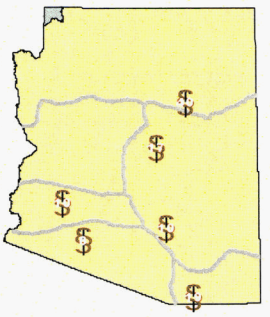
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistical\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Virgin River Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

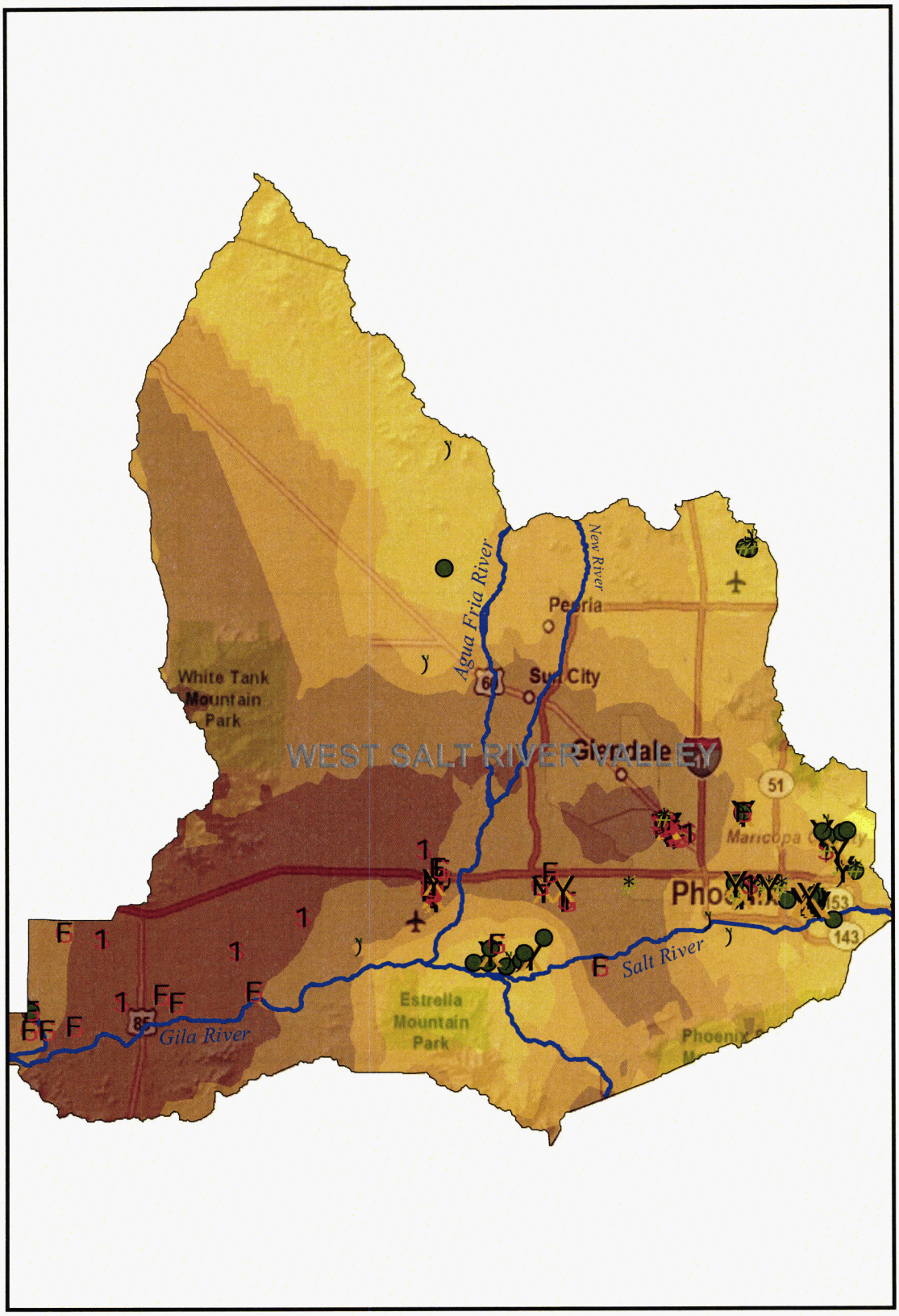
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

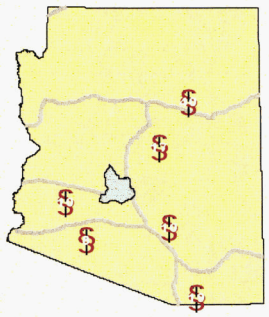
0 2.5 5
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway, 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Phoenix AMA Groundwater Basin, Arizona West Salt River Valley Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

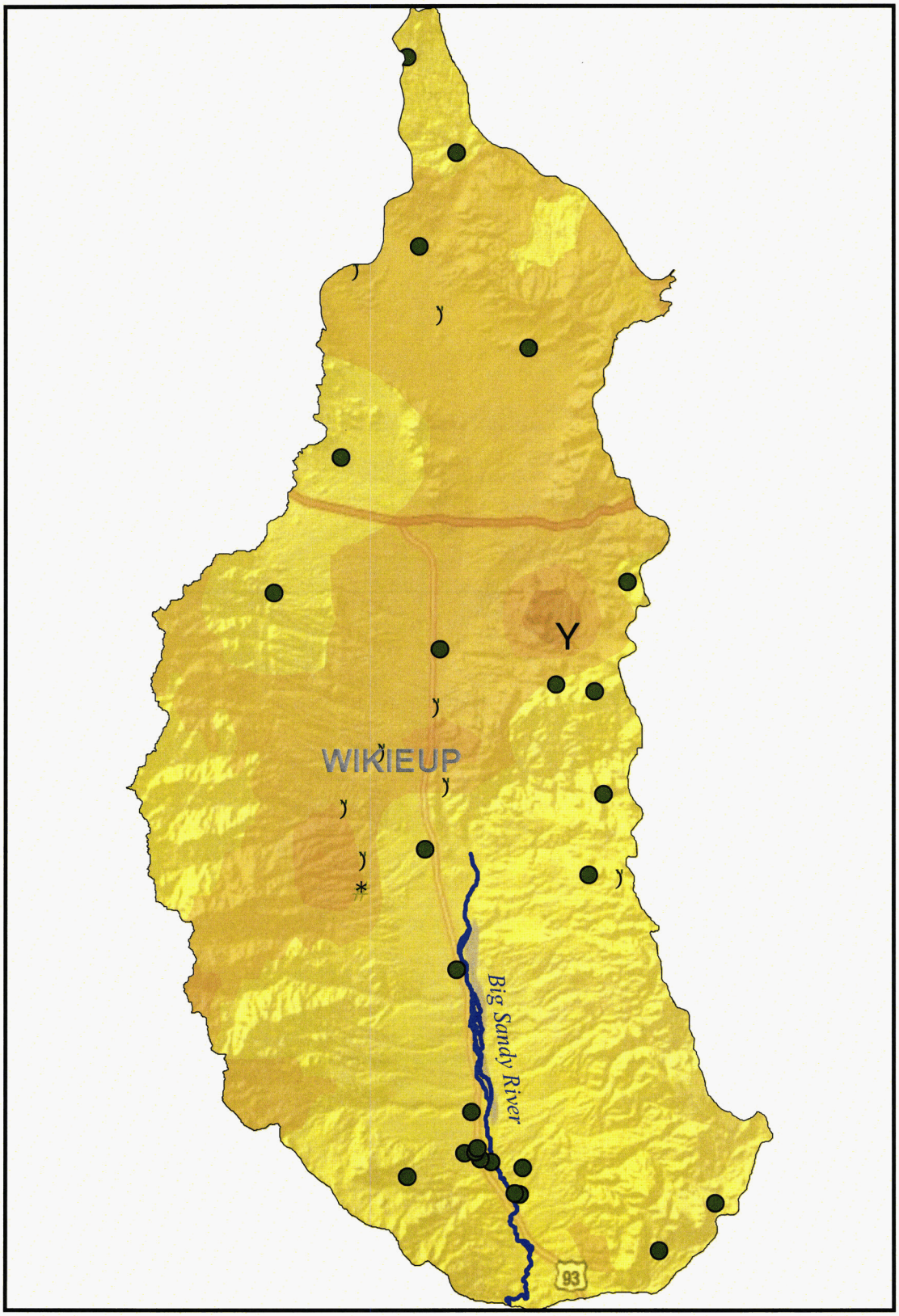
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

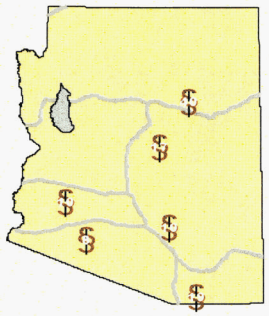
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdo\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Big Sandy Groundwater Basin, Arizona
Wikieup Sub-Basin





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

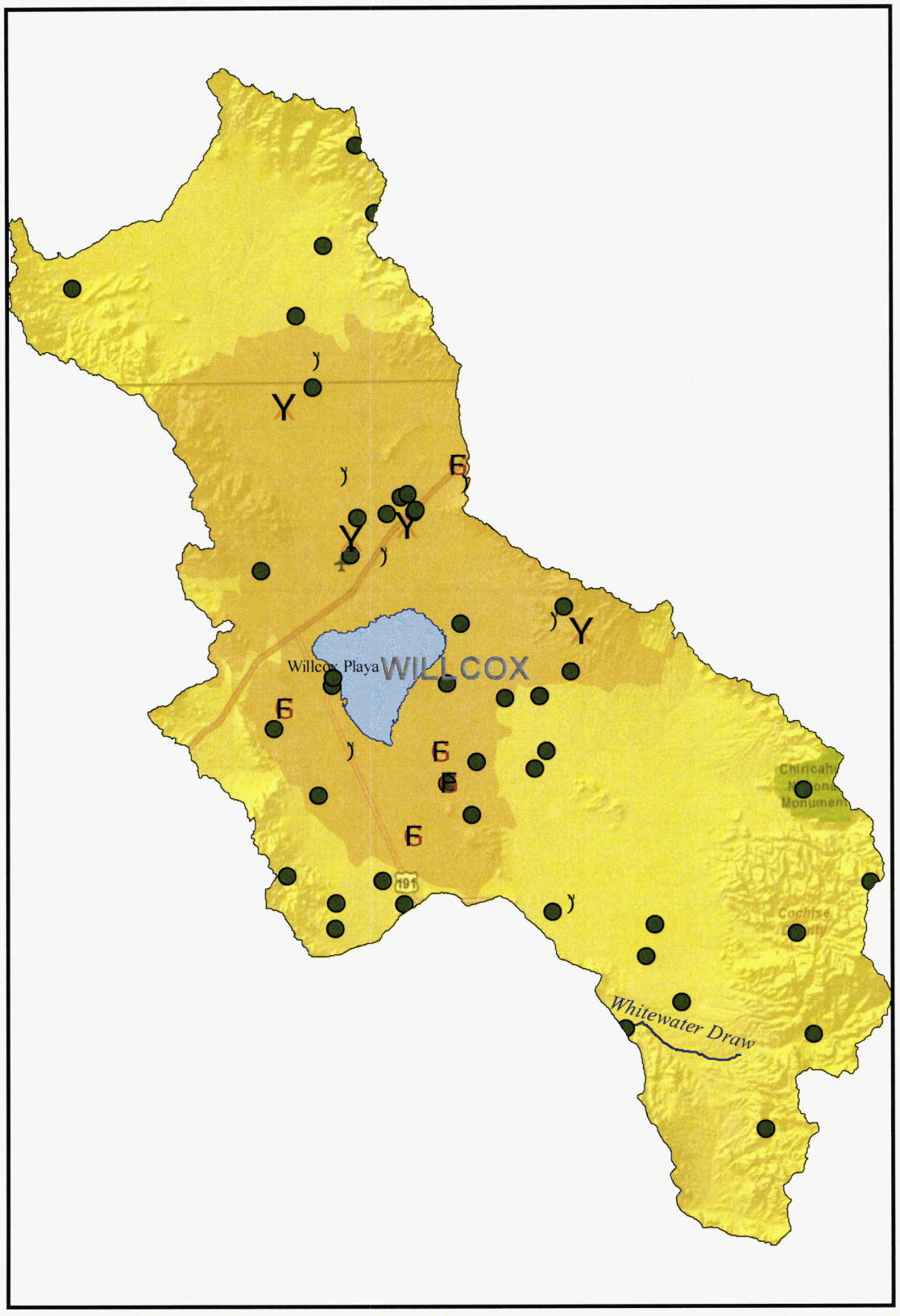
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

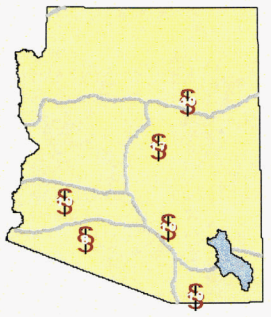
0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Willcox Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

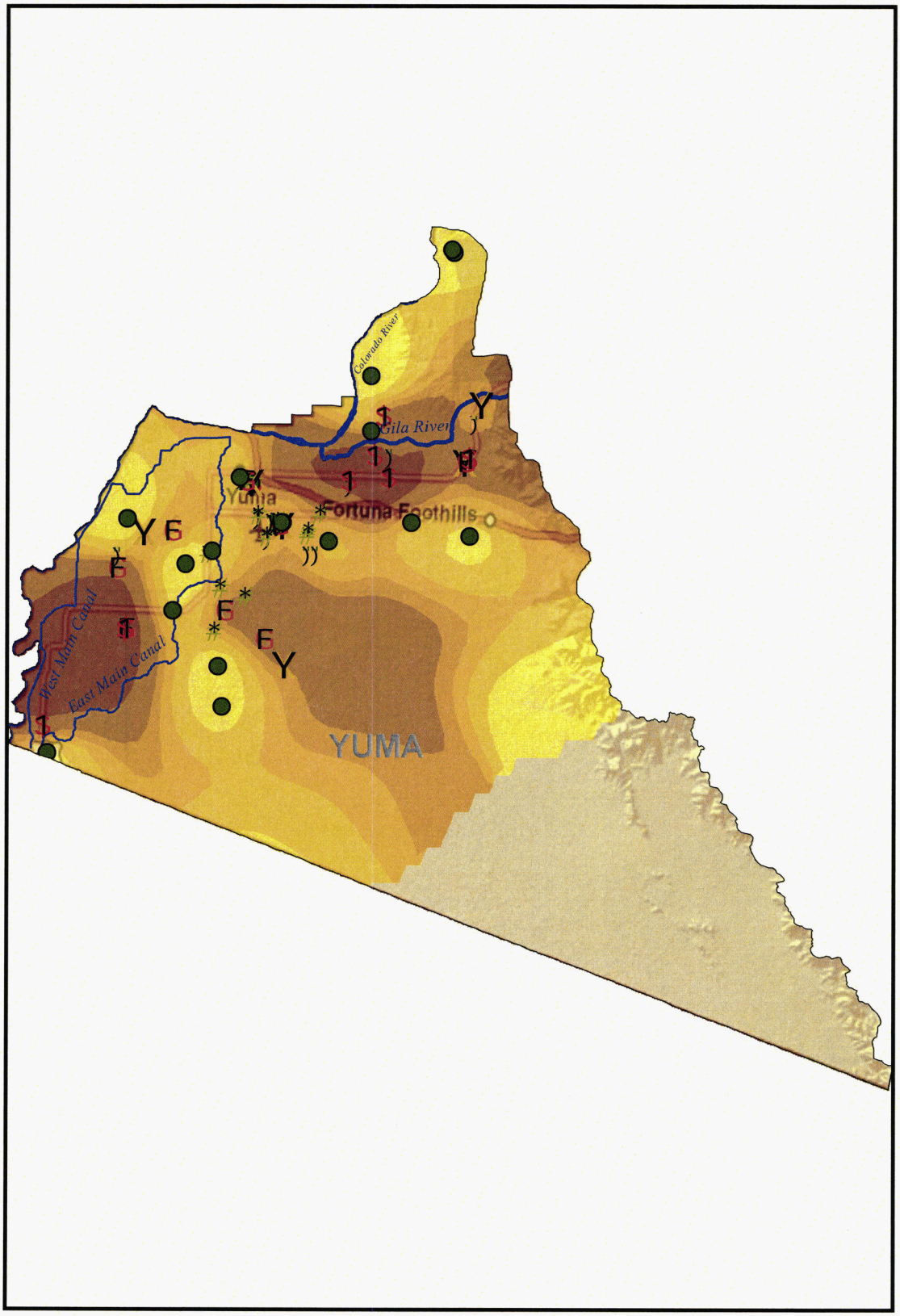
This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

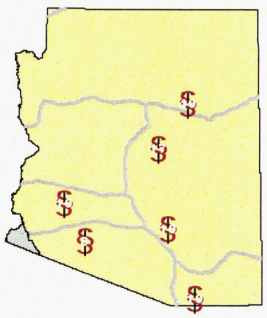
0 7 14
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdo\GW Geostatistics\Basins

Actual and Inferred Nitrate (as Nitrogen) Concentrations in Yuma Groundwater Basin, Arizona





Legend

Measured Nitrates (as N) Concentrations in mg/l

- 0.0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10.0
- >10.0 - 20.0
- > 20.0
- Lakes
- Minor Streams
- Major Streams
- Groundwater Basins

Inferred Nitrates (as N) by Ordinary Kriging in mg/l

- 0 - 2.5
- >2.5 - 5.0
- >5.0 - 7.5
- >7.5 - 10
- >10 - 20
- > 20
- World Street Map

Data Source: ADEQ Groundwater Quality Database (1995-2009)

This map is intended for regional use only and may not be all inclusive. Many complexities affect nitrate levels in groundwater and in a given well.

0 5 10
Miles

ADEQ Arizona Department of Environmental Quality

Steve Callaway 602-771-4454
S:\common\sdd\GW Geostatistics\Basins

FKS-23

Western Group Rate Case

Exhibit FKS-23

ARIZONA WATER COMPANY
PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION: Construct a 1,500 gpm Ion Exchange Nitrate Removal Facility at Pinal Valley Well No. 33, purchase property and construct a 500,000 gallon steel water storage tank and 3,000 gpm booster pump station.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 400,000	
	1	Treatment, Bypass, and Regeneration Piping	400,000	
	1	Ion Exchange Vessels and Media	1,100,000	
	1	Electrical and Instrumentation Controls, SCADA	450,000	
	1	Brine Regeneration System	600,000	
	1	Contracting Tax	125,000	
	1	Purchase Property	200,000	
	1	Construct 500,000 gallon welded steel water storage tank	600,000	
	1	Construct 3,000 gpm booster pump station	1,300,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 5,175,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			104,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			104,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 5,383,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			646,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			500,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 6,529,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	6,529,000

AFH

ARIZONA WATER COMPANY

PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION: Construct a 1,500 gpm Reverse Osmosis Nitrate Removal Facility at Pinal Valley Well No. 33, purchase property and construct a 500,000 gallon steel water storage tank and 3,000 gpm booster pump station.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 450,000	
	1	Pretreatment Filters	450,000	
	1	Chemical Systems for pH Adjustment and Scale Inhibitor	550,000	
	1	Treatment and Bypass Piping	650,000	
	1	Reverse Osmosis Treatment Trains and Feed Pumps	1,500,000	
	1	Building for Treatment Train and Chemical Systems	300,000	
	1	Electrical and Instrumentation Controls, SCADA	750,000	
	1	Waste Stream Handling System	750,000	
	1	Contracting Tax	200,000	
	1	Purchase Property	400,000	
	1	Construct 500,000 gallon welded steel water storage tank	600,000	
	1	Construct 3,000 gpm booster pump station	1,300,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 7,900,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			158,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			158,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 8,216,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			986,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			700,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 9,902,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	9,902,000

AFH

ARIZONA WATER COMPANY
PRELIMINARY COST ESTIMATE

DATE PREPARED:
7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION: Construct a 1,500 gpm Electrodialysis Nitrate Removal Facility at Pinal Valley Well No. 33, purchase property and construct a 500,000 gallon steel water storage tank and 3,000 gpm booster pump station.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 450,000	
	1	Pretreatment Filters	450,000	
	1	Chemical Systems for pH Adjustment and Scale Inhibitor	550,000	
	1	Treatment and Bypass Piping	650,000	
	1	Electrodialysis Treatment Trains	2,000,000	
	1	Building for Treatment Train and Chemical Systems	300,000	
	1	Electrical and Instrumentation Controls, SCADA	1,250,000	
	1	Waste Stream Handling System	750,000	
	1	Contracting Tax	225,000	
	1	Purchase Property	400,000	
	1	Construct 500,000 gallon welded steel water storage tank	600,000	
	1	Construct 3,000 gpm booster pump station	1,300,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 8,925,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			179,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			179,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 9,283,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			1,114,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			800,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 11,197,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	11,197,000

AFH

Western Group Rate Case

Exhibit FKS-24

Pinal Valley Well No. 7 Nitrate Removal Facility Project Description

Background

Arizona Water Company drilled Pinal Valley Well No. 7 in 1956. Since the well was completed nitrate concentrations have trended upwards, are currently above 9 mg/L and continue to increase. The United States Environmental Protection Agency Maximum Contaminant Level for nitrate is 10 mg/L. Exceeding this MCL is a Tier 1 violation requiring public notice within 24 hours of the violation. Arizona Water Company engineers evaluated multiple nitrate mitigation alternatives and determined constructing a nitrate removal facility is the most certain and cost effective solution to remove high nitrate concentrations from drinking water.

Location

Pinal Valley Well No. 7 is located at 125 W. Northern Road in Coolidge, Arizona, east of Highway 87 along Northern Road, in the Company's Pinal Valley water system.

Objective

Reduce the nitrate concentration in water from Pinal Valley Well No. 7 to comply with Safe Drinking Water Act.

Project Description

Currently Well No. 7 pumps to a water storage tank, then to the distribution system through a booster pump station. Arizona Water Company will purchase property to construct a nitrate removal facility. Arizona Water Company will investigate a suitable location near Well No. 7.

Arizona Water Company will pump groundwater from Pinal Valley Well No. 7 through the nitrate removal facility utilizing ion exchange technology to reduce elevated nitrate concentrations. The treated groundwater is pumped to the storage tank where the booster pump station will pump the water into the distribution system.

The nitrate removal facility will utilize ion exchange technology with a salt brine regeneration system. Major components of the nitrate removal facility include coated carbon steel treatment vessels, salt brine tank, recycle tank and waste tanks. Arizona Water Company will use ductile iron or other compatible pipe materials for the vessel face piping. The fully automated regeneration process will use motor operated valves and online analyzers to regenerate the ion exchange resin when it is saturated with nitrates. Arizona Water Company will integrate the nitrate removal facility into its existing Pinal Valley SCADA system.

Arizona Water Company will size the nitrate removal facility to treat 1,250 gallons per minute, the production capacity of Pinal Valley Well No. 7. The nitrate removal facility will treat a design raw water nitrate concentration of 15 mg/L down to a target treated nitrate concentration of 7 mg/L. The nitrate removal facility will include bypass piping to blend raw water with treated water to reach the 7 mg/L goal.

Arizona Water Company engineers estimate the cost to design and construct the nitrate removal facility, tank and booster pump station is $3.5 million.

ARIZONA WATER COMPANY

PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION:
Construct a 1,250 gpm Nitrate Removal Facility at Pinal Valley Well No. 7.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 400,000	
	1	Treatment, Bypass, and Regeneration Piping	350,000	
	1	Ion Exchange Vessels and Media	1,000,000	
	1	Electrical and Instrumentation Controls	400,000	
	1	Brine Regeneration System	500,000	
	1	Contracting Tax	50,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 2,700,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			54,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			54,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 2,808,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			337,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			325,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 3,470,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	3,470,000

AFH

Pinal Valley Well No. 27 Nitrate Removal Facility Project Description

Background

Arizona Water Company drilled Pinal Valley Well No. 27 in 1998. After the well was completed, nitrate concentrations were approximately 7 mg/L. Since that time, nitrate concentrations have trended upwards, are currently above 12 mg/L and continue to increase. AWC blends water from Well No. 27 with another low nitrate source to reduce the blended nitrate concentration to 9 mg/L prior to entry into the distribution system. The United States Environmental Protection Agency Maximum Contaminant Level for nitrate is 10 mg/L. Exceeding this MCL is a Tier 1 violation requiring public notice within 24 hours of the violation. Arizona Water Company engineers evaluated multiple nitrate mitigation alternatives and determined constructing a nitrate removal facility is the most certain and cost effective solution to remove high nitrate concentrations from drinking water.

Location

Pinal Valley Well No. 27 is located at 7317 W. McCartney Road in Casa Grande, Arizona, east of I-10, along McCartney Road in the Company's Pinal Valley water system.

Objective

Reduce the nitrate concentration in water from Pinal Valley Well No. 27 to comply with Safe Drinking Water Act.

Project Description

Currently Well No. 27 pumps to a water storage tank where it blends with another low nitrate source to reduce the blended nitrate concentration to 9 mg/L, then to the distribution system through a booster pump station.

Arizona Water Company will pump groundwater from Pinal Valley Well No. 27 through an on-site nitrate removal facility utilizing ion exchange technology to reduce elevated nitrate concentrations. The treated groundwater is pumped to the on-site water storage tank where the existing booster pump station will pump the water into the distribution system.

The nitrate removal facility will utilize ion exchange technology with a salt brine regeneration system. Major components of the nitrate removal facility include coated carbon steel treatment vessels, salt brine tank, recycle tank and waste tanks. Arizona Water Company will use ductile iron or other compatible pipe materials for the vessel face piping. The fully automated regeneration process will use motor operated valves and online analyzers to regenerate the ion exchange resin when it is saturated with nitrates. Arizona Water Company will integrate the nitrate removal facility into its existing Pinal Valley SCADA system.

Arizona Water Company will size the nitrate removal facility to treat 500 gallons per minute, the production capacity of Pinal Valley Well No. 27. The nitrate removal facility will treat a design raw water nitrate concentration of 18 mg/L down to a target treated nitrate concentration of 7 mg/L. The nitrate removal facility will include bypass piping to blend raw water with treated water to reach the 7 mg/L goal.

Arizona Water Company engineers estimate the cost to design and construct the nitrate removal facility, tank and booster pump station is $2.4 million.

ARIZONA WATER COMPANY
PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION:
Construct a 500 gpm Nitrate Removal Facility at Pinal Valley Well No. 27.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 300,000	
	1	Treatment, Bypass, and Regeneration Piping	200,000	
	1	Ion Exchange Vessels and Media	750,000	
	1	Electrical and Instrumentation Controls	300,000	
	1	Brine Regeneration System	250,000	
	1	Contracting Tax	50,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 1,850,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			37,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			37,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 1,924,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			231,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			225,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 2,380,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	2,380,000

AFH

Pinal Valley Well No. 32 Nitrate Removal Facility Project Description

Background

Arizona Water Company drilled Pinal Valley Well No. 32 in 2007. After the well was completed, nitrate concentrations were approximately 7 mg/L. Since that time, nitrate concentrations have trended upwards, are currently above 9 mg/L and continue to increase. The United States Environmental Protection Agency Maximum Contaminant Level for nitrate is 10 mg/L. Exceeding this MCL is a Tier 1 violation requiring public notice within 24 hours of the violation. Arizona Water Company engineers evaluated multiple nitrate mitigation alternatives and determined constructing a nitrate removal facility is the most certain and cost effective solution to remove high nitrate concentrations from drinking water.

Location

Pinal Valley Well No. 32 is located at 278 E. Santa Ynez in Casa Grande, Arizona, east of I-10, south of Florence Blvd. in the Company's Pinal Valley water system.

Objective

Reduce the nitrate concentration in water from Pinal Valley Well No. 32 to comply with Safe Drinking Water Act.

Project Description

Currently Well No. 32 pumps directly to the distribution system. However, Industry practice is for the well to pump to a water storage tank, then to the distribution system through a booster pump station. Arizona Water Company will purchase property to construct a water storage tank and booster pump station. Arizona Water Company is currently investigating a suitable location near Well No. 32.

Arizona Water Company will pump groundwater from Pinal Valley Well No. 32 through an on-site nitrate removal facility utilizing ion exchange technology to reduce elevated nitrate concentrations. The treated groundwater is pumped to an off-site water storage tank where a booster pump station will pump the water into the distribution system.

The nitrate removal facility will utilize ion exchange technology with a salt brine regeneration system. Major components of the nitrate removal facility include coated carbon steel treatment vessels, salt brine tank, recycle tank and waste tanks. Arizona Water Company will use ductile iron or other compatible pipe materials for the vessel face piping. The fully automated regeneration process will use motor operated valves and online analyzers to regenerate the ion exchange resin when it is saturated with nitrates. Arizona Water Company will integrate the nitrate removal facility into its existing Pinal Valley SCADA system.

Arizona Water Company will size the nitrate removal facility to treat 1,500 gallons per minute, the production capacity of Pinal Valley Well No. 32. The nitrate removal facility will treat a design raw water nitrate concentration of 15 mg/L down to a target treated nitrate concentration of 7 mg/L. The nitrate removal facility will include bypass piping to blend raw water with treated water to reach the 7 mg/L goal.

Arizona Water Company will construct a 500,000 gallon welded steel water storage tank on the purchased property. It is critical to have a water storage tank to limit the starts and stops of a treatment plant and well. A 3,000 gallon per minute booster pump station will pump water from the water storage tank into the distribution system. The booster pump station is sized with firm capacity to pump the sum of 1,500 gallons per minute from Well No. 32 and 1,500 gallons per minute for local fire flow.

Well No. 32 and the purchased property are located within the Mission Royale subdivision and bound by its Covenants, Conditions, and Restrictions. Arizona Water Company must amend the Covenants, Conditions, and Restrictions and obtain a Conditional Use Permit from the City of Casa Grande to construct the nitrate removal facility, water storage tank, and booster pump station.

Arizona Water Company engineers estimate the cost to design and construct the nitrate removal facility, tank and booster pump station is $6.5 million.

ARIZONA WATER COMPANY

PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION: Construct a 1,500 gpm Nitrate Removal Facility at Pinal Valley Well No. 32, purchase property and construct a 500,000 gallon steel water storage tank and 3,000 gpm booster pump station.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 400,000	
	1	Treatment, Bypass, and Regeneration Piping	400,000	
	1	Ion Exchange Vessels and Media	1,100,000	
	1	Electrical and Instrumentation Controls, SCADA	450,000	
	1	Brine Regeneration System	600,000	
	1	Contracting Tax	125,000	
	1	Purchase Property	200,000	
	1	Construct 500,000 gallon welded steel water storage tank	600,000	
	1	Construct 3,000 gpm booster pump station	1,300,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 5,175,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			104,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			104,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 5,383,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			646,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			500,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 6,529,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	6,529,000

AFH

Pinal Valley Well No. 33 Nitrate Removal Facility Project Description

Background

Arizona Water Company drilled Pinal Valley Well No. 33 in 2007. After the well was completed, nitrate concentrations were approximately 7 mg/L. Since that time, nitrate concentrations have trended upwards, are currently above 9 mg/L and continue to increase, as shown in Figure 1. The United States Environmental Protection Agency Maximum Contaminant Level for nitrate is 10 mg/L. Exceeding this MCL is a Tier 1 violation requiring public notice within 24 hours of the violation. Arizona Water Company engineers evaluated multiple nitrate mitigation alternatives and determined constructing a nitrate removal facility is the most certain and cost effective solution to remove high nitrate concentrations from drinking water.

Location

Pinal Valley Well No. 33 is located at 2602 E. Hancock in Casa Grande, Arizona, east of I-10, south of Florence Blvd. in the Company's Pinal Valley water system.

Objective

Reduce the nitrate concentration in water from Pinal Valley Well No. 33 to comply with Safe Drinking Water Act.

Project Description

Currently Well No. 33 pumps directly to the distribution system. However, Industry practice is for the well to pump to a water storage tank, then to the distribution system through a booster pump station. Arizona Water Company will purchase property to construct a water storage tank and booster pump station. Arizona Water Company is currently investigating a suitable location near Well No. 33.

Arizona Water Company will pump groundwater from Pinal Valley Well No. 33 through an on-site nitrate removal facility utilizing ion exchange technology to reduce elevated nitrate concentrations. The treated groundwater is pumped to an off-site water storage tank where a booster pump station will pump the water into the distribution system.

The nitrate removal facility will utilize ion exchange technology with a salt brine regeneration system. Major components of the nitrate removal facility include coated carbon steel treatment vessels, salt brine tank, recycle tank and waste tanks. Arizona Water Company will use ductile iron or other compatible pipe materials for the vessel face piping. The fully automated regeneration process will use motor operated valves and online analyzers to regenerate the ion exchange resin when it is saturated with nitrates. Arizona Water Company will integrate the nitrate removal facility into its existing Pinal Valley SCADA system. A conceptual design of the nitrate removal facility is provided on Figure 2.

Arizona Water Company will size the nitrate removal facility to treat 1,500 gallons per minute, the production capacity of Pinal Valley Well No. 33. The nitrate removal facility will treat a design raw water nitrate concentration of 15 mg/L down to a target treated nitrate concentration of 7 mg/L. The nitrate removal facility will include bypass piping to blend raw water with treated water to reach the 7 mg/L goal.

Arizona Water Company will construct a 500,000 gallon welded steel water storage tank on the purchased property. It is critical to have a water storage tank to limit the starts and stops of a treatment plant and well. A 3,000 gallon per minute booster pump station will pump water from the water storage tank into the distribution system. The booster pump station is sized with firm capacity to pump the sum of 1,500 gallons per minute from Well No. 33 and 1,500 gallons per minute for local fire flow. A conceptual design of the water storage tank and booster pump station is provided on Figure 3.

Well No. 33 and the purchased property are located within the Mission Royale subdivision and bound by its Covenants, Conditions, and Restrictions. Arizona Water Company must amend the Covenants, Conditions, and Restrictions and obtain a Conditional Use Permit from the City of Casa Grande to construct the nitrate removal facility, water storage tank, and booster pump station.

Arizona Water Company engineers estimate the cost to design and construct the nitrate removal facility, tank and booster pump station is $6.5 million, as shown in Figure 4. The estimated annual operations and maintenance costs are $1.77 million, as shown in Figure 5.

ARIZONA WATER COMPANY
PRELIMINARY COST ESTIMATE

DATE PREPARED: 7/31/15

PREPARED BY:	APPROVED BY:	SYSTEM:	DIVISION:
AJH		Pinal Valley	Casa Grande

NAME OF APPLICANT:	PE #	WA #

PROPERTY DESCRIPTION: Construct a 1,500 gpm Nitrate Removal Facility at Pinal Valley Well No. 33, purchase property and construct a 500,000 gallon steel water storage tank and 3,000 gpm booster pump station.

MATERIALS AND LABOR			ESTIMATED PROJECT COST	
ACCOUNT	QUANTITY	DESCRIPTION	ADVANCE FOR CONSTRUCTION	NON-REFUNDABLE CONTRIBUTION
	1	Concrete Slabs and Site Work	$ 400,000	
	1	Treatment, Bypass, and Regeneration Piping	400,000	
	1	Ion Exchange Vessels and Media	1,100,000	
	1	Electrical and Instrumentation Controls, SCADA	450,000	
	1	Brine Regeneration System	600,000	
	1	Contracting Tax	125,000	
	1	Purchase Property	200,000	
	1	Construct 500,000 gallon welded steel water storage tank	600,000	
	1	Construct 3,000 gpm booster pump station	1,300,000	
(1) SUBTOTAL - MATERIALS AND LABOR			$ 5,175,000	$ -
(2) PERFORMANCE BOND @ 2 % OF LINE (1)			104,000	-
(3) SURVEY, R.O.W. PERMITTING, TESTING AND FIELD INSPECTION			104,000	
(4) SUBTOTAL - LINES (1), (2) AND (3)			$ 5,383,000	$ -
(5) OVERHEAD - 12 % OF LINE (4)			646,000	-
(6) PREPARATION OF DETAILED PLANS, SPECIFICATIONS, AND COST ESTIMATES			500,000	
SUBTOTAL - LINES (4), (5) AND (6)			$ 6,529,000	$ -
ESTIMATED COST OF CONSTRUCTION			$	6,529,000

AFH

Western Group Rate Case

Exhibit FKS-25

Pinal Valley Well No. 33 Nitrate Removal Facility

Estimated Operational and Maintenance Costs

Background

- Arizona Water Company operates nitrate removal facility at Well Nos. 9 and 10 in Coolidge
- Operational and maintenance costs for the Well Nos. 9 and 10 nitrate removal facility were approximately $1,370 per acre-foot of treated water in 2014
- Operational and maintenance costs include chemicals, waste disposal, labor, vehicles, and repair materials
- Well No. 33 has similar water quality to Well Nos. 9 and 10 in Coolidge
- Well No. 33 nitrate removal facility will utilize the same ion exchange treatment technology at the Well Nos. 9 and 10 nitrate removal facility
- Well No. 33 is permitted for 1,290 acre-feet per year

Assumptions

- Assume operational and maintenance costs for the Well No. 33 nitrate removal facility will equal those of the Well Nos. 9 and 10 nitrate removal facility ($1,370 per acre-foot)
- Assume Arizona Water Company will pump and treat full annual allocation of Well No. 33 at the nitrate removal facility (1,290 acre-feet per year)

Calculations

$$Annual\ O\&M\ Costs = (1{,}290\ acre feet\ per\ year) * (\$1{,}370\ per\ acre foot)$$

$$\boldsymbol{Annual\ O}\&M\ Costs = \$1.77\ Million\ per\ \boldsymbol{year}$$

PAULINE M. AHERN

ARIZONA WATER COMPANY

Arizona Corporation Commission

Docket No. W-01445A-15-0277

2015

WESTERN GROUP

RATE HEARING

Direct Testimony

of

Pauline M. Ahern, CRRA

TABLE OF CONTENTS

I. Introduction 4

II. Summary 6

III. General Comments On Capital Market Conditions 8

IV. General Principles 13

V. Financial Risk 22

VI. Arizona Water Company's Western Group 23

VII. Proxy Group 24

VIII. Common Equity Cost Rate Models 25

A. Discounted Cash Flow Model ("DCF") 26

B. The Risk Premium Model ("RPM") 28

C. The Capital Asset Pricing Model ("CAPM") 37

IX. Conclusion of Common Equity Cost Rate 41

A. Credit Risk Adjustment 42

B. Business Risk Adjustment 44

APPENDIX & EXHIBITS

Professional Qualifications of Pauline M. Ahern ..... Appendix A

Summary of Cost of Capital and Fair Rate of Return PMA-1

Capital Intensity and Depreciation Rates for Arizona Water Company and the AUS Utility Reports Companies PMA-2

Financial Profile of Arizona Water Company PMA-3

Financial Profile of the Proxy Group of Eight Publicly Traded Water Companies PMA-4

Indicated Common Equity Cost Rate Using the Discounted Cash Flow Model ("DCF") PMA-5

Current Institutional Holdings PMA-6

Indicated Common Equity Cost Rate Using the Risk Premium Model ("RPM") PMA-7

Indicated Common Equity Cost Rate Using the Capital Asset Pricing Model ("CAPM") PMA-8

Standard & Poor's Cash Flow / Leverage Analysis Ratios PMA-9

EXECUTIVE SUMMARY

The direct testimony of Pauline M. Ahern addresses the following issues:

Arizona Water Company's Cost of Common Equity and Overall Required Rate of Return – Ms. Ahern concludes that Arizona Water Company's ("AWC" or "Company") cost of equity is 10.75% and its overall required rate of return is 8.93%. The overall required rate of return is based upon AWC's actual capital structure consisting of 46.31% long-term debt and 53.69% common equity.

Ms. Ahern's cost of equity recommendation is based on the results of her discounted cash flow ("DCF"), risk premium ("RPM") and capital asset pricing model ("CAPM") analyses applied to a proxy group of eight publicly traded water companies. Ms. Ahern concludes that the average cost of common equity to the proxy group is 9.60%, before any adjustment to reflect AWC's relative credit and business risks. In her opinion, if rated, AWC's bonds would likely be rated Baa2 by Moody's, compared with the average Moody's bond rating of A2/A3 for the proxy group, thus requiring a 0.63% credit risk premium. Further, based upon empirical evidence, AWC's smaller size relative to the proxy group requires a 0.50% business risk premium. Adding the required credit risk adjustment of 0.63%, coupled with the required business risk adjustment of 0.50%, to the 9.60% indicated cost of common equity to the proxy group, results in a cost of common equity of 10.73% to AWC. When rounded, Ms. Ahern's recommended cost of common equity for AWC is 10.75%.

ARIZONA WATER COMPANY

Direct Testimony of

Pauline M. Ahern

I. Introduction

Q. PLEASE STATE YOUR NAME, OCCUPATION AND BUSINESS ADDRESS.

A. My name is Pauline M. Ahern. I am a Partner with Sussex Economic Advisors, LLC. My business address is 161 Worcester Road, Suite 503, Framingham, MA 01701. My mailing address is 3000 Atrium Way, Suite 241, Mount Laurel, NJ 08054.

Q. PLEASE SUMMARIZE YOUR PROFESSIONAL EXPERIENCE AND EDUCATIONAL BACKGROUND.

A. I have offered expert testimony on behalf of investor-owned utilities before twenty-nine state regulatory commissions in the United States as well as one provincial regulatory commission in Canada on rate of return issues, including but not limited to common equity cost rate, fair rate of return, capital structure issues, relative investment risk and credit quality issues. I am a graduate of Clark University, Worcester, MA, where I received a Bachelor of Arts degree with honors in Economics. I have also received a Master of Business Administration with high honors and a concentration in finance from Rutgers University.

On behalf of the American Gas Association ("A.G.A."), I calculate the A.G.A. Gas Index, which serves as the benchmark against which the performance of the American Gas Index Fund ("AGIF") is measured monthly. The A.G.A. Gas Index and AGIF are a market capitalization weighted index and mutual fund, respectively, comprised of the common stocks of the publicly traded corporate members of the A.G.A.

I am a member of the Society of Utility and Regulatory Financial Analysts ("SURFA") where I serve on its Board of Directors, having served two terms as

President, from 2006 – 2008 and 2008 – 2010. Previously, I held the position of Secretary/Treasurer from 2004 – 2006. In 1992, I was awarded the professional designation "Certified Rate of Return Analyst" ("CRRA") by SURFA, which is based upon education, experience and the successful completion of a comprehensive written examination.

I am also an associate member of the National Association of Water Companies, serving on its Finance/Accounting/Taxation and Rates and Regulation Committees; a member of the Advisory Council of the Financial Research Institute – University of Missouri – Robert J. Trulaske, Sr. College of Business; a member of the American Finance and Financial Management Associations; a member of Edison Electric Institute's Cost of Capital Working Group; and a member of A.G.A.'s State Affairs Committee.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony addresses the overall fair rate of return, including the appropriate investor-required return on common equity, which Arizona Water Company ("AWC" or "Company") should be afforded the opportunity to earn on the fair value rate base of its Western Group.

Q. WHAT IS YOUR RECOMMENDED COMMON EQUITY COST RATE?

A. I recommend that the Arizona Corporation Commission ("ACC" or "the Commission") authorize the Company the opportunity to earn an overall rate of return of 8.93%, including a common equity cost rate of 10.75%, on its Western Group fair value rate base. A common equity cost rate of 10.75% results in an overall rate of return of 8.93% when applied to a common equity ratio of 53.69% at December 31, 2014, shown on Schedule D-1 of the Company's application, as summarized in Table 1 below:

Table 1

Type of Capital	Ratios	Cost Rate	Weighted Cost Rate
Long-Term Debt	46.31%	6.82%	3.16%
Common Equity	53.69%	10.75%	5.77%
Total	100.00%		8.93%

Q. HAVE YOU PREPARED EXHIBITS THAT SUPPORT YOUR RECOMMENDED COMMON EQUITY COST RATE?

A. Yes. They are Exhibits PMA-1 through PMA-9.

II. Summary

Q. PLEASE SUMMARIZE YOUR RECOMMENDED COMMON EQUITY COST RATE.

A. My recommended common equity cost rate of 10.75% is summarized on page 2 of Exhibit PMA-1. Because AWC's common stock is not publicly traded, a market-based common equity cost rate cannot be directly observed for the Company. Consequently, I have assessed the market-based common equity cost rates of companies of relatively similar, but not necessarily identical risk, i.e., a proxy group, for insight into a recommended common equity cost rate applicable to AWC. Using companies of relatively similar risk as proxies is consistent with the principle of fair rate of return established in the *Hope*[1] and *Bluefield*[2] cases, adding reliability to the informed expert judgment necessary to arrive at a recommended common equity cost rate. However, because no proxy is identical in risk to AWC, the proxy group's results must be adjusted, as necessary, to reflect the unique relative investment (financial and / or business) risk of the Company.

---

1 *Federal Power Commission v. Hope Natural Gas Co.*, 320 U.S. 591 (1944).

2 *Bluefield Water Works Improvement Co. v. Public Serv. Comm'n*, 262 U.S. 679 (1922).

My recommendation results from the application of market-based cost of common equity models, the Discounted Cash Flow ("DCF") approach, the Risk Premium Model ("RPM") and the Capital Asset Pricing Model ("CAPM"), to the market data of the proxy group of eight publicly traded water companies whose selection will be discussed below.

The results derived from each are as follows:

Table 2

	Proxy Group of Water Companies
Discounted Cash Flow Model	8.64%
Risk Premium Model	10.76
Capital Asset Pricing Model	9.58
Indicated Common Equity Cost Rate	9.60%
Credit Risk Adjustment	0.63
Business Risk Adjustment	0.50%
Indicated Common Equity Cost Rate	10.73%
Recommended Common Equity Cost Rate	10.75%

After reviewing the cost rates based upon these models, I conclude that a common equity cost rate of 9.60% is indicated before any adjustment for credit and business risks arising from AWC's likely Moody's bond rating in the Baa2 rating category and greater unique business risks relative to the proxy group of eight publicly traded water companies, as discussed in more detail below and in the direct testimony of Mr. Garfield. Thus, the indicated common equity cost rate based upon the eight publicly traded water companies needs to be adjusted upward by 0.63% for credit risk and 0.50% to reflect AWC's increased unique business risk, as noted above. The details of these adjustments will be discussed below. After adjustment, the indicated credit and business risk-adjusted common equity cost rate is 10.73%, which when rounded to 10.75%, is my recommended common equity cost rate and in my opinion, is reasonable, if not conservative.

III. General Comments On Capital Market Conditions

Q. PLEASE DESCRIBE CURRENT CAPITAL MARKET CONDITIONS.

A. The U.S. economy is slowly recovering from the Great Recession of 2008 – 2009, with the Federal Reserve Bank's ("Fed") Federal Open Market Committee ("FOMC") having tapered off and ended its quantitative easing[3] while maintaining the Federal Funds ("Fed Funds") rate and discount rate at record lows until certain economic thresholds are met and maintained for an undefined period. As a result, the stock market has recovered remarkably, with the Dow Jones Industrial Average ("DOW") up approximately 175% from the lows of early March 2009, notwithstanding the DOW's recent volatility.

In its June 12, 2015, Selection & Opinion, *Value Line Investment Survey ("Value Line")* notes that the economy has some catching up to do as it moves into mid-2015. However, *Value Line* notes that positive trends will continue relative to Gross Domestic Product ("GDP") and the strong U.S. dollar despite

[3] Purchase of mortgage backed securities.

the challenge facing the Fed to achieve a soft monetary landing after years of record low interest rates.[4]

The cost of capital, including the cost of common equity, is expectational in nature. So, expected interest rates are relevant to rate of return analyses, the current historically low interest rates are not. As noted by *Value Line* below, interest rates are expected to rise, and it is a matter of when, not if. On May 22, 2015, *Value Line* published its Quarterly Forecast for the U.S. Economy in its Selection & Opinion. *Value Line* projects interest rates to rise significantly by 2019. Specifically, the yield on the 3-month Treasury Bills is expected to rise from 0.01%[5] (June 3, 2015) to 3.5% in 2019[6]. *Value Line* expects the yield on long-term U.S. Treasury securities to rise from 3.10% (June 3, 2015) to 4.5% in 2019, and the prime rate to rise from 3.25% (June 3, 2015) to 6.0% in 2019.

In fact, the yield on 30-year U.S. Treasury securities has already risen 53 basis points (0.53%) during the last three months, from its February average of 2.57%, as shown on page 9 of Exhibit PMA-7, to the 3.10% noted above. Likewise, as shown on page 4 of Exhibit PMA-7, the average yield on Moody's A-rated public utility bonds has risen 43 basis points (0.43%), from its March 2015 average of 3.74% to 4.17% in May 2015. As noted below, the Fed considers recent levels of interest rates as below the longer-term "normal."

Clearly, the capital markets are reflecting both the recent historically low interest rate environment engineered by the Fed plus an expectation of rising interest rates. The Fed's engineering of interest rates impacts the measurement of the cost of capital, specifically the investor required return on common equity.

Q. HOW DOES THE FED'S ENGINEERING OF INTEREST RATES AFFECT THE TRADITIONAL COST OF COMMON EQUITY MODELS?

A. The traditional cost of common equity models (e.g., the DCF, RPM, and CAPM)

---

4 *Value Line Investment Survey*, Selection & Opinion, June 12, 2015, 4173.
5 *Value Line*, June 12, 2015, 4181.
6 *Value Line Investment Survey*, Selection & Opinion, May 22, 2015, 4211.

do not accurately or reliably capture the investors' required return under current economic and capital market conditions, which include artificially and historically low interest rates. The fact that such low interest rates are below the long-run "norm" is corroborated by the FOMC's own statements in the press release it issued following its latest meeting on April 28 - 29, 2015[7]. In that press release the FOMC stated that "The Committee anticipates that it will be appropriate to raise the target range for the federal funds rate when it has seen further improvement in the labor market and is reasonably confident that inflation will move back to its 2 percent objective over the medium term". . . and "economic conditions may, for some time, warrant keeping the target federal funds rate below levels the Committee views as normal in the longer run." Clearly, the FOMC anticipates that it will raise the target range for the federal funds rate. Again, it is a matter of when, not if.

The likelihood that the Fed will raise interest rates sooner rather than later is corroborated by the Vice Chair of the Fed, Stanley Fischer, who stated in an interview with CNBC on April 16, 2015[8]:

> We expect that the markets look ahead somewhat, so I think – I hope – that they are taking into account that the Fed, at some point, is likely to raise the interest rate, [markets] can't depend on the current situation continuing forever – or even probably – *beyond the end of this year. [Emphasis added]*

In fact, Fed chairwoman Janet Yellen said on May 22, 2015[9], "that she expects the central bank to begin raising interest rates later this year as the economy continues to improve over the coming months." In addition, Globe Staff & Wire Services also reports that "Earlier, economists predicted the first increase would come in June, but following a slowdown over the winter, many now

---

7 Board of Governors of the Federal Reserve System, Press Release, April 29, 2015.
8 "Fed's Fischer: Economy in A1 was 'poor,' but rebound coming," www.cnbc.com/id/102589051
9 Globe Staff and Wire Services, May 22, 2015

forecast that a rate hike will not happen before September." Paul Ashworth, chief US economist at Capital Economics was quoted as saying that, "Assuming that economic growth does rebound, we don't think the Fed can wait any longer than September."

These artificially low interest rates have led some analysts to the faulty conclusion that current capital costs are low and will continue to be so. These analysts are mistaken. Their conclusion only holds true under the hypothesis of Perfectly Competitive Capital Markets ("PCCM") and the classical valuation framework which, under normal economic conditions, underpins the traditional cost of common equity models. PCCM are capital markets where no single trader, known as a "market-mover", would have the power to change the prices of goods or services, including bond and common stock securities. In other words, under the PCCM hypothesis, no single trader would have a significant impact on market prices. Classic valuation theory means that investors would trade securities rationally with prices reflecting their perceptions of value. However, although the Fed has always had the ability to set the Fed Funds and discount rates, it has been maintaining below normal rates to stimulate continued economic and capital market recovery. Thus, it is logical to conclude that the Fed is acting as that market-mover, which has a significant impact on the market prices of both bonds and stocks. The presence of a market-mover like the Fed in the current capital markets invalidates the PCCM, which is the foundation of the traditional cost of common equity models. This is corroborated by Michael K. Farr of CNBC, who stated[10]:

> It seems like an eternity since the markets have behaved 'normally.' For at least the past 6 – 7 years, there has been a wholly different driver of supply and demand in the stock market. Market peaks and valleys have been clearly and unambiguously correlated to the various pronouncements of monetary support by the Federal

[10] Michael K. Farr, President, Farr, Miller & Washington, LLC, "Goldilocks lives! Time for Fed to stand down", www.cnbc.com/id/101888234 August 5, 2015.

> Reserve. The financial market distortions created by the Fed will have a lasting impact on the economy for years to come." (emphasis added)

In addition, relative to an April 15, 2015 interview with CNBC's "Squawk Box", former U.S. Treasury Secretary Hank Paulson, noted[11]:

> ... that stocks and other assets need to start to trade again on "real economic[s]," arguing the Federal Reserve should hike interest rates sooner rather than later.
>
> * * *
>
> He acknowledged the "disortational [sic] effects" of the Fed's easy money policies, which have benefited investors by pumping up assets, while hurting savers and Americans on fixed incomes.

In such a capital market, it is more important than ever to use projected data, including interest rates, growth rates and equity risk premiums, as well as multiple cost of common equity models, which will enhance the exercise of the informed expert judgment required of a rate of return analyst. It is also important to note that, due to the low interest rate environment, coupled with the Fed acting as a market-mover, the traditional cost of common equity models (DCF, RPM and CAPM) will have a tendency to understate the investor required cost of common equity. Consesequently, the results of these cost of common equity models, including those presented in this analysis, are particularly conservative estimates (i.e. on the low side) of the investor required rate of return on common equity. In my opinion, the results of traditional cost of common equity models[12] should be viewed with even greater scrutiny under current economic and capital market conditions.

---

11 "I worry about Fed-induced asset bubbles: Paulson," www.cnbc.com/id/102588168.

12 Discounted Cash Flow, Risk Premium and Capital Asset Pricing Models.

IV. General Principles

Q. WHAT GENERAL PRINCIPLES HAVE YOU CONSIDERED IN ARRIVING AT YOUR RECOMMENDED COMMON EQUITY COST RATE OF 10.75%?

A. In unregulated industries, the competition of the marketplace is the principal determinant of the price of products or services. For regulated public utilities, regulation must act as a substitute for marketplace competition. Assuring that the utility can fulfill its obligation to provide safe and reliable service at all times requires a level of earnings sufficient to maintain the integrity of presently invested capital, as well as permitting the attraction of needed new capital at a reasonable cost in competition with other firms of comparable risk. This is consistent with the fair rate of return standards established by the U.S. Supreme Court in the *Hope* and *Bluefield* cases. Consequently, marketplace data must be relied upon in assessing a common equity cost rate appropriate for ratemaking purposes. Therefore, my recommended common equity cost rate is based upon marketplace data of a proxy group of utilities as similar in risk as possible to AWC, based upon selection criteria discussed below. The use of the market data of a proxy group adds reliability to the informed expert judgment that is required in arriving at a recommended common equity cost rate. Likewise, the use of multiple common equity cost rate models adds reliability when arriving at a recommended common equity cost rate.

V. Business Risk

Q. PLEASE DEFINE BUSINESS RISK AND EXPLAIN WHY IT IS IMPORTANT TO THE DETERMINATION OF A FAIR RATE OF RETURN.

A. Business risk is important to the determination of a fair rate of return because the greater the level of risk, the greater the rate of return investors demand, consistent with the basic financial principle of risk and return. Business risk is the riskiness of a company's common stock without the use of debt and/or preferred capital. Examples of the general business risks faced by all utilities (i.e., electric,

natural gas distribution and water utilities) include, but are not limited to, the quality of management, the regulatory environment, customer mix and concentration of customers, service territory economic growth, capital intensity and size, all of which have a direct bearing on earnings. An individual utility may face different levels of one or more particular business risks.

Q. WHAT BUSINESS RISKS DOES THE WATER UTILITY INDUSTRY IN GENERAL FACE TODAY?

A. Water is essential to life and unlike electricity or natural gas, water is the only utility product which is intended for customers to ingest. Consequently, water quality is of paramount importance to the health and well-being of customers and is therefore subject to additional and increasingly stringent health and safety regulations. Beyond health and safety concerns, water utility customers also have significant aesthetic concerns regarding the water delivered to them, with regulators paying close attention to these concerns because of the strong feelings they evoke in consumers. Also, unlike many electric and natural gas utilities, water utilities serve a production and treatment function in addition to the delivery functions served by electric and gas utilities.

Water utilities obtain supply from wells, aquifers, surface water reservoirs or streams and rivers. Throughout the years, well supplies and aquifers have been environmentally threatened, with historically minor purification treatment giving way to major well rehabilitation, extensive treatment or replacement. Simultaneously, Safe Drinking Water Act ("SDWA") quality standards have tightened considerably, requiring multiple treatments prior to water delivery. Supply availability is also limited by drought, water source overuse, runoff, threatened species and habitat protection, and other operational, political and environmental factors. In addition, the United States Environmental Protection Agency ("EPA"), as well as individual state and local environmental agencies, are continually monitoring potential contaminants in the water supply and

promulgating or expanding regulations when necessary. Increasingly stringent environmental standards necessitate additional capital investment in the distribution and treatment of water, exacerbating the pressure on water utilities' free cash flows through increased capital expenditures for infrastructure, repair and replacement. In the course of procuring water supplies and treating water so that it complies with SDWA standards, water utilities have an ever-increasing responsibility to be stewards of the environment from which supplies are drawn, in order to preserve and protect essential natural resources of the United States.

Water utilities are typically vertically engaged in the entire process of acquisition, supply, production, treatment and distribution of water. In contrast, electric and natural gas companies, where transmission and distribution is generally separate from generation, do not produce the electricity or natural gas which they transmit and distribute. Hence, water utilities require significant capital investment not only in distribution and transmission systems but also in sources of supply (surface and groundwater), production (wells), and storage. Significant capital investment is necessary both to serve additional customers and to replace aging systems, creating a major risk facing the water utility industry.

Value Line Investment Survey ("*Value Line*")[13] observes the following about the water utility industry:

> The water infrastructure in the United States is in need of a major overhaul. Capital improvements have been deferred by just about every water system for years, if not decades. Large sums of money will be required to remove and replace old pipeline distribution systems.
>
> * * * *
>
> To finance the projected capital outlays, water utilities will be forced to issue new debt and equity. Currently, most of these companies

[13] *Value Line Investment Survey*, April 17, 2015 p 1781.

> have decent balance sheets. . . . Over the next three- to five-year period, we expect the financial metrics of the industry to decline somewhat. Still, there doesn't appear to be any one utility that is expected to become highly leveraged during this period.

In addition, because the water utility industry is more capital-intensive than the electric, combination electric and gas, or natural gas utilities, the investment required to produce a dollar of revenue is greater. For example, as shown on page 1 of Exhibit PMA-2, it took $3.95 of net utility plant on average to produce $1.00 in operating revenues in 2014 for the water utility industry as a whole. For AWC specifically, it took a much greater $5.06 of net utility plant to produce $1.00 in operating revenues in 2014. In contrast, for the electric, combination electric and gas, and natural gas utility industries, on average it took only $2.65, $2.18 and $1.69, respectively, to produce $1.00 in operating revenues in 2014. As financing needs have increased and will continue to increase, the competition for capital from traditional sources has increased and will also continue to increase, making the need to maintain financial integrity and the ability to attract needed new capital increasingly important.

Q. WHY IS THERE AN INCREASED NEED FOR FINANCING?

A. There are a number of challenges facing the water utility industry. The National Association of Regulatory Utility Commissioners ("NARUC") has highlighted the challenges facing the water utility industry stemming from its capital intensity. NARUC's Board of Directors adopted the following resolution in July 2013.[14]

> WHEREAS, There is both a constitutional basis and judicial precedent allowing investor owned public water and wastewater utilities the opportunity to earn a rate of return that is reasonably sufficient to assure confidence in the financial soundness of the utility and its ability to provide quality service; *and*
>
> **WHEREAS**, Through the *Resolution Supporting Consideration of Regulatory Policies Deemed as "Best Practices"* (2005), the

[14] "Resolution Supporting Consideration of Regulatory Policies Deemed as 'Best Practices'", Sponsored by the Committee on Water. Adopted by the NARUC Board of Directors, July 2013.

National Association of Regulatory Utility Commissioners (NARUC) has previously recognized the role of innovative regulatory policies and mechanisms in the ability for public water and wastewater utilities to address significant infrastructure investment challenges facing water and wastewater system operators; *and*

* * *

WHEREAS, Recent analysis shows that as compared to other regulated utility sectors, significant and widespread discrepancies continue to be observed between commission authorized returns on equity and observed actual returns on equity among regulated water and wastewater utilities; *and*

WHEREAS, The extent of such discrepancies suggests the existence of challenges unique to the regulation of water and wastewater utilities; *and*

* * *

WHEREAS, Deficient returns present a clear challenge to the ability of the water and wastewater industry to attract the capital necessary to address future infrastructure investment requirements necessary to provide safe and reliable service, which could exceed one trillion dollars over a 20-year period; *and*

WHEREAS, The NARUC Committee on Water recognizes the critical role of the implementation and the effective use of sound regulatory practice [sic] and the innovative regulatory policies identified in the *Resolution Supporting Consideration of Regulatory Policies Deemed as "Best Practices"*; and

* * *

RESOLVED, That the Board of Directors of the National Association of Regulatory Utility Commissioners, convened at its 2013 Summer Meeting in Denver, Colorado, identifies the implementation and effective use of sound regulatory practice [sic] and the innovative regulatory policies identified in the *Resolution Supporting Consideration of Regulatory Policies Deemed as "Best Practices"* (2005) as a critical component of a water and/or wastewater utility's reasonable ability to earn its authorized return; and *be it further*

RESOLVED, That NARUC recommends that economic regulators carefully consider and implement appropriate ratemaking measures as needed so that water and wastewater utilities have a reasonable opportunity to earn their authorized returns within their jurisdictions...

AWC itself is facing significant capital expenditures as it projects total capital investment needs of $82.5M for 2015 – 2017 (shown on Schedule F-3 of AWC application), representing an increase of more than 25% over 2014 net plant of $326.8M.

Q. PLEASE CONTINUE YOUR DISCUSSION OF BUSINESS RISKS.

A. Coupled with its capital-intensive nature, the water utility industry also experiences lower relative depreciation rates. Given that depreciation is one of the principal sources of internal cash flows for all utilities, lower depreciation rates mean that water utility depreciation as a source of internally-generated cash is far less than for electric, combination electric and gas or natural gas. Water utility assets have longer lives and, hence, longer capital recovery periods. As such, water utilities face greater risk due to inflation which results in a higher replacement cost per dollar of net plant than for other types of utilities. As shown on page 2 of Exhibit PMA-2, water utilities experienced an average depreciation rate of 3.0% for 2014, with AWC experiencing a lower rate of 2.67%. In contrast, in 2014, the electric, combination electric and gas, and natural gas utilities experienced average depreciation rates of 3.3%, 3.4% and 3.7%, respectively. Low depreciation rates (i.e. low cash flows) signify that the pressure on cash flows remains significantly greater for water utilities than for other types of utilities.

Not only is the water utility industry historically capital intensive, it is expected to incur significant capital expenditure needs over the next 20 years.

> In 2011, the EPA stated the following:[15]
> The survey estimated a total national infrastructure need of $384.2 billion for the 20-year period from January 2011 through December 2030.

* * *

[15] "Fact Sheet: "EPA's 2011 Drinking Water Infrastructure Needs Survey and Assessment," United States Environmental Protection Agency, Office of Water, April 2013.

> The large magnitude of the national need reflects the challenges confronting water systems as they deal with an infrastructure network that has aged considerably since these systems were constructed, in many cases, 50 to 100 years ago.
>
> * * *
>
> With $247.5 billion in needs over the next 20 years, transmission and distribution projects represent the largest category of need. This result is consistent with the fact that transmission and distribution mains account for most of the nation's water infrastructure. The other categories, in descending order of need are: treatment, storage, source and a miscellaneous category of needs called "other".

Q. FROM WHERE WILL THE NECESSARY CAPITAL TO FUND THIS LEVEL OF INFRASTRUCTURE REPLACEMENT BE RAISED?

A. This question highlights the importance of capital attraction. Water utility capital expenditures as large as those projected by the EPA will require significant amounts of financing. The three sources typically used for financing are debt, equity (common and preferred) and internally generated cash flow. All three are intricately linked to the opportunity to earn a sufficient rate of return as well as the ability to actually achieve that return. Consistent with *Hope* and *Bluefield*, the return must be sufficient to maintain credit quality as well as enable the attraction of necessary new capital, be it debt or equity capital. If unable to raise debt or equity capital, the utility must turn to either retained earnings or free cash flow [operating cash flow minus capital expenditures], both of which are directly linked to earning a sufficient rate of return. The level of free cash flows represents the financial flexibility of a company or a company's ability to meet the needs of its debt and equity holders. If either retained earnings or free cash flows are inadequate, it will be nearly impossible for the utility to attract the necessary new capital, on reasonable terms, to invest in needed new infrastructure. It is thus clear that an insufficient rate of return can be financially devastating for utilities and for their customers.

In view of the foregoing, the water utility industry's high capital intensity and low depreciation rates, coupled with the need for substantial infrastructure capital spending, makes the need to maintain financial integrity and the ability to attract needed new capital increasingly important in order for water utilities to be able to successfully meet the challenges they face.

Q. WHAT ARE THE BENEFITS TO THE COMPANY OF BEING ALLOWED THE OPPORTUNITY TO EARN A SUFFICIENT ROE?

A. The benefit to the Company of earning a sufficient ROE is that it provides the Company with improved cash flow, thus improving its creditworthiness and providing the ability to improve its retained earnings balance. This will allow AWC to issue less long-term debt than would otherwise be necessary. If the Company is required to increase borrowing because the allowed ROE is insufficient, it will incur a corresponding increase in financial risk, along with its cost of debt and its cost of common equity. This is consistent with the basic financial principle of risk and return, i.e., that the greater the perceived risk, the greater the investor required return.

Q. HAS THE COMMISSION FOUND THAT THE MAGNITUDE OF INFRASTRUCTURE REPLACEMENTS AND IMPROVEMENTS REQUIRED BY AWC NECESSITATES AN INCREASED ROE?

A. Yes. In AWC's recent general rate proceeding for its Eastern Group the Commission concluded that "the Eastern Group, due to the age of some of its systems and the resulting need for infrastructure replacement and improvement, necessitates a somewhat higher [authorized ROE].[16] Further, the Commission recognized in AWC's Eastern Group rate proceeding that an increased ROE "will assist the Company in attracting the capital necessary to fund the costs of replacing the Eastern Group's unique and extraordinary needs related to its aging

[16] Decision No. 73736, page 61, lines 11 – 17.

infrastructure."[17] In that proceeding, AWC's estimated total cost to replace aging infrastructure in the Eastern Group was $67 million. As presented by Mr. Schneider in Section VIII of his direct testimony, the estimated total cost to replace aging infrastructure in AWC's Western Group is $56 million. This is in addition to AWC's total projected capital investment needs of $82.5M for 2015 – 2017 (shown on Schedule F-3 off AWC application), cited above.

Q. DOES AWC FACE ADDITIONAL BUSINESS RISK?

A. Yes. AWC faces additional unique business risks due to declining sales which, when combined with an inverted-tier rate design, cause revenues to fall short of costs. Additionally, the impact of SDWA compliance as it relates to arsenic and nitrates, as explained by Mr. Garfield in Section V of his direct testimony, has a much greater impact on AWC than on other water utilities in other parts of the country and Arizona. Finally, AWC's small size relative to the proxy group results in increased business risk.

As discussed above, the greater the level of risk, the greater the rate of return required by investors, consistent with the basic financial precept of risk and return. Therefore an upward adjustment to the indicated common equity cost rate is necessary to reflect AWC's unique risks, and will be discussed below.

Q. HOW DOES AWC'S SMALLER SIZE INCREASE ITS BUSINESS RISK RELATIVE TO THE PROXY GROUP?

A. As I discuss below, AWC's smaller size, $161.959 million in total capitalization, shown on Exhibit PMA-3, relative to the average total capitalization of $2.229 billion for the eight publicly traded water companies, shown on Exhibit PMA-4, page 1, indicates greater relative business risk because all else being equal, size has a bearing on risk. Further evidence that smaller firms are more risky is the fact that investors demand greater returns to compensate for the lack of marketability and liquidity of the securities of smaller firms. The fact that it is the

[17] Decision No. 74463, page 42, lines 19 – 21.

use of funds invested, and not the source of those funds, which gives rise to the risk of any investment is a basic financial principle.[18]

Brigham,[19] a well known authority, states:

> A number of researchers have observed that portfolios of small-firms have earned consistently higher average returns than those of large-firms stocks; this is called "small-firm effect." On the surface, it would seem to be advantageous to the small firms to provide average returns in a stock market that are higher than those of larger firms. In reality, it is bad news for the small firm; what *the small-firm effect means is that the capital market demands higher returns on stocks of small firms than on otherwise similar stocks of the large firms.* (italics added)

Consistent with the financial principle of risk and return discussed above, such increased risk due to small size must be taken into account in the allowed rate of return on common equity. Therefore, the Commission should authorize a cost of equity in this proceeding that appropriately reflects AWC's relevant unique risks, including the impact of its small size.

V. Financial Risk

Q. PLEASE DEFINE FINANCIAL RISK AND EXPLAIN WHY IT IS IMPORTANT TO THE DETERMINATION OF A FAIR RATE OF RETURN.

A. Financial risk is the additional risk created by the introduction of senior capital, i.e., debt and preferred stock, into the capital structure. The higher the proportion of senior capital in the capital structure, the higher the financial risk which must be factored into the common equity cost rate, consistent with the previously mentioned basic financial principle of risk and return, i.e., investors demand a higher common equity return as compensation for bearing higher investment risk.

---

[18] Brealey, Richard A. and Myers, Stewart C., Principles of Corporate Finance (McGraw-Hill Book Company, 1996) 204-205, 229.

[19] Brigham, Eugene F., Fundamentals of Financial Management, Fifth Edition (The Dryden Press, 1989) 623.

Q. CAN THE COMBINED BUSINESS RISKS (I.E., INVESTMENT RISK) OF AN ENTERPRISE BE PROXIED BY BOND AND CREDIT RATINGS?

A. Yes, similar bond/issuer credit ratings reflect and are representative of similar combined business and financial risks, i.e., total risk faced by bond investors. Although specific business or financial risks may differ between companies, the same bond/credit rating indicates that the combined risks are similar, albeit not necessarily equal (as the purpose of the bond/credit rating process is to assess credit quality or credit risk and not common equity risk). Risk distinctions within Standard & Poor's ("S&P") bond/issuer rating categories are recognized by a plus or minus (i.e., within the A category, an S&P rating can be at A+, A, or A-). Similarly, risk distinctions for Moody's ratings are distinguished by numerical rating gradations (i.e., within the A category, a Moody's rating can be A1, A2 and A3). As shown on Exhibit PMA-7, page 5, the average S&P long-term issuer rating of the eight publicly traded water companies is A and the average Moody's long-term issuer rating is A2/A3.

VI. Arizona Water Company's Western Group

Q. HAVE YOU REVIEWED FINANCIAL DATA FOR AWC?

A. Yes. AWC's Western Group, operating through six public water systems, provided water service to an average 31,691 retail customers during the test year ended December 31, 2014. The six public water systems include: the Pinal Valley, Stanfield, Tierra Grande and Coolidge Airport systems (collectively referred to as the Pinal Valley service area), serving a total of 28,723 customers; the White Tank system with 2,321 customers; and, the Ajo system with 647 customers.

The total Company serves approximately 86,500 customers in Cochise, Coconino, Gila, Maricopa, Navajo, Pima, Pinal and Yavapai counties. As shown on Exhibit PMA-3, during the five year period ending 2014, the achieved average earnings rate on book common equity for AWC (total company) was 8.00%. The

five-year ending 2014 average common equity ratio, based upon total permanent capital, was 51.83%.

Total debt to EBITDA for the years 2010-2014 ranged between 2.64 and 3.83 times, averaging 3.13 times. Funds from operations relative to total debt ranged from 18.51% to 29.16%, averaging 24.36%. Funds from operations relative to interest ranged between 3.70 and 4.75 times, averaging 3.89 times. EBITDA relative to interest ranged between 3.98 and 6.16 times, averaging 5.20 times. Cash flows from operations relative to total debt ranged between 19.65% and 26.44%, averaging 23.68%. Free operating cash flows relative to total debt ranged between 4.55% and 12.05%, averaging 8.74%. Discretionary cash flows relative to total debt ranged between a negative 2.11% and 6.34%, averaging 2.48%. All of these metrics indicate greater credit risk for AWC compared to the proxy group.

VII. Proxy Group

Q. PLEASE EXPLAIN HOW YOU CHOSE THE PROXY GROUP OF EIGHT PUBLICLY TRADED WATER COMPANIES.

A. I chose the proxy group by selecting those companies which meet the following criteria: 1) they are included in the *Value Line's* standard edition (April 17, 2015; 2) they have 70% or greater of 2014 total operating income derived from, and 70% or greater of 2014 total assets devoted to, regulated water operations; 3) at the time of the preparation of this testimony, they had not publicly announced that they were involved in any major merger or acquisition activity (i.e., one publicly-traded utility merging with or acquiring another); 4) they have not cut or omitted their common dividends during the five years ending 2014, or through the time of the preparation of this testimony; 5) they have a *Value Line* adjusted beta; and 6) they have *Value Line*, Reuters, Zacks or Yahoo! Finance, consensus five-year earnings per share ("EPS") growth rate projections. The following eight publicly traded water companies meet these criteria: American

States Water Co., American Water Works Co., Inc., Aqua America, Inc., California Water Service Group., Connecticut Water Service, Inc., Middlesex Water Co., SJW Corp. and York Water Co.

Q. HAVE YOU REVIEWED FINANCIAL DATA FOR THE PROXY GROUP?

A. Yes. Page 1 of Exhibit PMA-4 contains comparative capitalization and financial statistics for the eight publicly traded water companies for the years 2010-2014.

As shown on page 1, during the five-year period ending 2014, the historically achieved average earnings rate on book common equity for the group averaged 10.03%. The average common equity ratio based upon permanent capital (excluding short-term debt) was 51.24%, and the average dividend payout ratio was 60.82%.

Total debt outstanding for the proxy group as a percent of EBITDA for the years 2010-2014 ranged between 3.65 and 4.55 times, averaging 4.01 times, while funds from operations relative to total debt range between 17.60% and 25.83%, averaging 21.31%.

VIII. Common Equity Cost Rate Models

Q. ARE THE COST OF COMMON EQUITY MODELS YOU USE MARKET-BASED MODELS?

A. Yes. It is important to use market-based models because the cost of common equity is a function of investors' perception of risk, which is embodied in the market prices they pay. The DCF model is market-based in that market prices are utilized in developing the dividend yield component of the model. The RPM is market-based in that the bond ratings and expected bond yields used in the application of the RPM reflect the market's assessment of bond/credit risk. Also, market prices are used in the development of the returns and equity risk premiums used in the Predictive Risk Premium Model ("PRPM"). In addition, the use of betas to determine the equity risk premium also reflects the market's assessment of market/systematic risk, as betas are derived from regression

analyses of market prices. The CAPM is market-based for many of the same reasons that the RPM is market-based (i.e., the use of expected bond (Treasury bond) yields and betas).

A. Discounted Cash Flow Model ("DCF")

Q. WHAT IS THE THEORETICAL BASIS OF THE DCF MODEL?

A. The theory underlying the DCF model is that the present value of an expected future stream of net cash flows during the investment holding period can be determined by discounting those cash flows at the cost of capital, or the investors' capitalization rate. DCF theory states that an investor buys a stock for an expected total return rate which is derived from cash flows received in the form of dividends plus appreciation in market price (the expected growth rate). Mathematically, the dividend yield on market price plus a growth rate equals the capitalization rate (i.e., the total common equity return rate expected by investors).

Q. WHICH VERSION OF THE DCF MODEL DO YOU USE?

A. I utilize the single-stage constant growth DCF model. Because utilities, especially water utilities, are generally in the mature stage of their lifecycles and not transitioning from one growth stage to another, this version of the DCF model is appropriate. Further, in my experience, the single-stage constant growth DCF model is the most widely utilized version of the DCF in public utility rate regulation.

Q. PLEASE DESCRIBE THE DIVIDEND YIELD YOU USED IN YOUR APPLICATION OF THE DCF MODEL.

A. The unadjusted dividend yields are based upon a recent (May 29, 2015) indicated dividend, divided by the average of closing market prices for the 60 days ending May 29, 2015, as shown in Column [1] on page 1 of Exhibit PMA-5.

Q. PLEASE EXPLAIN THE ADJUSTED DIVIDEND YIELD SHOWN ON PAGE 1 OF EXHIBIT PMA-5, COLUMN [7].

A. Because dividends are paid quarterly, or periodically, as opposed to continuously (daily), an adjustment must be made to the dividend yield. This is often referred to as the discrete, or the Gordon Periodic, version of the DCF model.

DCF theory calls for the use of the full growth rate, referred to as D_1, in calculating the dividend yield component of the model. However, since the various companies in the proxy group increase their quarterly dividend at various times during the year, a reasonable assumption is to reflect one-half the annual dividend growth rate in the dividend yield component, referred to as $D_{1/2}$. This is a conservative approach because it does not overstate the dividend yield, which should be representative of the next twelve-month period. Therefore, the actual average dividend yields in Column [1], page 1 of Exhibit PMA-5, have been adjusted upward to reflect one-half the average projected growth rate shown in Column [6].

Q. PLEASE EXPLAIN THE BASIS OF THE GROWTH RATES OF THE PROXY GROUP WHICH YOU USE IN YOUR APPLICATION OF THE DCF MODEL.

A. Exhibit PMA-6 shows that on average, approximately 42% of the common shares of the eight publicly traded water companies are held by individuals as opposed to institutional investors. Individual investors, who tend to have more limited resources than institutional investors, are likely to place great significance on the opinions expressed by financial information services, such as *Value Line*, Reuters, Zacks and Yahoo! Finance, which are easily accessible and/or available on the Internet and through public libraries. Individual, as well as institutional, investors recognize that security analysts have significant insight into the dynamics of the industries and individual companies they analyze, as well as an entity's historical and future abilities to effectively manage the effects of changing laws and regulations and ever changing economic and market conditions.

Security analysts' earnings expectations have a significant, but not sole, influence on market prices and are therefore reasonable indicators of investor expectations.[20] As noted by Morin[21]:

> Because of the dominance of institutional investors and their influence on individual investors, analysts' forecasts of long-run growth rates provide a sound basis for estimating required returns. Financial analysts exert a strong influence on the expectations of many investors who do not possess the resources to make their own forecasts, that is, they are a cause of g.

Thus, the use of security analysts earnings growth rate forecasts in a DCF analysis provides a better matching between investors' market price appreciation expectations and the growth rate component of the DCF than other proxies for growth, e.g., historical EPS or dividend per share ("DPS") growth rates.

Q. PLEASE SUMMARIZE THE DCF MODEL RESULTS.

A. As shown on page 1 of Exhibit PMA-5, the average result of the single-stage DCF model is 8.93%, while the median result is 8.35%. I have averaged these two results in arriving at a conclusion of a DCF-indicated common equity cost rate of 8.64% for the proxy group. By doing so, I have not only considered the DCF results for each company, but have not given undue weight to outliers on either the high or the low side.

B. <u>The Risk Premium Model ("RPM")</u>

Q. PLEASE DESCRIBE THE THEORETICAL BASIS OF THE RPM.

A. The RPM is based upon the basic financial principle of risk and return (i.e., that investors require greater returns for bearing greater risk). The RPM recognizes that common equity capital has greater investment risk than debt capital, as common equity shareholders are last in line in any claim on an entity's assets and earnings, behind debt holders. Therefore, investors require higher returns

---

20 Roger A. Morin, <u>New Regulatory Finance</u> (Public Utility Reports, Inc., 2006) 298-303.
21 Morin 298.

from investment in common stocks than from investment in bonds to compensate them for bearing the additional risk.

While the investor required common equity return cannot be directly determined or observed, it is possible to directly observe bond returns and yields. According to RPM theory, one can assess a common equity risk premium over bonds, either historically or prospectively, and then use that premium to derive a cost rate of common equity. In summary, according to RPM theory, the cost of common equity equals the expected cost rate for long-term debt capital, plus a risk premium over that cost rate to compensate common shareholders for the added risk of being unsecured and last-in-line for any claim on a corporation's assets and earnings.

Q. PLEASE EXPLAIN HOW YOU DERIVED YOUR INDICATED COST OF COMMON EQUITY BASED UPON THE RPM.

A. I relied upon the results of the application of two risk premium methods. The first method is the Predictive Risk Premium Model (PRPM). The second method is a risk premium model using an adjusted total market approach.

Q. PLEASE EXPLAIN THE PRPM.

A. The PRPM, published in the *Journal of Regulatory Economics (JRE)*[22] and *The Electricity Journal (TEJ)*,[23] was developed from the work of Robert F. Engle, who shared the Nobel Prize in Economics in 2003, "for methods of analyzing economic time series with time-varying volatility ("ARCH")"[24] (with "ARCH" standing for autoregressive conditional heteroskedasticity). In other words, the

---

22 "A New Approach for Estimating the Equity Risk Premium for Public Utilities", Pauline M. Ahern, Frank J. Hanley and Richard A. Michelfelder, Ph.D. The Journal of Regulatory Economics (December 2011), 40:261-278.

23 "Comparative Evaluation of the Predictive Risk Premium Model™, the Discounted Cash Flow Model and the Capital Asset Pricing Model", Pauline M. Ahern, Richard A. Michelfelder, Ph.D., Rutgers University, Dylan W. D'Ascendis, and Frank J. Hanley, The Electricity Journal (May, 2013).

24 www.nobelprize.org

volatility of stock returns and equity risk premiums changes over time and is related from one period to the next. Engle discovered that the volatility in market prices, returns, and equity risk premiums also clusters over time, making them highly predictable and available to predict future levels of risk and risk premiums. In other words, the predicted equity risk premium is derived from the prediction of volatility (risk). The PRPM estimates the risk / return relationship directly by analyzing the actual results of investor behavior, rather than using subjective judgment, as to the inputs required for the application of other cost of common equity models. Thus, the PRPM is not based upon an estimate of investor behavior, but rather upon the evaluation of the actual results of that behavior (i.e., the variance of historical equity risk premiums).

The inputs to the model are the historical returns on the common shares of each publicly traded utility in the proxy group, minus the historical monthly yield on long-term U.S. Treasury securities, through May 2015. Using a generalized form of ARCH, known as GARCH, each water utility's projected equity risk premium was determined using Eviews© statistical software. The forecasted 30-year U.S. Treasury Bond yield of 3.7% according to the June 2, 2015, *Blue Chip Financial Forecasts (Blue Chip)* consensus forecast for the six quarters ending with the third quarter 2016, was averaged with *Blue Chip's* long-range forecasts for 2017-2021 and 2022-2026, shown on pages 9 and 10 of Exhibit PMA-7. The risk-free rate of 3.69% was then added to each company's PRPM-derived equity risk premium to arrive at a PRPM-derived cost of common equity, as shown on page 2 of Exhibit PMA-7, which presents the average and median results for each proxy company. As shown on page 2, the average PRPM indicated common equity cost rate is 11.94%, while the median is 11.24% for the eight publicly traded water companies. Consistent with my use of the average of the average and median DCF results, I rely upon the average of the

average and median PRPM results of 11.59% (11.59% = (11.94% + 11.24%)/2) as my conclusion of the PRPM equity cost rate.

Q. PLEASE EXPLAIN THE ADJUSTED TOTAL MARKET APPROACH RPM.

A. The adjusted total market approach RPM adds a prospective public utility bond yield to an equity risk premium, which is derived from a beta-adjusted total market equity risk premium and an equity risk premium based upon the S&P Utilities Index.

Q. PLEASE EXPLAIN THE BASIS OF THE ADJUSTED PROSPECTIVE BOND YIELD OF 5.06% APPLICABLE TO THE EIGHT PUBLICLY TRADED WATER COMPANIES, SHOWN ON PAGE 3 OF EXHIBIT PMA-7.

A. The first step in the adjusted total market approach RPM analysis is to determine the expected bond yield. Because both ratemaking and the cost of capital, including the common equity cost rate, are prospective in nature, a prospective yield on long-term debt, similarly rated to the proxy group, is essential. Hence, I rely upon the June 1, 2015, *Blue Chip* consensus forecast of the expected yield on Aaa rated corporate bonds for the six calendar quarters ending with the third calendar quarter of 2016, averaged with *Blue Chip's* long-range forecasts for 2017-2021 and 2022-2026 (shown on pages 9 and 10 of Exhibit PMA-7). As shown on Line No. 1 of page 3, the average expected yield on Moody's Aaa rated corporate bonds is 4.75%. An adjustment of 0.18% is necessary to adjust the average Aaa corporate bond yield to reflect an A rated public utility bond, as shown on Line No. 2 of the exhibit, resulting in an expected Moody's A rated public utility bond yield of 4.93%, shown on Line No. 3.

Since the eight publicly traded water companies' average Moody's issuer rating is A2/A3, an additional adjustment of 0.13% is necessary to make the prospective bond yield applicable to the proxy group's average A2/A3 long-term issuer rating, as detailed in Note 3 on page 3 of Exhibit PMA-7. Therefore, the

adjusted prospective bond yield is 5.06% for the eight publicly traded water companies, as shown on Line No. 5.

Q. PLEASE EXPLAIN THE METHOD OF ESTIMATING THE EQUITY RISK PREMIUM IN THE ADJUSTED TOTAL MARKET APPROACH.

A. I evaluated the results of market equity risk premium studies based upon Ibbotson Associates' data and *Value Line's* forecasted total annual market return in excess of the prospective yield on Moody's Aaa rated corporate bonds, as well as two different studies of the equity risk premium for public utilities with Moody's A rated bonds, as detailed on pages 8 and 11 of Exhibit PMA-7. As shown on Line No. 3, page 7 of Exhibit PMA-7, the average equity risk premium applicable to the eight publicly traded water companies is 4.87%. This estimate is the result of a beta-derived equity risk premium averaged with the average public utility equity risk premium based upon holding period returns relative to bonds rated A by Moody's.

Q. PLEASE EXPLAIN THE BASIS OF THE BETA-DERIVED EQUITY RISK PREMIUM.

A. The basis of the beta-derived equity risk premium applicable to the proxy group is shown on page 8 of Exhibit PMA-7. The beta-derived equity risk premium is relevant because betas are derived from the market prices of common stocks over a recent five-year period. Beta is a measure of relative risk to the market as a whole and a logical means by which to allocate an entity's/proxy group's share of the total market's equity risk premium relative to corporate bond yields.

The total market equity risk premium utilized is 6.44%, based upon an average of the long-term arithmetic mean historical market equity risk premium; a predicted market equity risk premium based upon the PRPM; a forecasted market equity risk premium based upon *Value Line's* projected market appreciation and dividend yield; and, a forecasted market equity risk premium

based upon the S&P 500's projected market appreciation and dividend yield, as detailed below and in Notes 1 through 4 on page 8 of Exhibit PMA-7.

Q. HOW DID YOU DERIVE THE LONG-TERM HISTORICAL MARKET EQUITY RISK PREMIUM?

A. To derive the historical (expectational) market equity risk premium, I used the most recent data on holding period returns for large company common stocks from the Stocks, Bonds, Bill and Inflation Ibbotson® SBBI® 2015 Market Report ("SBBI – 2015 Market Report")[25], and the average historical yield on Moody's Aaa and Aa rated corporate bonds for the period 1926-2014. The use of holding period returns over a very long period of time is useful because it is consistent with the long-term investment horizon presumed by the DCF model. As explained in Note 1 on page 8 of Exhibit PMA-7, the long-term arithmetic mean monthly total return on large company common stocks of 12.07% and the long-term arithmetic mean monthly yield on Moody's Aaa and Aa rated corporate bonds of 6.18%, were used. As shown on Line No. 1, the resultant long-term historical equity risk premium on the market as a whole is 5.89%.

I used arithmetic mean monthly total return rates for the large company stocks and yields (income returns) for Moody's Aaa/Aa corporate bonds, because they are appropriate for cost of capital purposes, as noted in the Ibbotson® SBBI® 2015 Classic Yearbook – Market Results for Stocks, Bonds, Bill and Inflation 1926 – 2015 ("SBBI – 2015")[26]. Arithmetic mean return rates and yields are appropriate because ex-post (historical) total returns and equity risk premiums differ in size and direction over time, providing insight into the variance and standard deviation of returns. Because the arithmetic mean captures the prospect for variance in returns and equity risk premiums, it provides the valuable insight needed by investors in estimating future risk when making a current

---

[25] Stocks, Bonds, Bills and Inflation Ibbotson® SBBI® 2015 Market Report, Morningstar, Inc., 2015.

[26] Ibbotson® SBBI® 2015 Classic Yearbook – Market Results for Stocks, Bonds, Bills and Inflation 1926 – 2014, Morningstar, Inc., 2015 153.

investment. Absent such valuable insight into the potential variance of returns, investors cannot meaningfully evaluate prospective risk. If investors alternatively relied upon the geometric mean of ex-post equity risk premiums, they would have no insight into the potential variance of future returns because the geometric mean relates the change over many periods of time to a constant rate of change, thereby obviating the period-to-period fluctuations, or variance, *critical to risk analysis.*

Only the arithmetic mean takes into account all of the returns/premiums, hence, providing meaningful insight into the variance and standard deviation of those returns/premiums.

Q. PLEASE EXPLAIN THE DERIVATION OF PRPM MARKET EQUITY RISK PREMIUM.

A. The inputs to the model are the historical monthly returns on large company common stocks from the SBBI – 2015 Market Report, minus the monthly yields on Aaa and Aa corporate bonds during the period from January 1926, through April 2015, consistent with the rationale for using the long-term historical arithmetic market equity risk premium, discussed above. Using the previously discussed generalized form of ARCH, known as GARCH, the market's projected equity risk premium was determined using Eviews© statistical software. The resulting predicted market equity risk premium based upon the PRPM is 6.34%.

Q. PLEASE EXPLAIN THE DERIVATION OF A MARKET EQUITY RISK PREMIUM BASED UPON *VALUE LINE'S* 3-5 YEAR ESTIMATED MEDIAN TOTAL ANNUAL MARKET RETURN, MINUS THE PROSPECTIVE YIELD ON AAA RATED CORPORATE BONDS, IN YOUR DEVELOPMENT OF A MARKET EQUITY RISK PREMIUM FOR YOUR RPM ANALYSIS.

A. Because both ratemaking and the cost of capital, including the cost rate of common equity, are prospective, a prospective market equity risk premium is

required. The derivation of the *Value Line* based forecasted or prospective market equity risk premium of 5.05% can be found in Note 3 on page 8 of Exhibit PMA-7. Consistent with the development of the dividend yield component of my DCF analysis, it is derived from an average of the most recent thirteen weeks ending May 29, 2015, 3-5 year estimated median market price appreciation potential from *Value Line,* plus an average of the median estimated dividend yield for the common stocks of the approximately 1,700 firms covered in *Value Line*'s Standard Edition.

The average median expected price appreciation is 35%, which translates to a 7.79% annual appreciation and, when added to the average (similarly calculated) median dividend yield of 2.01% equates to a forecasted annual total market return rate of 9.80%. The forecasted total market equity risk premium of 5.05%, shown on Line No. 3, page 8 of Exhibit PMA-7, is derived by deducting the 4.75% prospective yield on Moody's Aaa rated corporate bonds, discussed previously, from the *Value Line*-derived projected market return of 9.80% (5.05% = 9.80% - 4.75%).

Q. PLEASE EXPLAIN THE DERIVATION OF THE MARKET EQUITY RISK PREMIUM BASED UPON THE S&P 500.

A. Using data from Bloomberg Professional Service, an expected total return for the S&P 500 can be derived by adding the expected dividend yield for the S&P 500 to long-term growth in earnings per share (as a proxy for capital appreciation). The expected total return for the S&P 500 is 13.22%. Subtracting the prospective yield on Moody's Aaa rated corporate bonds of 4.75% results in a 8.47% projected market equity risk premium.

In arriving at my conclusion of market equity risk premium of 6.44% on Line No. 5 on page 8 of the exhibit, I averaged the historical market equity risk premium of 5.89%; the PRPM based market equity risk premium of 6.34%; the *Value Line*-based forecasted market equity risk premium of 5.05%; and, the S&P

500 projected market equity risk premium of 8.47% shown on Line Nos. 1 through 4. (6.44% = ((5.89% + 6.34% + 5.05% + 8.47%) / 4).

Q. WHAT IS YOUR CONCLUSION OF A BETA-DERIVED EQUITY RISK PREMIUM FOR USE IN YOUR RPM ANALYSIS?

A. As shown on Exhibit PMA-8, the average of the average and median *Value Line* and Bloomberg betas for the eight publicly traded water companies average is 0.77. Applying a beta of 0.77 to the market equity risk premium of 6.44%, on Line No. 5 of page 8 of Exhibit PMA-7, results in a beta adjusted equity risk premium of 4.96% for the eight publicly traded water companies.

Q. HOW DID YOU DERIVE THE 4.77% EQUITY RISK PREMIUM BASED UPON THE S&P UTILITY INDEX AND MOODY'S A RATED PUBLIC UTILITY BONDS?

A. First, I derived the long-term monthly arithmetic mean equity risk premium for the S&P Utility Index total returns (10.69%) over monthly A rated public utility bond yields (6.48%) from 1928-2014 to arrive at an equity risk premium of 4.21%, as shown on Line No. 3, on page 11 of Exhibit PMA-7. I then performed the PRPM using historical monthly equity risk premiums from January 1928, through May 2015, to arrive at the PRPM derived equity risk premium of 4.47%, shown on Line No. 4, on page 11. Finally, I derived the projected total return on the S&P Utilities Index using data from Bloomberg Professional Service of 10.55%, as explained in Footnote 4 on poll, and subtracted the prospective Moody's A rated public utility bond yield of 4.93% (Line No. 3 on page 3 of Exhibit PMA-7). The resulting equity risk premium is 5.62%.

I rely upon the average of the historical (4.21%), the PRPM (4.47%) and S&P Utilities Index (5.62%) derived equity risk premiums, which is 4.77%. (4.77% = ((4.21% + 4.47% + 5.62%) / 3).

Q. WHAT IS YOUR CONCLUSION OF AN EQUITY RISK PREMIUM FOR USE IN YOUR ADJUSTED TOTAL MARKET APPROACH RPM ANALYSIS?

A. The equity risk premium applicable to the proxy group of eight publicly traded water companies is 4.87%. This was derived by averaging the beta-derived premium of 4.96% (calculated on page 8 of Exhibit PMA-7) with the equity risk premium of 4.77% based upon the holding period returns of public utilities with Moody's A rated bonds (calculated on page 11 of Exhibit PMA-7), as summarized on Line No. 3, page 7 of Exhibit PMA-7, (i.e., (4.87% = (4.96% + 4.77%) / 2)).

Q. WHAT IS THE INDICATED RPM COMMON EQUITY COST RATE BASED UPON THE ADJUSTED TOTAL MARKET APPROACH?

A. It is 9.93% for the eight publicly traded water companies, as shown on Line No. 7, page 3 of Exhibit PMA-7 page 3.

Q. WHAT ARE THE RESULTS OF YOUR APPLICATION OF THE PRPM AND THE ADJUSTED TOTAL MARKET APPROACH RPM?

A. As shown on page 1 of Exhibit PMA-7, the indicated RPM-derived common equity cost rate is 10.76%, derived by averaging the PRPM results with those based upon the adjusted total market approach. (10.76% = ((11.59% + 9.93%) / 2).

C. <u>The Capital Asset Pricing Model ("CAPM")</u>

Q. PLEASE EXPLAIN THE THEORETICAL BASIS OF THE CAPM.

A. CAPM theory defines risk as the covariability of a security's returns with the market's returns as measured by beta (β). A beta less than 1.0 indicates lower variability while a beta greater than 1.0 indicates greater variability than the market.

The CAPM assumes that all other risk, i.e., all non-market or unsystematic risk, can be eliminated through diversification. The risk that cannot be eliminated through diversification is called market or systematic risk. In addition, the CAPM presumes that investors require compensation only for these systematic risks that are the result of macroeconomic and other events that affect the returns on all assets. The model is applied by adding a risk-free rate of return to a market

risk premium, which is adjusted proportionately to reflect the systematic risk of the individual security relative to the total market, as measured by beta. The traditional CAPM model is expressed as:

$$Rs = Rf + \beta(Rm - Rf)$$

Where:
- Rs = Return rate on the common stock
- Rf = Risk-free rate of return
- Rm = Return rate on the market as a whole
- β = Adjusted beta (volatility of the security relative to the market as a whole)

Numerous tests of the CAPM have measured the extent to which security returns and betas are related, as predicted by the CAPM, confirming the CAPM's validity. The empirical CAPM ("ECAPM") reflects the reality that, while the results of these tests support the notion that beta is related to security returns, the empirical Security Market Line ("SML") described by the CAPM formula is not as steeply sloped as the predicted SML.[27]

In view of theory and practical research, I have applied both the traditional CAPM and the ECAPM to the companies in the proxy group, and averaged the results.

Q. PLEASE DESCRIBE YOUR SELECTION OF THE BETA COEFFICIENT FOR YOUR CAPM ANALYSIS?

A. I relied upon an average of the adjusted betas published by the *Value Line* and provided by Bloomberg Professional Service.

Q. PLEASE DESCRIBE YOUR SELECTION OF A RISK-FREE RATE OF RETURN FOR YOUR CAPM ANALYSIS.

---

[27] Morin 175.

A. As shown in column [5], of Exhibit PMA-8, the risk-free rate adopted for both applications of the CAPM is 3.69%. The risk-free rate for my CAPM analysis is based upon the average of the June 1, 2015, *Blue Chip* consensus forecast for the third calendar quarter of 2016, averaged with *Blue Chip's* long-range forecasts for 2017-2021, and 2022-2026, as shown in Note 2.

Q. WHY IS THE YIELD ON LONG-TERM U.S. TREASURY BONDS APPROPRIATE FOR USE AS THE RISK-FREE RATE?

A. The yield on long-term U.S. Treasury T-Bonds is almost risk-free and its term is consistent with the long-term cost of capital to public utilities (measured by the yields on A rated public utility bonds), the long-term investment horizon inherent in utilities' common stocks, the long-term investment horizon presumed in the standard DCF model employed in regulatory ratemaking, and the long-term life of the jurisdictional rate base to which the allowed fair rate of return (i.e., cost of capital) is applied. In contrast, short-term U.S. Treasury yields are more volatile and largely a function of Federal Reserve monetary policy.

Q. PLEASE EXPLAIN THE ESTIMATION OF THE EXPECTED EQUITY RISK PREMIUM FOR THE MARKET.

A. The basis of the market equity risk premium is explained in detail in Note 1 of Exhibit PMA-8. It is derived from *Value Line's* 3-5 year median total market price appreciation projections, averaged over the most recent thirteen weeks ending May 29, 2015; the arithmetic mean monthly equity risk premiums of large company common stocks relative to long-term U.S. Treasury bond income yields, according to the SBBI – 2015 Market Report, from 1926-2014; the PRPM predicted market equity risk premium using monthly equity risk premiums for large company common stocks relative to long-term U.S. Treasury securities from January 1926 through April 2015, and the projected total return on the S&P 500, less the projected risk free rate, as detailed below and in Note 1 on of Exhibit PMA-8.

The *Value Line*-derived forecasted total market equity risk premium is derived by deducting the 3.69% risk-free rate, discussed above, from the *Value Line* projected total annual market return of 9.80%, also discussed above, resulting in a forecasted total market equity risk premium of 6.11%.

The Ibbotson Arithmetic Mean Market Risk Premium ("MRP") is derived by deducting the long-term income return on U.S. Government Securities of 5.23%, from the SBBI – 2015 Market Report monthly historical total market return of 12.07%, resulting in an historical market equity risk premium of 6.84%.

The PRPM market equity risk premium is 7.15%, derived using the PRPM, discussed above, relative to the yields on long-term U.S. Treasury securities from January 1926, through April 2015.

The S&P 500 projected market equity risk premium of 9.53% is derived by subtracting the 3.69% projected risk-free rate, discussed above, from the projected total return of 13.22%, also discussed above.

These four market equity risk premiums result in an average total market equity risk premium of 7.41%. (7.41% = ((6.11% + 6.84% + 7.15% + 9.53%) / 4)

Q. WHAT ARE THE RESULTS OF YOUR APPLICATION OF THE TRADITIONAL AND EMPIRICAL CAPM TO THE PROXY GROUP?

A. As shown on Exhibit PMA-8, the average traditional CAPM equity cost rate is 9.31%, while the average ECAPM result is 9.76%. Likewise, the median traditional CAPM cost rate is 9.40%, while the median ECAPM cost rate is 9.82%. Consistent with my reliance upon the average of the average and median results of the DCF discussed above, I rely upon the average of the average and median results of the traditional CAPM and ECAPM for the proxy group, 9.54% and 9.61%, respectively, or 9.58% as shown on column [8] of Exhibit PMA-8. (9.58% = ((9.54% + 9.61%) / 2).

IX. Conclusion of Common Equity Cost Rate

Q. WHAT IS YOUR RECOMMENDED COMMON EQUITY COST RATE?

A. It is 10.75%, based upon the common equity cost rates resulting from the application of cost of common equity models to the eight publicly traded water companies, as adjusted for AWC's credit and unique business risks.

As discussed above, I employ multiple cost of common equity models as primary tools in arriving at my recommended common equity cost rate because: 1) no single model is so inherently precise that it can solely be relied upon to the exclusion of other theoretically sound models; 2) all of the models are market-based; 3) the use of multiple models adds reliability to the estimation of the common equity cost rate; and 4) the prudence of using multiple cost of common equity models is supported in both the financial literature and regulatory precedent. Therefore, no single model should be relied upon exclusively to estimate investors' required rate of return on common equity.

The results of my cost of common equity models applied to the eight water companies are shown on Exhibit PMA-1, page 2 and are summarized below:

Table 3

	Proxy Group of Eight Publicly Traded Water Companies
Discounted Cash Flow Model	8.64%
Risk Premium Model	10.76%
Capital Asset Pricing Model	9.58%
Indicated Common Equity Cost	9.60%
Credit Risk Adjustment	0.63%
Business Risk Adjustment	0.50%
Indicated Common Equity Cost Rate	10.73%
Recommended Common Equity Cost Rate	10.75%

Based upon these common equity cost rate results, I conclude that a common equity cost rate of 9.60% is indicated for the eight publicly traded water companies before applying the credit and unique business risk adjustments to determine AWC's common equity cost rate of 10.75%, as previously discussed.

A. Credit Risk Adjustment

Q. PLEASE DISCUSS AWC'S CREDIT RISK.

A. In my opinion, AWC's bonds, if rated by Moody's and/or S&P, would be rated in the Baa/BBB bond rating category. First, the cost rate on AWC's General Mortgage Bonds ("GMBs") includes a premium over the cost rate on the First Mortgage Bonds ("FMBs") of its utility affiliate, San Gabriel Valley Water Company ("SGVWC"), which in turn is based upon the spread between Baa corporate bonds over 30-year U.S. Treasury Bonds. Albeit a corporate, not public utility,[28] profile, it is reasonable to assume that were SGVWC's bonds

[28] Given that public utility bond yields are generally higher than corporate bond yields, the Company is actually being reasonably conservative.

rated by either Moody's or S&P, they would be rated Baa/BBB. Because AWC's debt cost rate is similar to, albeit slightly higher than, SGVWC's, it is conservative to assume that AWC's bonds, if rated, would be rated no higher than Baa/BBB.

In addition, although S&P states that its metrics are not intended to be precise indications or guarantees of ratings opinions, they can be used to provide insight into the likely bond rating of AWC. To that end, AWC's cash flow/leverage metrics are consistent with S&P's cash flow/leverage metrics for a public utility assigned a "Significant" to "Aggressive" financial risk profile, as shown on Exhibit PMA-9. As shown on the exhibit, 4 of AWC's cash flow/leverage metrics indicate a "Significant" financial risk profile, while 3 of AWC's metrics indicate an "Aggressive" financial risk profile. As can be gleaned from Table 3 at the bottom of Exhibit PMA-9, assuming either an "Excellent" or "Strong" business risk profile, AWC's bonds/issuer rating would be in the bbb or Baa bond/issuer rating category. Given that a premium of 10 basis points over SGVWC's debt cost rate was required by Prudential, which purchased AWC's most recent bond issue, it is nonetheless reasonable to assume that AWC's bonds, if rated, would likely be rated no better than Baa/BBB by Moody's and S&P. Hence, an upward credit risk adjustment is necessary to reflect the lower credit risk, i.e., Baa2 (middle of Moody's Baa bond/issuer rating category), of AWC relative to the A2/A3 average Moody's bond rating of the proxy group of eight publicly traded water companies, as shown on page 5 of Exhibit PMA-7.

An indication of the magnitude of the necessary upward adjustment to reflect the greater credit risk inherent in a Baa2 bond rating is five-sixths of a recent three-month average spread between Moody's A and Baa2 rated public utility bond yields of 0.76%, shown on page 4 of Exhibit PMA-7, or 0.63% (0.63% = 0.76% * (5/6)).

B. Business Risk Adjustment

Q. IS THERE A WAY TO QUANTIFY AN ADJUSTMENT DUE TO AWC'S GREATER BUSINESS RISK RELATIVE TO THE PROXY GROUP OF EIGHT PUBLICLY TRADED WATER COMPANIES?

A. Yes, the available empirical evidence on the effect of AWC's small size relative to the proxy group, provides insight into the magnitude of such an adjustment. As discussed above, increased risk due to small size must be taken into account in the cost of common equity, consistent with the financial principle of risk and return. Since the Company is smaller in size relative to the proxy group, it has greater business risk than the average company in the proxy group.

SBBI – 2015 discusses the nature of the small size phenomenon, providing an indication of the magnitude of the size premium for the deciles of the NYSE/AMEX/NASDAQ-listed securities. In discussing "Aspects of the Company Size Effect," SBBI-2015 states[29]:

> The company size phenomenon is remarkable in several ways. First, the greater risk of small stocks does not, in the context of the capital asset pricing model, fully account for their higher returns over the long term. In the CAPM, only systematic, or beta risk, is rewarded; small company stocks have had returns in excess of those implied by their betas.

Furthermore, in "The Capital Asset Pricing Model: Theory and Evidence,"[30] Fama and French note that size is indeed a risk factor which must be reflected when estimating the cost of common equity. On page 14, they note:

> . . . the higher average returns on small stocks and high book-to-market stocks reflect unidentified state variables that produce undiversifiable risks (covariance's) in returns not capture in the market return and are priced separately from market betas.

---

[29] SBBI – 2015 99.

[30] Eugene F. Fama and Kenneth R. French, "The Capital Asset Pricing Model: Theory and Evidence," *Journal of Economic Perspectives*, Volume 18, Number 3, Summer 2004, 25-43.

Based upon this evidence, Fama and French proposed their three-factor model which includes a size variable in recognition of the effect of size on the cost of common equity.

In view of all of the foregoing, adding a business risk adjustment of 0.50%, coupled with a credit risk adjustment of 0.63%, to the 9.60% indicated common equity cost rate based upon the eight publicly traded water companies, results in a business risk-adjusted common equity cost rate of 10.73%[31], which, when rounded to 10.75%, is my recommended common equity cost rate.

In my opinion, a common equity cost rate of 10.75%, which results in an overall rate of return of 8.93%, is both reasonable and conservative given AWC's above-normal and increasing capital requirements related to the replacement of aging infrastructure, its inability to earn its authorized ROE when sales decline, and the relative impact of SDWA compliance.

A common equity cost rate of 10.75% is consistent with the *Hope* and *Bluefield* standards of a fair and reasonable return which ensures the integrity of presently invested capital and enables the attraction of needed new capital on reasonable terms. It also ensures the continued reliability and quality of service to the benefit of ratepayers. Thus, it balances the interests of both ratepayers and the Company.

Q. DOES THAT CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

---

[31] 10.75% (rounded) = 9.60% + 0.63% + 0.50%.

APPENDIX
A

APPENDIX A

PROFESSIONAL QUALIFICATIONS

OF

PAULINE M. AHERN, CRRA
PARTNER

SUSSEX ECONOMIC ADVISORS, LLC

PROFESSIONAL QUALIFICATIONS
OF
PAULINE M. AHERN, CRRA
PARTNER
SUSSEX ECONOMIC ADVISORS, LLC

PROFESSIONAL EXPERIENCE

2015-Present

In 2015, I joined Sussex Economic Advisors, LLC as a partner. I am responsible for providing testimony as an expert witness on subjects of fair rate of return, cost of capital and related issues before public utility regulatory commissions. I also provide assistance and support to clients throughout the entire ratemaking litigation process.

I continue to be responsible for maintaining and calculating the performance of the AGA Index, a market capitalization weighted index of the common stocks of the approximately 70 corporate members of the AGA, which serves as the benchmark for the AGA Gas Utility Index Fund.

As a Partner, I am also involved in strategic planning for Sussex Economic Advisors, LLC.

1994-2015

In 2014, I became a Managing Principal of AUS Consultants responsible for continuing to manage the consulting practice, in addition to providing testimony as an expert witness as described below. I am also a Vice President of AUS Inc.

In 1996, I became a Principal of AUS Consultants, continuing to offer testimony as an expert witness on the subjects of fair rate of return, cost of capital and related issues before state public utility commissions. I provide assistance and support to clients throughout the entire ratemaking litigation process. In addition, I supervise the financial analyst and administrative staff in the preparation of fair rate of return and cost of capital exhibits which are filed along with expert testimony before various state and federal public utility regulatory bodies. The team also assists in the preparation of interrogatory responses, as well as rebuttal exhibits.

As the Publisher of AUS Utility Reports (formerly C. A. Turner Utility Reports), I am responsible for the production, publishing, and distribution of the reports. AUS Utility Reports provides financial data and related ratios for about 80 public utilities, i.e., electric, combination gas and electric, natural gas distribution, natural gas transmission, telephone, and water utilities, on a monthly, quarterly and annual basis. Among the subscribers of AUS Utility Reports are utilities, many state regulatory commissions, federal agencies, individuals, brokerage firms, attorneys, as well as public and academic libraries. The publication has continuously provided financial statistics on the utility industry since 1930.

I am also responsible for maintaining and calculating the performance of the AGA Index, a market capitalization weighted index of the common stocks of the

approximately 70 corporate members of the AGA, which serves as the benchmark for the AGA Gas Utility Index Fund.

As an Assistant Vice President from 1994 - 1996, I prepared fair rate of return and cost of capital exhibits which were filed along with expert testimony before various state and federal public utility regulatory bodies. These supporting exhibits include the determination of an appropriate ratemaking capital structure and the development of embedded cost rates of senior capital. The exhibits also support the determination of a recommended return on common equity through the use of various market models, such as, but not limited to, Discounted Cash Flow analysis, Capital Asset Pricing Model and Risk Premium Methodology, as well as an assessment of the risk characteristics of the client utility. I also assisted in the preparation of responses to any interrogatories received regarding such testimonies filed on behalf of client utilities. Following the filing of fair rate of return testimonies, I assisted in the evaluation of opposition testimony in order to prepare interrogatory questions, areas of cross-examination, and rebuttal testimony. I also evaluated and assisted in the preparation of briefs and exceptions following the hearing process. I also submitted testimony before state public utility commissions regarding appropriate capital structure ratios and fixed capital cost rates.

1990-1994

As a Senior Financial Analyst, I supervised two analysts and assisted in the preparation of fair rate of return and cost of capital exhibits which are filed along with expert testimony before various state and federal public utility regulatory bodies. The team also assisted in the preparation of interrogatory responses.

I evaluated the final orders and decisions of various commissions to determine whether further actions were warranted and to gain insight which assisted in the preparation of future rate of return studies.

I assisted in the preparation of an article authored by Frank J. Hanley and A. Gerald Harris entitled "Does Diversification Increase the Cost of Equity Capital?" published in the July 15, 1991 issue of Public Utilities Fortnightly.

In 1992, I was awarded the professional designation "Certified Rate of Return Analyst" (CRRA) by the National Society of Rate of Return Analysts (now the Society of Utility and Regulatory Financial Analysts (SURFA)). This designation is based upon education, experience and the successful completion of a comprehensive examination.

As Administrator of Financial Analysis for AUS Utility Reports, which then reported financial data for over 200 utility companies with approximately 1,000 subscribers, I oversaw the preparation of this monthly publication, as well as the accompanying annual publication, Financial Statistics - Public Utilities.

1988-1990

As a Financial Analyst, I assisted in the preparation of fair rate of return studies including capital structure determination, development of senior capital cost rates, as well as the determination of an appropriate rate of return on equity. I also assisted in the preparation of interrogatory responses, interrogatory questions of the opposition,

areas of cross-examination and rebuttal testimony. I also assisted in the preparation of the annual publication C. A. Turner Utility Reports - Financial Statistics -Public Utilities.

1973-1975

As a Research Assistant in the Research Department of the Regional Economics Division of the Federal Reserve Bank of Boston, I was involved in the development and maintenance of econometric models to simulate regional economic conditions in New England in order to study the effects of, among other things, the energy crisis of the early 1970's and property tax revaluations on the economy of New England. I was also involved in the statistical analysis and preparation of articles for the New England Economic Review. Also, I was Assistant Editor of New England Business Indicators.

1972

As a Research Assistant in the Office of the Assistant Secretary for International Affairs, U.S. Treasury Department, Washington, D.C., I developed and maintained econometric models which simulated the economy of the United States in order to study the results of various alternate foreign trade policies so that national trade policy could be formulated and recommended.

Clients Served

I have offered expert testimony before the following commissions:

Alaska
Arkansas
Arizona
British Columbia
California
Connecticut
Delaware
Florida
Hawaii
Idaho
Illinois
Indiana
Iowa
Kentucky
Louisiana
Maine
Maryland
Michigan
Missouri
Nevada
New Hampshire
New Jersey
New York
North Carolina
Ohio
Pennsylvania
Rhode Island
South Carolina
Virginia
Washington

I have sponsored testimony on fair rate of return and related issues for:

Alpena Power Company
Apple Canyon Utility Company
Applied Wastewater Management, Inc.
Aqua Illinois, Inc.

Aqua New Jersey, Inc.
Aqua North Carolina, Inc.
Aquarion Water Company
Aquarion Water Co. of New Hampshire, Inc.
Arizona Water Company
Artesian Water Company
The Atlantic City Sewerage Company
Audubon Water Company
Bermuda Water Company
Carolina Pines Utilities, Inc.
Carolina Water Service, Inc. of NC
Carolina Water Service, Inc. of SC
Chaparral City Water Company
The Columbia Water Company
The Connecticut Water Company
Consumers Illinois Water Company
Consumers Maine Water Company
Consumers New Jersey Water Company
Corix Utilities
City of DuBois, Pennsylvania
Elizabethtown Water Company
Emporium Water Company
EPCOR Water Arizona, Inc.
Fairbanks Natural Gas LLC
Greenridge Utilities, Inc.
The Borough of Hanover, PA
GTE Hawaiian Telephone Inc.
Illinois American Water Company
Indiana American Water Company
Iowa American Water Company
Jersey Central Power & Light Co.
Lake Wildwood Utilities Corp.
Land'Or Utility Company
Long Island American Water Company
Long Neck Water Company
Louisiana Water Service, Inc.
Maine Water Company
Massanutten Public Service Company
Middlesex Water Company
Missouri Gas Energy
Missouri-American Water Company
Mt. Holly Water Company
Nero Utility Services, Inc.
New Jersey Utilities Association
Aqua Ohio, Inc.
Aqua Virginia, Inc.
The Newtown Artesian Water Company
NRG Energy Center Harrisburg LLC
NRG Energy Center Pittsburgh LLC
Ohio-American Water Company
Penn Estates Utilities
Pinelands Waste Water Company
Pinelands Water Company
Pioneer Water LLC
Pittsburgh Thermal
San Gabriel Valley Water Company
San Jose Water Company
Southland Utilities, Inc.
Spring Creek Utilities, Inc.
Sussex Shores Water Company
Tega Cay Water Services, Inc.
Thames Water Americas
Tidewater Utilities, Inc.
Total Environmental Services, Inc. – Treasure Lake Water & Sewer Divisions
Transylvania Utilities, Inc.
Trigen – Philadelphia Energy Corporation
Twin Lakes Utilities, Inc.
United Utility Companies
United Water Arkansas, Inc.
United Water Arlington Hills Sewerage, Inc.
United Water Connecticut, Inc.
United Water Delaware, Inc.
United Water Great Gorge Inc./United Water Vernon Transmission, Inc.
United Water Idaho, Inc.
United Water Indiana, Inc.
United Water New Jersey, Inc.
United Water New Rochelle, Inc.
United Water New York, Inc.
United Water Owego/Nichols, Inc.
United Water Pennsylvania, Inc.
United Water Rhode Island, Inc.
United Water South County, Inc.
United Water Toms River, Inc.
United Water Vernon Sewage Inc.

United Water Virginia, Inc.
United Water West Lafayette, Inc.
United Water West Milford, Inc.
United Water Westchester, Inc.
Utilities, Inc.
Utilities Inc. of Central Nevada
Utilities, Inc. of Florida
Utilities, Inc. of Louisiana
Utilities, Inc. of Nevada
Utilities, Inc. of Pennsylvania
Utilities, Inc. - Westgate
Utilities Services of South Carolina
Utility Center, Inc.
Valley Energy, Inc.
Water Services Corp. of Kentucky
Wellsboro Electric Company
Western Utilities, Inc.

I have sponsored testimony on generic/uniform methodologies for determining the return on common equity for:

Aquarion Water Company
The Connecticut Water Company
Corix Multi-Utility Services, Inc.
United Water Connecticut, Inc.
Utilities, Inc.

I have sponsored testimony on the rate of return and capital structure effects of merger and acquisition issues for:

California-American Water Company
New Jersey-American Water Company

I have sponsored testimony on capital structure and senior capital cost rates for the following clients:

Alpena Power Company
Arkansas-Western Gas Company
Associated Natural Gas Company
PG Energy Inc.
United Water Delaware, Inc.
Washington Natural Gas Company

I have sponsored testimony on Distribution System Improvement Charges (DSIC):

Arizona Water Company

I have assisted in the preparation of rate of return studies on behalf of the following clients:

Algonquin Gas Transmission Company
Anadarko Petroleum Corporation
Arizona Water Company
Arkansas-Louisiana Gas Company
Arkansas Western Gas Company
Artesian Water Company
Associated Natural Gas Company
Atlantic City Electric Company
Bridgeport-Hydraulic Company
Cambridge Electric Light Company
Carolina Power & Light Company
Citizens Gas and Coke Utility
City of Vernon, CA
Columbia Gas/Gulf Transmission Cos.
Commonwealth Electric Company
Commonwealth Telephone Company
Conestoga Telephone & Telegraph Co.
Connecticut Natural Gas Corporation
Consolidated Gas Transmission Company

Consumers Power Company
CWS Systems, Inc.
Delmarva Power & Light Company
East Honolulu Community Services, Inc.
Equitable Gas Company
Equitrans, Inc.
Fairbanks Natural Gas, LLC
Florida Power & Light Company
Gary Hobart Water Company
Gasco, Inc.
Great Lakes Gas Transmission L.P.
GTE Arkansas, Inc.
GTE California, Inc.
GTE Florida, Inc.
GTE Hawaiian Telephone
GTE North, Inc.
GTE Northwest, Inc.
GTE Southwest, Inc.
Hawaiian Electric Company
Hawaiian Electric Light Company
IES Utilities Inc.
Illinois Power Company
Interstate Power Company
Interstate Power & Light Co.
Iowa Electric Light and Power Company
Iowa Southern Utilities Company
Kentucky-West Virginia Gas Company
Lockhart Power Company
Middlesex Water Company
Milwaukee Metropolitan Sewer District
Mountaineer Gas Company
National Fuel Gas Distribution Corp.
National Fuel Gas Supply Corp.
Newco Waste Systems of NJ, Inc.
New Jersey Natural Gas Company
New Jersey-American Water Company
New York-American Water Company
North Carolina Natural Gas Corp.
Northumbrian Water Company
Ohio-American Water Company
Oklahoma Natural Gas Company
Orange and Rockland Utilities
Paiute Pipeline Company
PECO Energy Company
Penn Estates Utilities, Inc.
Penn-York Energy Corporation
Pennsylvania-American Water Co.
PG Energy Inc.
Philadelphia Electric Company
Providence Gas Company

South Carolina Pipeline Company
Southwest Gas Corporation
Stamford Water Company
Tesoro Alaska Petroleum Company
Tesoro Refining & Marketing Co.
United Telephone of New Jersey
United Utility Companies
United Water Arkansas, Inc.
United Water Delaware, Inc.
United Water Idaho, Inc.
United Water Indiana, Inc.
United Water New Jersey, Inc.
United Water New York, Inc.
United Water Pennsylvania, Inc.
United Water Virginia, Inc.
United Water West Lafayette, Inc.
Utilities, Inc. of Pennsylvania
Utilities, Inc. - Westgate
Vista-United Telecommunications Corp.
Washington Gas Light Company
Washington Natural Gas Company
Washington Water Power Corporation
Waste Management of New Jersey – Transfer Station A
Wellsboro Electric Company
Western Reserve Telephone Company
Western Utilities, Inc.
Wisconsin Power and Light Company

EDUCATION:

1973 – Clark University – B.A. – Honors in Economics (Concentration: Econometrics and Regional/International Economics)
1991 – Rutgers University – M.B.A. – High Honors (Concentration: Corporate Finance)

PROFESSIONAL AFFILIATIONS:

Advisory Council – Financial Research Institute – University of Missouri – Robert J. Trulaske, Sr. School of Business
Edison Electric Institute – Cost of Capital Working Group
National Association of Water Companies – Member of the Finance/Accounting/Taxation and Rates and Regulation Committees
Society of Utility and Regulatory Financial Analysts
Member, Board of Directors – 2010-2014
President – 2006-2008 and 2008-2010
Secretary/Treasurer – 2004-2006
American Finance Association
Financial Management Association

SPEAKING ENGAGEMENTS:

"Leadership in the Financial Services Sector", Guest Professor – Cost of Capital, Business Leader Development Program, Rutgers University School of Business, May 22, 2015, Camden, NJ.

"ROE: Trends & Analysis", American Gas Association, AGA Mini-Forum for the Financial Analysts Community & Finance Committee Meeting, September 11, 2014, The Princeton Club, New York, NY.

Guest Professor, "Measuring Risk", Asset Supervision and Administration Commission of the State Council of the Peoples' Republic of China, Rutgers School of Business, July 21, 2014, New Brunswick, NJ.

Instructor, "Cost of Capital 101", EPCOR Water America, Inc., Regulatory Management Team, June 9, 2014, Phoenix, AZ.

Moderator: Society of Utility Financial Analysts: 46th Financial Forum – "The Rating Agencies' Perspectives: Regulatory Mechanisms and the Regulatory Compact", April 22-25, 2014, Indianapolis, IN.

"The Return on Equity Debate: Its Impact on Budgeting and Investment and Wall Street's View of Risk", National Association of Water Companies – 2014 Indiana Chapter Water Summit, March 13, 2014, Indianapolis, IN.

"Regulatory Training in Financing, Planning, Strategies and Accounting Issues for Publicly- and Privately-Owned Water and Wastewater Utilities", New Mexico State University Center for Public Utilities, October 13-18, 2013, Instructor (Cost of Capital).

"Regulated Utilities – Access to Capital", (panelist) - Innovation: Changing the Future of Energy, 2013 Deloitte Energy Conference, Deloitte Center for Energy Solutions, May 22, 2013, Washington, DC.

"Comparative Evaluation of the Predictive Risk Premium Model, the Discounted Cash Flow Model and the Capital Asset Pricing Model for Estimating the Cost of Common Equity", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) – Advanced Workshop in Regulation and Competition, 32nd Annual Eastern Conference of the Center for Research in Regulated Industries (CRRI), May 17, 2013, Rutgers University, Shawnee on the Delaware, PA.

"Decoupling: Impact on the Risk and Cost of Common Equity of Public Utility Stocks", before the Society of Utility and Regulatory Financial Analysts: 45th Financial Forum, April 17-18, 2013, Indianapolis, IN.

"Issues Surrounding the Determination of the Allowed Rate of Return", before the Staff Subcommittee on Electricity of the National Association of Regulatory Utility Commissioners, Winter 2013 Committee Meetings, February 3, 2013, Washington, DC.

"Leadership in the Financial Services Sector", Guest Professor – Cost of Capital, Business Leader Development Program, Rutgers University School of Business, February 1, 2013, Camden, NJ.

"Analyst Training in the Power and Gas Sectors", SNL Center for Financial Education, Downtown Conference Center at Pace University, New York City, December 12, 2012, Instructor (Financial Statement Analysis).

"Regulatory Training in Financing Planning, Strategies and Accounting Issues for Publicly and Privately Owned Water and Wastewater Utilities", New Mexico State University Center for Public Utilities, October 14-19, 2012, Instructor (Cost of Financial

Capital).

"Application of a New Risk Premium Model for Estimating the Cost of Common Equity", Co-Presenter with Dylan W. D'Ascendis, CRRA, AUS Consultants, Edison Electric Institute Cost of Capital Working Group, October 3, 2012, Webinar.

"Application of a New Risk Premium Model for Estimating the Cost of Common Equity", Co-Presenter with Dylan W. D'Ascendis, CRRA, AUS Consultants, Staff Subcommittee on Accounting and Finance of the National Association of Regulatory Commissioners, September 10, 2012, St. Paul, MN.

"Analyst Training in the Power and Gas Sectors", SNL Center for Financial Education, Downtown Conference Center at Pace University, New York City, August 7, 2012, Instructor (Financial Statement Analysis).

"Advanced Regulatory Training in Financing Planning, Strategies and Accounting Issues for Publicly and Privately Owned Water and Wastewater Utilities", New Mexico State University Center for Public Utilities, May 13-17, 2012, Instructor (Cost of Financial Capital).

"A New Approach for Estimating the Equity Risk Premium Applied to Public Utilities", before the Finance and Regulatory Committees of the National Association of Water Companies, March 29, 2012, Telephonic Conference.

"A New Approach for Estimating the Equity Risk Premium Applied to Public Utilities", (co-presenter with Frank J. Hanley, Principal and Director, AUS Consultants) before the Water Committee of the National Association of Regulatory Utility Commissioners' Winter Committee Meetings, February 7, 2012, Washington, DC.

"A New Approach for Estimating the Equity Risk Premium Applied to Public Utilities", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University and Frank J. Hanley, Principal and Director, AUS Consultants) before the Wall Street Utility Group, December 19, 2011, New York City, NY.

"Advanced Cost and Finance Issues for Water", (co-presenter with Gary D. Shambaugh, Principal & Director, AUS Consultants), 2011 Advanced Regulatory Studies Program – Ratemaking, Accounting and Economics, September 29, 2011, Kellogg Center at Michigan State University – Institute for Public Utilities, East Lansing, MI.

"Public Utility Betas and the Cost of Capital", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) – Advanced Workshop in Regulation and Competition, 30th Annual Eastern Conference of the Center for Research in Regulated Industries (CRRI), May 20, 2011, Rutgers University, Skytop, PA.

Moderator: Society of Utility and Regulatory Financial Analysts: 43rd Financial Forum – "Impact of Cost Recovery Mechanisms on the Perception of Public Utility Risk", April 14-

15, 2011, Washington, DC.

"A New Approach for Estimating the Equity Risk Premium for Public Utilities", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) – Hot Topic Hotline Webinar, December 3, 2010, Financial Research Institute of the University of Missouri.

"A New Approach for Estimating the Equity Risk Premium for Public Utilities", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) before the Indiana Utility Regulatory Commission Cost of Capital Task Force, September 28, 2010, Indianapolis, IN

Tomorrow's Cost of Capital: Cost of Capital Issues 2010, Deloitte Center for Energy Solutions, 2010 Deloitte Energy Conference, "Changing the Great Game: Climate, Customers and Capital", June 7-8, 2010, Washington, DC.

"A New Approach for Estimating the Equity Risk Premium for Public Utilities", (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) – Advanced Workshop in Regulation and Competition, 29th Annual Eastern Conference of the Center for Research in Regulated Industries (CRRI), May 20, 2010, Rutgers University, Skytop, PA

Moderator: Society of Utility and Regulatory Financial Analysts: 42nd Financial Forum – "The Changing Economic and Capital Market Environment and the Utility Industry", April 29-30, 2010, Washington, DC

"A New Model for Estimating the Equity Risk Premium for Public Utilities" (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) – Spring 2010 Meeting of the Staff Subcommittee on Accounting and Finance of the National Association of Regulatory Utility Commissioners, March 17, 2010, Charleston, SC

"New Approach to Estimating the Cost of Common Equity Capital for Public Utilities" (co-presenter with Richard A. Michelfelder, Ph.D., Rutgers University) - Advanced Workshop in Regulation and Competition, 28th Annual Eastern Conference of the Center for Research in Regulated Industries (CRRI), May 14, 2009, Rutgers University, Skytop, PA

Moderator: Society of Utility and Regulatory Financial Analysts: 41st Financial Forum – "Estimating the
Cost of Capital in Today's Economic and Capital Market Environment", April 16-17, 2009, Washington, DC

"Water Utility Financing: Where Does All That Cash Come From?", AWWA Pre-Conference Workshop: Water Utility Ratemaking, March 25, 2008, Atlantic City, NJ

PUBLICATIONS:

Contributor: The Lawyer's Guide to the Cost of Capital: Understanding Risk and Return for Valuing Businesses and Other Investments, Shannon Pratt and Roger Grabowski, American Bar Association, 2014.

"Comparative Evaluation of the Predictive Risk Premium Model™, the Discounted Cash Flow Model and the Capital Asset Pricing Model", co-authored with Richard A. Michelfelder, Ph.D., Rutgers University, Dylan W. D'Ascendis, and Frank J. Hanley, The Electricity Journal, May, 2013.

"A New Approach for Estimating the Equity Risk Premium for Public Utilities", co-authored with Frank J. Hanley and Richard A. Michelfelder, Ph.D., Rutgers University, The Journal of Regulatory Economics (December 2011), 40:261-278.

"Comparable Earnings: New Life for Old Precept" co-authored with Frank J. Hanley, Financial Quarterly Review, (American Gas Association), Summer 1994.

EXHIBITS

Arizona Water Company
Table of Contents
to the Financial Supporting Exhibits
of Pauline M. Ahern, CRRA

	Exhibit
Summary of Cost of Capital and Fair Rate of Return	PMA-1
Capital Intensity and Depreciation Rates for Arizona Water Company and the Proxy Group of Eight Water Companies	PMA-2
Financial Profile of Arizona Water Company	PMA-3
Financial Profile of the Proxy Group of Eight Water Companies	PMA-4
Indicated Common Equity Cost Rate Using the Discounted Cash Flow Model	PMA-5
Current Institutional Holdings	PMA-6
Indicated Common Equity Cost Rate Using the Risk Premium Model	PMA-7
Indicated Common Equity Cost Rate Using the Capital Asset Pricing Model	PMA-8
Standard & Poor's Cash Flow / Leverage Analysis Ratios	PMA-9

PMA-1

Arizona Water Company
Summary of Cost of Capital and Fair Rate of Return
Based upon the Actual Capital Structure
at Test-Year Ended December 31, 2014

Type Of Capital	Ratios (1)	Cost Rate		Weighted Cost Rate
Long-Term Debt	46.31%	6.82%	(1)	3.16%
Common Equity	53.69%	10.75%	(2)	5.77%
Total	100.00%			8.93%

Notes:

(1) Company provided.
(2) From page 2 of this Exhibit.

Arizona Water Company
Brief Summary of Common Equity Cost Rate

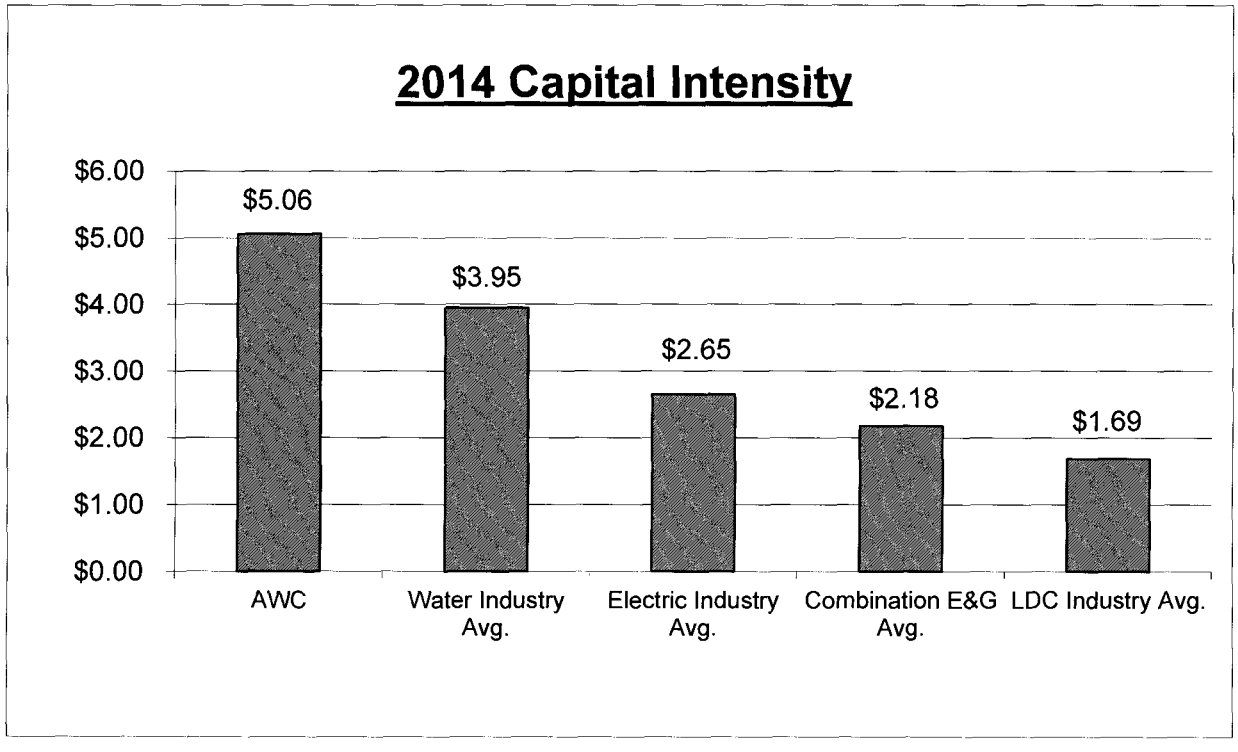
Line No.	Principal Methods	Proxy Group of Eight Publicly Traded Water Companies
1.	Discounted Cash Flow Model (DCF) (1)	8.64 %
2.	Risk Premium Model (RPM) (2)	10.76
3.	Capital Asset Pricing Model (CAPM) (3)	9.58
4.	Indicated Common Equity Cost Rate before Adjustment for Business Risk	9.60 %
5.	Credit Risk Adjustment (4)	0.63
6.	Business Risk Adjustment (5)	0.50
7.	Indicated Common Equity Cost Rate	10.73
8.	Recommended Common Equity Cost Rate	10.75 %

Notes:
(1) From page 1 of Exhibit PMA-5.
(2) From page 1 of Exhibit PMA-7.
(3) From page 1 of Exhibit PMA-8.
(4) Credit risk adjustment to reflect Arizona Water Company's likely Moody's bond rating of Baa2 relative to the proxy group's average Moody's Bond rating of A2/A3 as detailed in Ms. Ahern's accompany direct testimony.
(5) Business risk adjustment to reflect Arizona Water Company's greater business risk due to its unique riskds as well as small size relative to the proxy group as detailed in Ms. Ahern's accompanying direct testimony.

PMA-2

Arizona Water Company
2014 Capital Intensity of Utilities, Inc. of Central Nevada and
Utility Company Groups and Industry Averages

	Average Net Plant ($ mill)	Total Operating Revenue ($ mill)	Capital Intensity ($)	Capital Intensity Arizona Water Company v. Other Industries (times)
Arizona Water Company	$ 323.66	$ 63.97	$ 5.06	- -
Water Industry Average	$ 2,411.70	$ 611.15	$ 3.95	128.10%
Electric Industry Average	$ 17,004.84	$ 6,422.08	$ 2.65	190.94%
Combination Elec. & Gas Industry Average	$ 16,109.32	$ 7,385.21	$ 2.18	232.11%
Gas Distribution Average	$ 3,842.72	$ 2,271.59	$ 1.69	299.41%

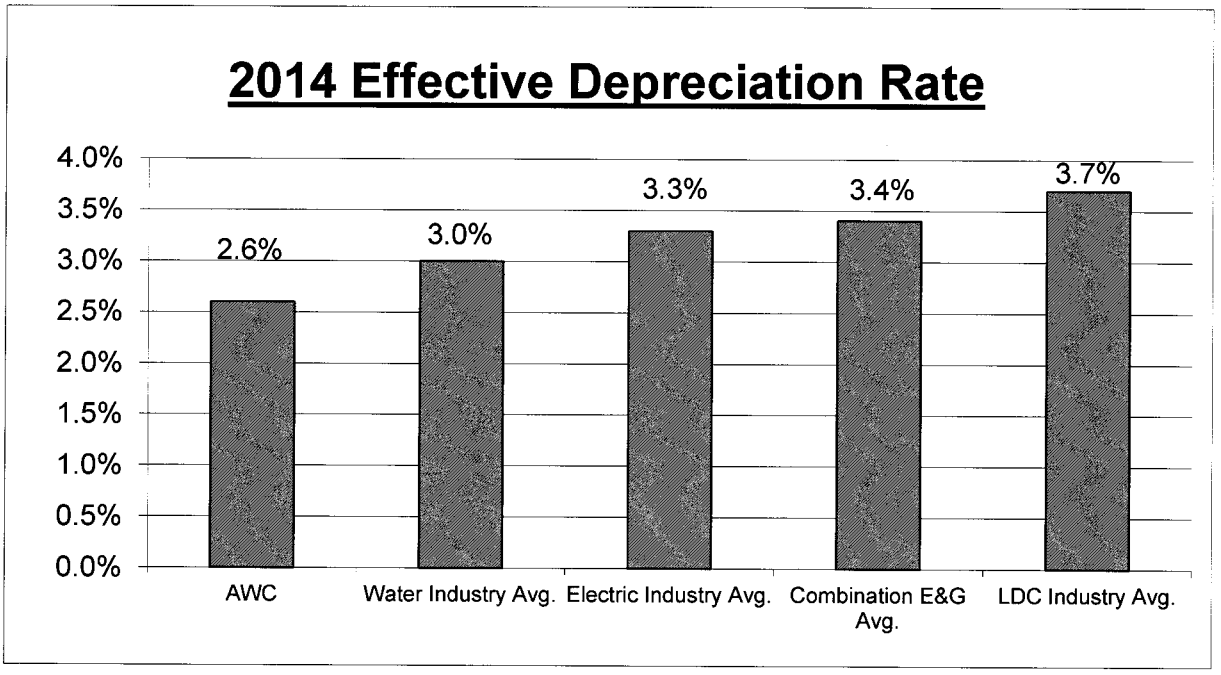


Notes:
Capital Intensity is equal to Average Net Plant divided by Total Operating Revenue.

Source of Information:
Company Annual Forms 10-K
Arizona Water Company's Audited Financial Statements for the year ended December 31, 2014.

Arizona Water Company
2014 Depreciation Rate of Arizona Water Company and
Utility Company Groups and Industry Averages

	Depreciation Depletion & Amort. Expense ($ mill)	Average Total Gross Plant Less CWIP ($ mill)	Depreciation Rate (%)	Depreciation Rate Arizona Water Company v. Other Industries (times)
Arizona Water Company	$ 10.10	$ 382.35	2.6%	--
Water Industry Average	$ 80.97	$ 2,739.56	3.0%	86.67%
Electric Industry Average	$ 727.38	$ 22,063.71	3.3%	78.79%
Combination Elec. & Gas Industry Average	$ 756.74	$ 22,241.95	3.4%	76.47%
LDC Gas Distribution Industry Average	$ 182.93	$ 4,979.82	3.7%	70.27%



Notes:
Effective Depreciation Rate is equal to Depreciation, Depletion and Amortization Expense divided by average beginning and ending year's Gross Plant minus Construction Work in Progress.

Source of Information:
Company Annual Forms 10-K
Arizona Water Company's Audited Financial Statements for the year ended December 31, 2014.

Arizona Water Company
CAPITALIZATION AND FINANCIAL STATISTICS (1)
2010 - 2014, Inclusive

	2014	2013	2012	2011	2010	5 YEAR AVERAGE
			(MILLIONS OF DOLLARS)			
CAPITALIZATION STATISTICS						
AMOUNT OF CAPITAL EMPLOYED						
TOTAL PERMANENT CAPITAL	$ 161.959	$ 158.284	$ 152.478	$ 153.221	$ 152.975	
SHORT-TERM DEBT	-	-	-	-	-	
TOTAL-CAPITAL EMPLOYED	$161.959	$158.284	$152.478	$153.221	$152.975	
INDICATED AVERAGE CAPITAL COST RATES (2)						
TOTAL DEBT	6.83 %	6.83 %	6.83 %	6.83 %	6.83 %	
PREFERRED STOCK						
CAPITAL STRUCTURE RATIOS						
BASED ON TOTAL PERMANENT CAPITAL:						
LONG-TERM DEBT	46.31 %	47.38 %	49.19 %	48.95 %	49.03 %	48.17 %
PREFERRED STOCK	-	-	-	-	-	-
COMMON EQUITY	53.69	52.62	50.81	51.05	50.97	51.83
TOTAL	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
BASED ON TOTAL CAPITAL:						
TOTAL DEBT, INCLUDING SHORT-TERM	46.31 %	47.38 %	49.19 %	48.95 %	49.03 %	48.17 %
PREFERRED STOCK	-	-	-	-	-	-
COMMON EQUITY	53.69	52.62	50.81	51.05	50.97	51.83
TOTAL	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
DIVIDEND PAYOUT RATIO	57.61 %	29.53 %	111.73 %	94.99 %	114.16 %	81.60 %
RATE OF RETURN ON AVERAGE BOOK COMMON EQUITY	10.19 %	10.25 %	8.14 %	6.29 %	5.14 %	8.00 %
TOTAL DEBT / EBITDA (3)	2.64 x	2.72 x	3.08 x	3.37 x	3.83 x	3.13 x
FUNDS FROM OPERATIONS / TOTAL DEBT (4)	29.16 %	26.92 %	23.82 %	23.40 %	18.51 %	24.36 %
TOTAL DEBT / TOTAL CAPITAL	46.31 %	47.38 %	49.19 %	48.95 %	49.03 %	48.17 %
FUNDS FROM OPERATIONS / INTEREST (5)	4.75 x	4.32 x	3.84 x	3.70 x	2.82 x	3.89 x
EBITDA / INTEREST (6)	6.16 x	5.90 x	5.25 x	4.69 x	3.98 x	5.20 x
CASH FLOWS FROM OPERATIONS / TOTAL DEBT (7)	25.76 %	26.44 %	23.66 %	22.87 %	19.65 %	23.68 %
FREE OPERATING CASH FLOW / TOTAL DEBT (8)	4.55 %	9.12 %	7.95 %	10.03 %	12.05 %	8.74 %
DISCRETIONARY CASH FLOWS / TOTAL DEBT (9)	-2.11 %	5.87 %	-1.49 %	3.81 %	6.34 %	2.48 %

Notes:

(1) All capitalization and financial statistics for the group are the arithmetic average of the achieved results for each individual company in the group, and are based upon financial statements as originally reported in each year.

(2) Computed by relating actual total debt interest or preferred stock dividends booked to average of beginning and ending total debt or preferred stock reported to be outstanding.

(3) Total debt relative to EBITDA (Earnings before Interest, Income Taxes, Depreciation and Amortization)

(4) Funds from operations (sum of net income, depreciation, amortization, net deferred income tax and investment tax credits, less total AFUDC) plus interest charges as a percentage of total debt.

(5) Funds from operations (sum of net income, depreciation, amortization, net deferred income tax and investment tax credits, less total AFUDC) plus interest charges as a percentage of cash interest.

(6) EBITDA (Earnings before Interest, Income Taxes, Depreciation and Amortization) relative to cash interest.

(7) Cash flows from operations as a percentage of total debt.

(8) Free operating cash flows (cash flows from operations less capital expenditures) as a percentage of total debt.

(9) Discretionary cash flow (free operating cash flow minus all dividend payments) as a percentage of total debt.

Source of Information: Arizona Water Company's Audited Financial Statements.

Proxy Group of Eight Publicly Traded Water Companies
CAPITALIZATION AND FINANCIAL STATISTICS (1)
2010 - 2014, Inclusive

	2014	2013	2012	2011	2010	
			(MILLIONS OF DOLLARS)			
CAPITALIZATION STATISTICS						
AMOUNT OF CAPITAL EMPLOYED						
TOTAL PERMANENT CAPITAL	$2,156.407	$2,058.747	$1,998.358	$1,926.369	$1,901.851	
SHORT-TERM DEBT	$72.459	$95.589	$60.594	$89.698	$56.420	
TOTAL CAPITAL EMPLOYED	$2,228.866	$2,154.336	$2,058.952	$2,016.067	$1,958.271	
INDICATED AVERAGE CAPITAL COST RATES (2)						
TOTAL DEBT	5.09 %	5.19 %	5.36 %	5.32 %	5.54 %	
PREFERRED STOCK	5.30 %	5.51 %	5.53 %	5.53 %	5.54 %	
CAPITAL STRUCTURE RATIOS						5 YEAR AVERAGE
BASED ON TOTAL PERMANENT CAPITAL:						
LONG-TERM DEBT	45.71 %	46.24 %	49.32 %	50.91 %	50.74 %	48.58 %
PREFERRED STOCK	0.13	0.16	0.18	0.21	0.21	0.18
COMMON EQUITY	54.16	53.60	50.50	48.88	49.05	51.24
TOTAL	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
BASED ON TOTAL CAPITAL:						
TOTAL DEBT, INCLUDING SHORT-TERM	47.00 %	47.77 %	50.87 %	52.68 %	52.82 %	50.23 %
PREFERRED STOCK	0.13	0.15	0.17	0.19	0.20	0.17
COMMON EQUITY	52.87	52.08	48.96	47.13	46.98	49.60
TOTAL	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
FINANCIAL STATISTICS						
FINANCIAL RATIOS - MARKET BASED						
EARNINGS / PRICE RATIO	5.44 %	4.84 %	5.47 %	5.19 %	5.18 %	5.22 %
MARKET / AVERAGE BOOK RATIO	212.84	206.33	187.65	181.94	181.79	194.11
DIVIDEND YIELD	2.76	2.91	3.17	3.40	3.39	3.13
DIVIDEND PAYOUT RATIO	52.68	60.11	59.10	66.53	65.70	60.82
RATE OF RETURN ON AVERAGE BOOK COMMON EQUITY	11.38 %	10.08 %	10.12 %	9.30 %	9.29 %	10.03 %
TOTAL DEBT / EBITDA (3)	3.74 X	3.65 X	3.83 X	4.30 X	4.55 X	4.01 X
FUNDS FROM OPERATIONS / TOTAL DEBT (4)	25.83 %	22.91 %	20.95 %	19.26 %	17.60 %	21.31 %
TOTAL DEBT / TOTAL CAPITAL	47.00 %	47.77 %	50.87 %	52.68 %	52.82 %	50.23 %

Notes:

(1) All capitalization and financial statistics for the group are the arithmetic average of the achieved results for each individual company in the group, and are based upon financial statements as originally reported in each year.

(2) Computed by relating actual total debt interest or preferred stock dividends booked to average of beginning and ending total debt or preferred stock reported to be outstanding.

(3) Total debt relative to EBITDA (Earnings before Interest, Income Taxes, Depreciation and Amortization).

(4) Funds from operations (sum of net income, depreciation, amortization, net deferred income tax and investment tax credits, less total AFUDC) plus interest charges as a percentage of total debt.

Source of Information: Company Annual Forms 10-K

Capital Structure Based upon Total Permanent Capital for the
Proxy Group of Eight Publicly Traded Water Companies
2010 - 2014, Inclusive

	2014	2013	2012	2011	2010	5 YEAR AVERAGE
American States Water Co.						
Long-Term Debt	39.15 %	40.30 %	42.49 %	45.46 %	44.30 %	42.34 %
Preferred Stock	0.00	0.00	0.00	0.00	0.00	0.00
Common Equity	60.85	59.70	57.51	54.54	55.70	57.66
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
American Water Works Co., Inc.						
Long-Term Debt	52.70 %	52.42 %	54.30 %	55.72 %	56.73 %	54.37 %
Preferred Stock	0.15	0.17	0.21	0.27	0.29	0.22
Common Equity	47.15	47.41	45.49	44.01	42.98	45.41
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
Aqua America, Inc.						
Long-Term Debt	49.45 %	50.32 %	53.41 %	54.11 %	57.05 %	52.87 %
Preferred Stock	0.00	0.01	0.01	0.02	0.02	0.01
Common Equity	50.55	49.67	46.58	45.87	42.93	47.12
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
California Water Service Group						
Long-Term Debt	40.46 %	42.03 %	50.39 %	52.04 %	52.51 %	47.49 %
Preferred Stock	0.00	0.00	0.00	0.00	0.00	0.00
Common Equity	59.54	57.97	49.61	47.96	47.49	52.51
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
Connecticut Water Service, Inc.						
Long-Term Debt	45.91 %	47.34 %	49.03 %	53.05 %	49.32 %	48.93 %
Preferred Stock	0.20	0.20	0.21	0.30	0.34	0.25
Common Equity	53.90	52.46	50.76	46.65	50.34	50.82
Total Capital	100.01 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
Middlesex Water Company						
Long-Term Debt	41.54 %	41.36 %	43.53 %	43.12 %	43.91 %	42.69 %
Preferred Stock	0.71	0.88	1.02	1.06	1.07	0.95
Common Equity	57.75	57.76	55.45	55.82	55.02	56.36
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
SJW Corporation						
Long-Term Debt	51.66 %	51.09 %	55.39 %	56.63 %	53.79 %	53.71 %
Preferred Stock	0.00	0.00	0.00	0.00	0.00	0.00
Common Equity	48.34	48.91	44.61	43.37	46.21	46.29
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
York Water Company						
Long-Term Debt	44.81 %	45.07 %	45.98 %	47.16 %	48.28 %	46.26 %
Preferred Stock	0.00	0.00	0.00	0.00	0.00	0.00
Common Equity	55.19	54.93	54.02	52.84	51.72	53.74
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %
Proxy Group of Eight Publicly Traded Water Companies						
Long-Term Debt	45.71 %	46.24 %	49.32 %	50.91 %	50.74 %	48.58 %
Preferred Stock	0.13	0.16	0.18	0.21	0.21	0.18
Common Equity	54.16	53.60	50.50	48.88	49.05	51.24
Total Capital	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %

Source of Information
Annual Forms 10-K

PMA-5

Arizona Water Company
Indicated Common Equity Cost Rate Using the Discounted Cash Flow Model for
the Proxy Group of Eight Publicly Traded Water Companies

Proxy Group of Eight Publicly Traded Water Companies	[1] Average Dividend Yield (1)	[2] Value Line Projected Five Year Growth in EPS (2)	[3] Reuters Mean Consensus Projected Five Year Growth Rate in EPS	[4] Zack's Five Year Projected Growth Rate in EPS	[5] Yahoo! Finance Projected Five Year Growth in EPS	[6] Average Projected Five Year Growth in EPS (3)	[7] Adjusted Dividend Yield (4)	[8] Indicated Common Equity Cost Rate (5)
American States Water Co.	2.16 %	6.50 %	5.00 %	5.00 %	5.00 %	5.38 %	2.22 %	7.60 %
American Water Works Co., Inc.	2.53	7.50	7.50	7.40	7.50	7.48	2.62	10.10
Aqua America, Inc.	2.49	8.00	5.00	5.30	5.00	5.83	2.56	8.39
California Water Service Group	2.74	7.50	5.00	5.00	5.00	5.63	2.82	8.45
Connecticut Water Service, Inc.	2.84	6.50	5.00	5.00	5.00	5.38	2.92	8.30
Middlesex Water Company	3.43	5.00	NA	NA	2.70	3.85	3.50	7.35
SJW Corporation	2.54	6.50	NA	NA	14.00	10.25	2.67	12.92
York Water Company	2.54	6.50	NA	NA	4.90	5.70	2.61	8.31
							Average	8.93 %
							Median	8.35 %
							Average of Mean and Median	8.64 %

NA= Not Available
NMF = Not Meaningful Figure

Notes:

(1) Indicated dividend at 05/29/2015 divided by the average closing price of the last 60 trading days ending 05/29/2015 fc each company.

(2) From pages 2 through 9 of this Exhibit.

(3) Average of columns 2 through 5 excluding negative growth rates.

(4) This reflects a growth rate component equal to one-half the conclusion of growth rate (from column 6) x column 1 to reflect the periodic payment of dividends (Gordon Model) as opposed to the continuous payment. Thus, for American States Water Co., 2.16% x (1+(1/2 x 5.38%)) = 2.22%.

(5) Column 6 + column 7.

Source of Information:

Value Line Investment Survey
www.reuters.com Downloaded on 05/29/2015
www.zacks.com Downloaded on 05/29/2015
www.yahoo.com Downloaded on 05/29/2015

AMER. STATES WATER NYSE-AWR

RECENT PRICE 39.76 | P/E RATIO 24.0 (Trailing: 25.5 Median: 21.0) | RELATIVE P/E RATIO 1.24 | DIV'D YLD 2.2% | VALUE LINE

TIMELINESS 3 Lowered 5/16/14
SAFETY 2 Raised 7/20/12
TECHNICAL 2 Raised 4/3/15
BETA .70 (1.00 = Market)

2018-20 PROJECTIONS

	Price	Gain	Ann'l Total Return
High	50	(+25%)	8%
Low	35	(-10%)	Nil

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	0	0	0	0	0	0	0	0	0
Options	0	0	0	0	0	0	1	0	1
to Sell	0	1	0	0	1	0	3	0	1

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	96	81	99
to Sell	68	86	87
Hld's(000)	23236	23032	23380

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
	6.45	6.08	6.53	6.89	6.99	6.81	7.03	7.88	8.75	9.21	9.74	10.71	11.12	12.12	12.19	12.17	*12.35*	*13.35*	Revenues per sh	*15.35*
	1.13	1.10	1.26	1.27	1.04	1.11	1.32	1.45	1.65	1.69	1.70	2.11	2.13	2.48	2.65	*2.65*	*2.70*	*2.80*	"Cash Flow" per sh	*3.70*
	.60	.64	.67	.67	.39	.53	.66	.67	.81	.78	.81	1.11	1.12	1.41	1.61	1.57	*1.60*	*1.65*	Earnings per sh [A]	*2.15*
	.43	.43	.43	.44	.44	.44	.45	.46	.48	.50	.51	.52	.55	.64	.76	.83	*.88*	*.93*	Div'd Decl'd per sh [B■]	*1.12*
	2.15	1.51	1.59	1.34	1.88	2.51	2.12	1.95	1.45	2.23	2.09	2.12	2.13	1.77	2.52	1.90	*2.05*	*2.10*	Cap'l Spending per sh	*2.40*
	5.91	6.37	6.61	7.02	6.98	7.51	7.86	8.32	8.77	8.97	9.70	10.13	10.84	11.80	12.72	13.24	*13.80*	*14.25*	Book Value per sh	*15.45*
	26.87	30.24	30.24	30.36	30.42	33.50	33.60	34.10	34.46	34.60	37.06	37.26	37.70	38.53	38.72	38.29	*38.00*	*37.50*	Common Shs Outst'g [C]	*37.50*
	17.1	15.9	16.7	18.3	31.9	23.2	21.9	27.7	24.0	22.6	21.2	15.7	15.4	14.3	17.2	22.2	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*20.5*
	.97	1.03	.86	1.00	1.82	1.23	1.17	1.50	1.27	1.36	1.41	1.00	.97	.91	.97	1.17			Relative P/E Ratio	*1.30*
	4.2%	4.2%	3.9%	3.6%	3.5%	3.6%	3.1%	2.5%	2.5%	2.9%	2.9%	3.0%	3.2%	3.1%	2.7%	2.4%			Avg Ann'l Div'd Yield	*2.7%*
							236.2	268.6	301.4	318.7	361.0	398.9	419.3	466.9	472.1	465.8	*470*	*500*	Revenues ($mill)	*575*
							22.5	23.1	28.0	26.8	29.5	41.4	42.0	54.1	62.7	61.1	*61.0*	*62.5*	Net Profit ($mill)	*80.0*
							47.0%	40.5%	42.6%	37.8%	38.9%	43.2%	41.7%	39.9%	36.3%	38.4%	*38.5%*	*38.0%*	Income Tax Rate	*38.0%*
							--	12.2%	8.5%	6.9%	3.2%	5.8%	2.0%	2.5%	2.5%	*.5%*	*.5%*	*1.0%*	AFUDC % to Net Profit	*2.0%*
							50.4%	48.6%	46.9%	46.2%	45.9%	44.3%	45.4%	42.2%	39.8%	39.1%	*41.0%*	*43.0%*	Long-Term Debt Ratio	*42.0%*
							49.6%	51.4%	53.1%	53.8%	54.1%	55.7%	54.6%	57.8%	60.2%	60.9%	*59.0%*	*57.0%*	Common Equity Ratio	*58.0%*
							532.5	551.6	569.4	577.0	665.0	677.4	749.1	787.0	818.4	832.6	*890*	*935*	Total Capital ($mill)	*1070*
							713.2	750.6	776.4	825.3	866.4	855.0	896.5	917.8	981.5	1003.5	*1060*	*1120*	Net Plant ($mill)	*1240*
							5.4%	6.0%	6.7%	6.4%	5.9%	7.6%	7.1%	8.3%	8.9%	8.6%	*9.0%*	*8.5%*	Return on Total Cap'l	*8.5%*
							8.5%	8.1%	9.3%	8.6%	8.2%	11.0%	10.3%	11.9%	12.7%	12.1%	*11.5%*	*11.5%*	Return on Shr. Equity	*13.0%*
							8.5%	8.1%	9.3%	8.6%	8.2%	11.0%	10.3%	11.9%	12.7%	12.1%	*11.5%*	*11.5%*	Return on Com Equity	*13.0%*
							2.8%	2.7%	3.9%	3.1%	3.2%	5.8%	5.3%	6.6%	6.8%	5.6%	*5.0%*	*5.0%*	Retained to Com Eq	*6.0%*
							67%	67%	58%	64%	61%	47%	49%	45%	47%	53%	*55%*	*56%*	All Div'ds to Net Prof	*52%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $326.1 mill. **Due in 5 Yrs** $41.6 mill.
LT Debt $325.8 mill. **LT Interest** $21.5 mill.
(LT interest earned: 5.7 x; total interest coverage: 5.4 x) (39% of Cap'l)
Leases, Uncapitalized: Annual rentals $0.4 mill.
Pension Assets-12/14 $140.6 mill.
Oblig. $185.2 mill.
Pfd Stock None.

Common Stock 38,220,567 shs.
as of 2/23/15

MARKET CAP: $1.6 billion (Mid Cap)

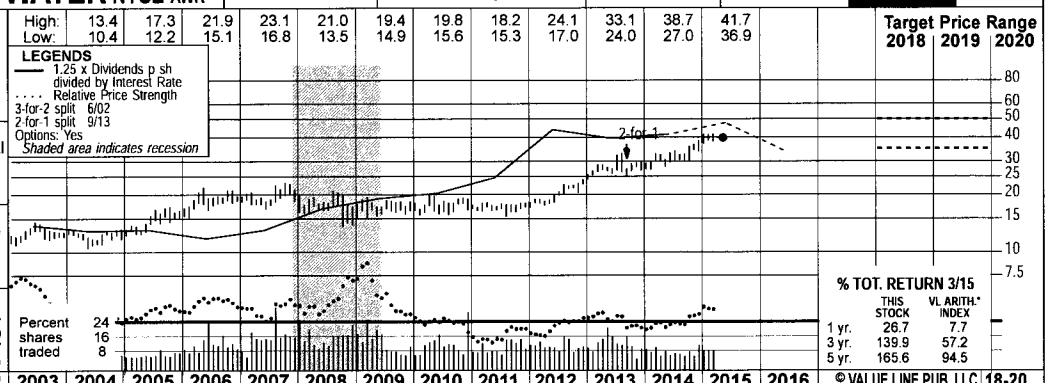
CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	23.5	38.2	76.0
Other	160.5	153.4	133.5
Current Assets	184.0	191.6	209.5
Accts Payable	40.6	49.8	41.9
Debt Due	3.3	6.3	.3
Other	49.8	44.8	57.1
Current Liab.	93.7	100.9	99.3
Fix. Chg. Cov.	488%	531%	533%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	5.5%	6.5%	*4.0%*
"Cash Flow"	7.5%	8.5%	*6.0%*
Earnings	9.0%	13.0%	*6.5%*
Dividends	4.0%	6.5%	*8.0%*
Book Value	5.5%	6.5%	*4.0%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	107.6	114.3	133.5	111.5	466.9
2013	110.6	120.7	130.9	109.9	472.1
2014	102.0	115.6	138.3	109.9	465.8
2015	*103*	*117*	*140*	*110*	*470*
2016	*105*	*125*	*150*	*120*	*500*

Calendar	EARNINGS PER SHARE [A] Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.27	.40	.49	.26	1.41
2013	.35	.43	.53	.30	1.61
2014	.28	.39	.54	.36	1.57
2015	*.30*	*.45*	*.55*	*.30*	*1.60*
2016	*.31*	*.46*	*.57*	*.31*	*1.65*

Calendar	QUARTERLY DIVIDENDS PAID [B■] Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.13	.14	.14	.14	.55
2012	.14	.14	.1775	.1775	.64
2013	.1775	.1775	.2025	.2025	.76
2014	.2025	.2025	.213	.213	.83
2015	.213				



BUSINESS: American States Water Co. operates as a holding company. Through its principal subsidiary, Golden States Water Company, it supplies water to 258,191 customers in 75 communities and 10 counties. Service areas include the greater metropolitan areas of Los Angeles and Orange Counties. The company also provides electric utility services to 23,716 customers in the city of Big Bear Lake and in areas of San Bernardino County. Sold Chaparral City Water of Arizona (6/11). Has 707 employees. Blackrock, Inc., owns 9.8% of out. shares; Vanguard, 8.5%; off. & dir. 1.5%. (4/15 Proxy). Chairman: Lloyd Ross. President & CEO: Robert J. Sprowls. Inc: CA. Addr: 630 East Foothill Boulevard, San Dimas, CA 91773. Tel: 909-394-3600. Internet: www.aswater.com.

American States Water's earnings growth should be modest through 2016. The company's main subsidiary, Golden State Water Co., has been coming close to earning the allowable return on its common equity for the past two years. Thus, there isn't much room for bottom-line expansion in the near term. All told, we only expect share net to increase 2% this year, followed by a 3% increase in 2016.

Growth in the military business should bolster long-term profits. Through its ASUS subsidiary, the company provides water to nine armed forces bases under six 50-year contracts. This operation, in which returns are not capped by state regulators, has been responsible for 20% to 25% of American States' share earnings. Over the next five years, up to 50 more bases may privatize their water and wastewater systems. As ASUS has performed successfully in this sector, we expect it to win a proportionate amount of these contracts.

Operating in California has not been a negative for the company. Regulators in the state have worked well with the industry in response to the record-breaking drought now plaguing the region. Usually, a decrease in water usage translates into reduced revenues for a utility, making conservation almost not in their interest. In a process known as decoupling, GSWC is allowed to structure fees that result in it not being penalized to incentivize households to use less water. Indeed, over the past six years, water usage has declined 16%-17%. Moreover, California permits utilities to collect increased expenses as they are incurred, not after the fact, as many other state regulators require.

Management believes that a 5% dividend growth rate is sustainable over the next 3- to 5-year period. Though this is below historical levels, the expected increase in the annual payout is not far off the industry average. With the help from nonregulated businesses, we think there is potential upside to this figure.

American Water shares do not stand out for either short- or long-term potential performance. The stock's strong showing has eliminated much of its attractiveness.

James A. Flood *April 17, 2015*

(A) Primary earnings. Excludes nonrecurring gains/(losses): '04, 7¢; '05, 13¢; '06, 3¢; '08, (14¢); '10, (23¢) '11, 10¢. Next earnings report due mid-May. Quarterly earnings may not add due to rounding.
(B) Dividends historically paid in early March, June, September, and December. ■ Div'd reinvestment plan available.
(C) In millions, adjusted for splits.

Company's Financial Strength	A
Stock's Price Stability	85
Price Growth Persistence	70
Earnings Predictability	85

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

AMERICAN WATER NYSE-AWK

RECENT PRICE 54.68 | P/E RATIO 20.5 (Trailing: 23.0 Median: NMF) | RELATIVE P/E RATIO 1.06 | DIV'D YLD 2.4% | VALUE LINE

TIMELINESS 2 Raised 1/23/15
SAFETY 3 New 7/25/08
TECHNICAL 2 Raised 4/10/15
BETA .70 (1.00 = Market)

2018-20 PROJECTIONS

	Price	Gain	Ann'l Total Return
High	80	(+45%)	12%
Low	50	(-10%)	1%

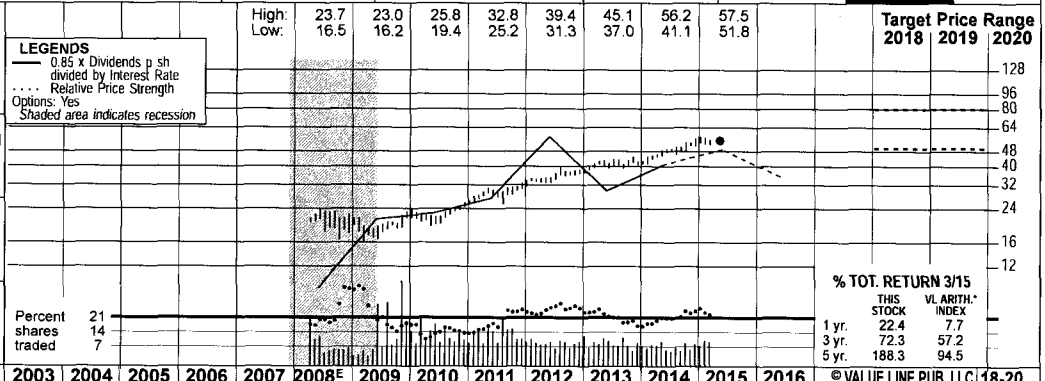
Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	0	0	0	0	0	0	0	0	0
Options	3	0	0	4	0	0	3	0	0
to Sell	3	0	0	6	0	0	3	0	0

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	208	206	223
to Sell	194	189	201
Hld's(000)	146101	146606	143322

LEGENDS
0.85 x Dividends p sh divided by Interest Rate
Relative Price Strength
Options: Yes
Shaded area indicates recession



1999	2000	2001	2002	2003	2004	2005	2006	2007	2008E	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
--	--	--	--	--	--	--	13.08	13.84	14.61	13.98	15.49	15.18	16.25	16.28	16.78	17.70	18.50	Revenues per sh	21.40
--	--	--	--	--	--	--	.65	d.47	2.87	2.89	3.56	3.73	4.27	4.36	4.75	4.65	5.10	"Cash Flow" per sh	6.15
--	--	--	--	--	--	--	d.97	d2.14	1.10	1.25	1.53	1.72	2.11	2.06	2.39	2.60	2.80	Earnings per sh A	3.25
--	--	--	--	--	--	--	--	--	.40	.82	.86	.91	1.21	.84	1.21	1.33	1.42	Div'd Decl'd per sh B■	1.70
--	--	--	--	--	--	--	4.31	4.74	6.31	4.50	4.38	5.27	5.25	5.50	5.33	5.55	5.55	Cap'l Spending per sh	6.25
--	--	--	--	--	--	--	23.86	28.39	25.64	22.91	23.59	24.11	25.11	26.52	27.39	27.60	29.00	Book Value per sh D	34.55
--	--	--	--	--	--	--	160.00	160.00	160.00	174.63	175.00	175.66	176.99	178.25	179.46	179.50	179.50	Common Shs Outst'g C	185.00
--	--	--	--	--	--	--	--	--	18.9	15.6	14.6	16.8	16.7	19.9	20.1	Bold figures are Value Line estimates		Avg Ann'l P/E Ratio	20.0
--	--	--	--	--	--	--	--	--	1.14	1.04	.93	1.05	1.06	1.12	1.06			Relative P/E Ratio	1.25
--	--	--	--	--	--	--	--	--	1.9%	4.2%	3.8%	3.1%	3.4%	2.0%	2.5%			Avg Ann'l Div'd Yield	2.6%
--	--	--	--	--	--	--	2093.1	2214.2	2336.9	2440.7	2710.7	2666.2	2876.9	2901.9	3011.3	3175	3325	Revenues ($mill)	3960
--	--	--	--	--	--	--	d155.8	d342.3	187.2	209.9	267.8	304.9	374.3	369.3	429.8	465	505	Net Profit ($mill)	600
--	--	--	--	--	--	--	--	--	37.4%	37.9%	40.4%	39.5%	40.7%	39.1%	39.4%	39.5%	38.5%	Income Tax Rate	37.5%
--	--	--	--	--	--	--	--	--	--	--	--	--	6.2%	5.1%	1.4%	5.0%	5.0%	AFUDC % to Net Profit	6.0%
--	--	--	--	--	--	--	56.1%	50.9%	53.1%	56.9%	56.8%	55.7%	53.9%	52.4%	52.4%	53.5%	53.0%	Long-Term Debt Ratio	55.0%
--	--	--	--	--	--	--	43.9%	49.1%	46.9%	43.1%	43.2%	44.2%	46.1%	47.6%	47.4%	46.5%	47.0%	Common Equity Ratio	45.0%
--	--	--	--	--	--	--	8692.8	9245.7	8750.2	9289.0	9561.3	9580.3	9635.5	9940.7	10363.8	10955	11500	Total Capital ($mill)	13300
--	--	--	--	--	--	--	8720.6	9318.0	9991.8	10524	11059	11021	11739	12391	13029.3	13600	14250	Net Plant ($mill)	15000
--	--	--	--	--	--	--	NMF	NMF	3.7%	3.8%	4.4%	4.8%	5.4%	5.1%	5.5%	5.0%	5.5%	Return on Total Cap'l	6.0%
--	--	--	--	--	--	--	NMF	NMF	4.6%	5.2%	6.5%	7.2%	8.4%	7.8%	8.7%	8.5%	8.5%	Return on Shr. Equity	9.0%
--	--	--	--	--	--	--	NMF	NMF	4.6%	5.2%	6.5%	7.2%	8.4%	7.8%	8.7%	8.5%	8.5%	Return on Com Equity	9.0%
--	--	--	--	--	--	--	NMF	NMF	3.0%	1.8%	2.8%	3.5%	3.6%	4.7%	4.3%	4.0%	4.5%	Retained to Com Eq	4.5%
--	--	--	--	--	--	--	--	--	34%	65%	56%	52%	57%	40%	51%	53%	51%	All Div'ds to Net Prof	51%

CAPITAL STRUCTURE as of 12/31/14
Total Debt $5959.3 mil. **Due in 5 Yrs** $1294.5 mil.
LT Debt $5448.2 mil. **LT Interest** $278.0 mil.
(Total interest coverage: 3.0x) (53% of Cap'l)

Leases, Uncapitalized: Annual rentals $14.0 mill.
Pension Assets 12/14 $1428.2 mill
Oblig. $1746.5 mill.
Pfd Stock $17.2 mill. **Pfd Div'd** $.5 mill

Common Stock 179,787,780 shs.
as of 2/19/2015

MARKET CAP: $9.8 billion (Large Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	24.4	27.0	23.1
Other	475.0	523.3	638.3
Current Assets	499.4	550.3	661.4
Accts Payable	279.6	264.1	285.8
Debt Due	385.9	644.5	511.1
Other	329.3	326.9	444.1
Current Liab.	994.8	1235.5	1241.0
Fix. Chg. Cov.	297%	307%	300%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	--	3.0%	4.5%
"Cash Flow"	--	32.5%	6.0%
Earnings	--	--	7.5%
Dividends	--	--	8.0%
Book Value	--	-.5%	5.0%

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	618.5	745.6	831.8	681.0	2876.9
2013	636.1	724.3	829.2	712.3	2901.9
2014	679.0	754.8	846.1	731.4	3011.3
2015	700	805	880	790	3175
2016	735	840	920	830	3325

Calendar	EARNINGS PER SHARE A Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.28	.66	.87	.30	2.11
2013	.32	.57	.84	.33	2.06
2014	.39	.62	.86	.52	2.39
2015	.45	.70	1.00	.45	2.60
2016	.50	.75	1.05	.50	2.80

Calendar	QUARTERLY DIVIDENDS PAID B■ Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.22	.23	.23	.23	.91
2012	.23	.23	.25	.50	1.21
2013	--	.28	.28	.28	.84
2014	.28	.31	.31	.31	1.21
2015	.31				

BUSINESS: American Water Works Company, Inc. is the largest investor-owned water and wastewater utility in the U.S., providing services to over 15 million people in over 47 states and Canada. (Regulated presence in 16 states.) Nonregulated business assists municipalities and military bases with the maintenance and upkeep as well. Regulated operations made up 88.8% of 2014 revenues. New Jersey is its largest market accounting for 22.7% of regulated revenues. Has roughly 6,400 employees. BlackRock, Inc., owns 10.0% of outstanding shares; Vanguard, 6.3%; officers & directors, less than 1.0%. (4/14 Proxy). Pres. & CEO: Susan Story. Chairman: George Mackenzie. Addr.: 1025 Laurel Oak Road, Voorhees, NJ 08043. Tel.: 856-346-8200. Internet: www.amwater.com.

American Water Works recently completed another successful year. Thanks to a strong fourth quarter, the company posted a hefty 16% year-over-year share-net gain in 2014.

We expect this trend to continue. One of the strengths of American Water is in its ability to make many small tuck-in acquisitions and integrate them into existing operations. In addition to the synergies realized from these purchases, management continues to place a significant emphasis on driving down costs. (Last year's key expense ratio fell from 38.5% to 36.7%.) Since, like most members of this industry, the company needs to make large expenditures to improve its infrastructure, it will have to spend roughly $1 billion annually for the foreseeable future. Higher investment increases American Water's assets that it is allowed to earn a return on. Though comparison with last year's impressive results will be difficult, we expect the company to record healthy earnings-per-share gains of 8% in both 2015 and 2016.

American Water stands out in comparison to most of its peers. For starters, this is a market in which size matters. AWK's market capitalization represents more than half that of all of the nine stocks in this industry combined. As smaller municipally-run water districts realize that they don't have the financial wherewithal required to maintain their systems, American Water should be the main beneficiary. As the largest buyer of pipes, meters, etc., it is able to get better pricing. Moreover, being so diversified geographically, the utility already is familiar with all federal and state regulations.

The balance sheet should remain about average. American Water probably won't be able to generate sufficient cash to cover its large construction budget through late decade. So, more debt will be required. As a result, we don't expect the Financial Strength rating to be raised.

These shares are ranked to outperform the market averages in the year ahead. But despite all of the company's positive attributes, the equity's total return potential through 2016-2018 is below average for the typical stock in the *Value Line* universe.

James A. Flood *April 17, 2015*

(A) Diluted earnings. Excludes nonrecurring losses: '08, $4.62; '09, $2.63; '11, $0.07. Discontinued operations: '06, ($0.04); '11, $0.03; '12, ($0.10); '13,($0.01); '14, ($0.05). Next earnings report due early May. Quarterly earnings may not sum due to rounding. (B) Dividends paid in March, June, September, and December. ■ Div. reinvestment available. Two payments made in 4th quarter of 2012. (C) In millions. (D) Includes intangibles. In 2014: $1.21 billion, $6.73/share. (E) Pro forma numbers for '06 & '07.

Company's Financial Strength	B+
Stock's Price Stability	100
Price Growth Persistence	85
Earnings Predictability	20

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

AQUA AMERICA NYSE-WTR

RECENT PRICE 26.81 | P/E RATIO 21.6 (Trailing: 22.2 Median: 24.0) | RELATIVE P/E RATIO 1.12 | DIV'D YLD 2.6% | VALUE LINE

TIMELINESS 3 Lowered 5/24/13
SAFETY 2 Raised 4/20/12
TECHNICAL 2 Raised 4/3/15
BETA .70 (1.00 = Market)

2018-20 PROJECTIONS

	Price	Gain	Ann'l Total Return
High	40	(+50%)	13%
Low	30	(+10%)	6%

Insider Decisions

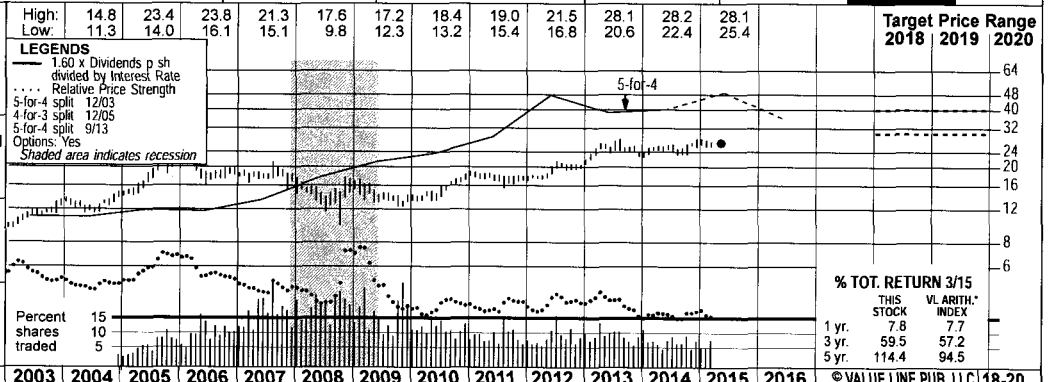
	M	J	J	A	S	O	N	D	J
to Buy	0	0	0	0	0	0	0	0	0
Options	2	1	0	1	0	0	2	1	1
to Sell	3	1	1	2	1	2	5	2	2

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	127	139	137
to Sell	133	126	140
Hld's(000)	81999	80311	81382

	14.8	23.4	23.8	21.3	17.6	17.2	18.4	19.0	21.5	28.1	28.2	28.1
High:	11.3	14.0	16.1	15.1	9.8	12.3	13.2	15.4	16.8	20.6	22.4	25.4

LEGENDS
1.60 x Dividends p sh divided by Interest Rate
.... Relative Price Strength
5-for-4 split 12/03
4-for-3 split 12/05
5-for-4 split 9/13
Options: Yes
Shaded area indicates recession



Target Price Range

2018	2019	2020
64	64	64
48	48	48
40	40	40
32	32	32
24	24	24
20	20	20
16	16	16
12	12	12
8	8	8
6	6	6

% TOT. RETURN 3/15

	THIS STOCK	VL ARITH.* INDEX
1 yr.	7.8	7.7
3 yr.	59.5	57.2
5 yr.	114.4	94.5

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
1.93	1.97	2.16	2.28	2.38	2.78	3.08	3.23	3.61	3.71	3.93	4.21	4.10	4.32	4.32	4.37	*4.55*	*4.70*	Revenues per sh	*5.70*
.58	.61	.69	.76	.77	.87	.97	1.01	1.10	1.14	1.29	1.42	1.45	1.51	1.82	*1.90*	*2.35*	*2.50*	"Cash Flow" per sh	*3.05*
.33	.37	.41	.43	.46	.51	.57	.56	.57	.58	.62	.72	.83	.87	1.16	1.20	*1.25*	*1.30*	Earnings per sh [A]	*1.65*
.22	.23	.24	.26	.28	.29	.32	.35	.38	.41	.44	.47	.50	.54	.58	.63	*.71*	*.77*	Div'd Decl'd per sh [B■]	*.98*
.72	.93	.87	.96	1.06	1.23	1.47	1.64	1.43	1.58	1.66	1.89	1.90	1.98	1.73	1.84	*1.95*	*2.00*	Cap'l Spending per sh	*2.00*
2.74	3.08	3.32	3.49	4.27	4.71	5.04	5.57	5.85	6.26	6.50	6.81	7.21	7.90	8.63	9.27	*9.65*	*10.05*	Book Value per sh	*11.40*
133.50	139.78	142.47	141.49	154.31	158.97	161.21	165.41	166.75	169.21	170.61	172.46	173.60	175.43	177.93	178.59	*176.50*	*175.00*	Common Shs Outst'g [C]	*170.00*
21.2	18.2	23.6	23.6	24.5	25.1	31.8	34.7	32.0	24.9	23.1	21.1	21.3	21.9	21.2	20.2	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*21.5*
1.21	1.18	1.21	1.29	1.40	1.33	1.69	1.87	1.70	1.50	1.54	1.34	1.34	1.39	1.19	1.06			Relative P/E Ratio	*1.35*
3.0%	3.3%	2.5%	2.5%	2.5%	2.3%	1.8%	1.8%	2.1%	2.8%	3.1%	3.1%	2.8%	2.8%	2.4%	2.6%			Avg Ann'l Div'd Yield	*2.6%*
496.8	533.5	602.5	627.0	670.5	726.1	712.0	757.8	768.6	779.9	*800*	*825*	Revenues ($mill)	*970*
91.2	92.0	95.0	97.9	104.4	124.0	144.8	153.1	205.0	213.9	*225*	*230*	Net Profit ($mill)	*280*
38.4%	39.6%	38.9%	39.7%	39.4%	39.2%	32.9%	39.0%	10.0%	*10.5%*	*18.0%*	*20.0%*	Income Tax Rate	*27.0%*
--	--	--	--	--	--	--	--	1.1%	2.4%	*2.0%*	*2.5%*	AFUDC % to Net Profit	*3.0%*
52.0%	51.6%	55.4%	54.1%	55.6%	56.6%	52.7%	52.7%	48.9%	48.5%	*49.5%*	*50.0%*	Long-Term Debt Ratio	*50.0%*
48.0%	48.4%	44.6%	45.9%	44.4%	43.4%	47.3%	47.3%	51.1%	51.5%	*50.5%*	*50.0%*	Common Equity Ratio	*50.0%*
1690.4	1904.4	2191.4	2306.6	2495.5	2706.2	2646.8	2929.7	3003.6	3216.1	*3370*	*3505*	Total Capital ($mill)	*3955*
2280.0	2506.0	2792.8	2997.4	3227.3	3469.3	3612.9	3936.2	4167.3	4402.0	*4550*	*4700*	Net Plant ($mill)	*5000*
6.9%	6.4%	5.9%	5.7%	5.6%	5.9%	6.9%	6.6%	8.0%	*7.5%*	*8.0%*	*7.5%*	Return on Total Cap'l	*8.5%*
11.2%	10.0%	9.7%	9.3%	9.4%	10.6%	11.6%	11.0%	13.4%	12.9%	*13.0%*	*13.0%*	Return on Shr. Equity	*14.5%*
11.2%	10.0%	9.7%	9.3%	9.4%	10.6%	11.6%	11.0%	13.4%	12.9%	*13.0%*	*13.0%*	Return on Com Equity	*14.5%*
4.9%	3.7%	3.2%	2.8%	2.7%	3.7%	4.6%	4.3%	6.7%	6.1%	*5.5%*	*5.5%*	Retained to Com Eq	*6.0%*
56%	63%	67%	70%	72%	65%	60%	61%	50%	53%	*57%*	*53%*	All Div'ds to Net Prof	*59%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $1630.7 mill. **Due in 5 Yrs** $436.9 mill.
LT Debt $1560.7 mill. **LT Interest** $70.0 mill.
(Total interest coverage: 3.9x) (49% of Cap'l)

Pension Assets-12/14 232.4 mill.
Oblig. $281.2 mill.

Pfd Stock None
Common Stock 176,823,519 shares
as of 2/12/15

MARKET CAP: $4.7 billion (Mid Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	5.5	5.1	4.1
Receivables	92.9	95.4	97.0
Inventory (AvgCst)	11.8	11.4	12.8
Other	150.7	59.8	38.6
Current Assets	260.9	171.7	152.5
Accts Payable	55.5	65.8	60.0
Debt Due	125.4	123.0	70.0
Other	93.3	78.1	95.3
Current Liab.	274.2	266.9	225.3
Fix. Chg. Cov.	413%	388%	389%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	6.5%	4.0%	*4.5%*
"Cash Flow"	8.0%	8.0%	*9.5%*
Earnings	8.5%	11.0%	*8.0%*
Dividends	7.5%	7.0%	*9.0%*
Book Value	8.0%	6.0%	*5.5%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2102	164.0	191.7	214.6	187.5	757.8
2013	180.0	195.7	204.3	188.6	768.6
2014	182.7	195.3	210.5	191.4	779.9
2015	*185*	*200*	*215*	*200*	*800*
2016	*190*	*205*	*220*	*210*	*825*

Calendar	EARNINGS PER SHARE [A] Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2012	.15	.24	.29	.19	.87
2013	.26	.30	.36	.24	1.16
2014	.24	.31	.38	.28	1.20
2015	*.25*	*.32*	*.39*	*.29*	*1.25*
2016	*.26*	*.33*	*.41*	*.30*	*1.30*

Calendar	QUARTERLY DIVIDENDS PAID [B■] Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.124	.124	.124	.132	.50
2012	.132	.132	.132	.14	.54
2013	.14	.14	.152	.152	.58
2014	.152	.152	.165	.165	.63
2015	.165				

BUSINESS: Aqua America, Inc. is the holding company for water and wastewater utilities that serve approximately three million residents in Pennsylvania, Ohio, North Carolina, Illinois, Texas, New Jersey, Florida, Indiana, and five other states. Has 1,617 employees. Acquired AquaSource, 7/03; Consumers Water, 4/99; and others. Water supply revenues '14: residential, 68%; commercial, 17%; industrial & other, 15%. Officers and directors own .8% of the common stock; Vanguard Group, 6.6%; State Street Capital Corp., 6.3%; Blackrock, Inc, 6.1% (4/14 Proxy). Chairman & Chief Executive Officer: Nicholas DeBenedictis. Incorporated: Pennsylvania. Address: 762 West Lancaster Avenue, Bryn Mawr, Pennsylvania 19010. Telephone: 610-525-1400. Internet: www.aquaamerica.com.

Aqua America has healthy long-term dividend growth prospects. Based upon our projections of the company's ability to internally generate cash, we estimate that the annual payout may increase roughly 9% per annum through 2018-2020. This is a much higher rate than that of the typical stock in the industry.

Earnings gains will probably moderate both this year and next. Excluding the $0.11-a-share gain from the sale of its operations in Fort Wayne, Aqua's share net rose 3.4% in 2014. Considering that 2013 was an exceptional year, the comparison was actually good. Due to some rate relief, synergies from acquisitions, and the ability to earn returns on capital investments with little regulatory lag, we expect the utility to record 4% bottom-line increases in both 2015 and 2016.

Expansion via acquisitions is a major part of the company's strategy. Most water systems in the U.S. are small and municipally owned. Over the past two decades, Aqua has made over 300 purchases, including 16 in 2014. As these smaller water districts realize that they do not have the finances to modernize their aging infrastructures, they will continue to look toward merging with larger companies. With a significant amount of redundancies, cost savings from synergies can be significant in this industry

Low energy prices could impact nonregulated operations. Hydraulic fracking has become a major presence in Aqua's service areas. With each well requiring five million gallons of water, transporting it by truck is both burdensome and expensive. Extending pipeline systems directly to the wells can be very profitable for water utilities. Revenues from this sector should decline, however, as drillers shut wells until the energy market recovers.

Investors willing to sacrifice some returns for more certainty may like these shares. On the plus side, Aqua America stock has a decent well-protected dividend yield, favorable payout growth prospects, a solid balance sheet, the highest (95) mark for Stock Price Stability, well-defined earnings, and a 2 (Above Average) Safety rank. All told, we believe that the potential total returns are adequate on a risk-adjusted basis.

James A. Flood *April 17, 2015*

(A) Diluted eqs. Excl. nonrec. gains (losses): '99, (9¢); '00, 2¢; '01, 2¢; '02, 4¢; '03, 3¢; '12, 18¢. Excl. gain from disc. operations: '12, 7¢; '13, 9¢; '14, 11¢. May not sum due to rounding.

Next earnings report due mid-May.
(B) Dividends historically paid in early March, June, Sept. & Dec. ■ Div'd. reinvestment plan available (5% discount).

(C) In millions, adjusted for stock splits.

Company's Financial Strength	A
Stock's Price Stability	95
Price Growth Persistence	60
Earnings Predictability	95

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

CALIFORNIA WATER NYSE-CWT

RECENT PRICE 24.76 | P/E RATIO 19.2 (Trailing: 23.1 Median: 20.0) | RELATIVE P/E RATIO 0.99 | DIV'D YLD 2.7% | VALUE LINE

TIMELINESS 3 Raised 6/20/14
SAFETY 3 Lowered 7/27/07
TECHNICAL 2 Raised 4/3/15
BETA .75 (1.00 = Market)

2018-20 PROJECTIONS

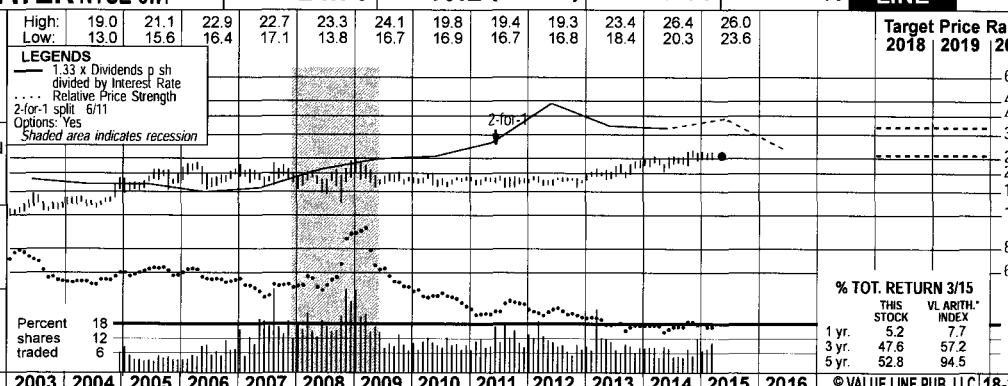
	Price	Gain	Ann'l Total Return
High	35	(+40%)	11%
Low	25	(Nil)	3%

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	0	0	0	0	0	0	0	0	0
Options	0	0	0	1	0	0	0	0	0
to Sell	1	0	0	0	0	0	3	2	0

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	57	53	81
to Sell	56	53	59
Hld's(000)	30279	29552	29654



Target Price Range 2018 | 2019 | 2020
64 48 40 32 24 20 16 12 8 6

% TOT. RETURN 3/15

	THIS STOCK	VL ARITH.* INDEX
1 yr.	5.2	7.7
3 yr.	47.6	57.2
5 yr.	52.8	94.5

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
7.98	8.08	8.13	8.67	8.18	8.59	8.72	8.10	8.88	9.90	10.82	11.05	12.00	13.34	12.23	12.50	*12.80*	*13.25*	Revenues per sh	*16.80*
1.37	1.26	1.10	1.32	1.26	1.42	1.52	1.36	1.56	1.86	1.93	1.93	2.07	2.32	2.21	*2.50*	*2.60*	*2.65*	"Cash Flow" per sh	*3.20*
.77	.66	.47	.63	.61	.73	.74	.67	.75	.95	.98	.91	.86	1.02	1.02	1.19	*1.20*	*1.20*	Earnings per sh A	*1.55*
.54	.55	.56	.56	.56	.57	.57	.58	.58	.59	.59	.60	.62	.63	.64	.65	*.67*	*.69*	Div'd Decl'd per sh B ■	*.97*
1.72	1.23	2.04	2.91	2.19	1.87	2.01	2.14	1.84	2.41	2.66	2.97	2.83	3.04	2.58	*2.75*	*2.50*	*2.60*	Cap'l Spending per sh	*3.10*
6.71	6.45	6.48	6.56	7.22	7.83	7.90	9.07	9.25	9.72	10.13	10.45	10.76	11.28	12.54	13.22	*13.75*	*14.25*	Book Value per sh C	*16.00*
25.87	30.29	30.36	30.36	33.86	36.73	36.78	41.31	41.33	41.45	41.53	41.67	41.82	41.98	47.74	47.81	*48.00*	*48.00*	Common Shs Outst'g D	*50.00*
17.8	19.6	27.1	19.8	22.1	20.1	24.9	29.2	26.1	19.8	19.7	20.3	21.3	17.9	20.1	19.3	*Bold figures are*		Avg Ann'l P/E Ratio	*20.0*
1.01	1.27	1.39	1.08	1.26	1.06	1.33	1.58	1.39	1.19	1.31	1.29	1.34	1.14	1.13	1.02	*Value Line*		Relative P/E Ratio	*1.25*
4.0%	4.3%	4.4%	4.5%	4.2%	3.9%	3.1%	2.9%	3.0%	3.1%	3.1%	3.2%	3.4%	3.5%	3.1%	2.8%	*estimates*		Avg Ann'l Div'd Yield	*3.2%*
320.7	334.7	367.1	410.3	449.4	460.4	501.8	560.0	584.1	597.5	*615*	*635*	Revenues ($mill) E	*840*
27.2	25.6	31.2	39.8	40.6	37.7	36.1	42.6	47.3	56.7	*57.5*	*57.5*	Net Profit ($mill)	*77.5*
42.4%	37.4%	39.9%	37.7%	40.3%	39.5%	40.5%	37.5%	30.3%	*33.0%*	*28.5%*	*29.5%*	Income Tax Rate	*36.0%*
3.3%	10.6%	8.3%	8.6%	7.6%	4.2%	7.6%	8.0%	4.3%	2.7%	*2.0%*	*4.5%*	AFUDC % to Net Profit	*5.0%*
48.3%	43.5%	42.9%	41.6%	47.1%	52.4%	51.7%	47.8%	41.6%	40.1%	*43.0%*	*43.5%*	Long-Term Debt Ratio	*41.5%*
51.1%	55.9%	56.6%	58.4%	52.9%	47.6%	48.3%	52.2%	58.4%	59.9%	*57.0%*	*56.5%*	Common Equity Ratio	*58.5%*
568.1	670.1	674.9	690.4	794.9	914.7	931.5	908.2	1024.9	1045.9	*1160*	*1215*	Total Capital ($mill)	*1370*
862.7	941.5	1010.2	1112.4	1198.1	1294.3	1381.1	1457.1	1515.8	1590.4	*1660*	*1730*	Net Plant ($mill)	*1820*
6.3%	5.2%	5.9%	7.1%	6.5%	5.5%	5.5%	6.3%	6.0%	6.8%	*6.5%*	*6.0%*	Return on Total Cap'l	*7.0%*
9.3%	6.8%	8.1%	9.9%	9.6%	8.6%	8.0%	9.0%	7.9%	9.0%	*9.0%*	*8.5%*	Return on Shr. Equity	*9.5%*
9.3%	6.8%	8.1%	9.9%	9.6%	8.6%	8.0%	9.0%	7.9%	9.0%	*9.0%*	*8.5%*	Return on Com Equity	*9.5%*
2.1%	1.0%	1.8%	3.8%	3.8%	3.0%	2.3%	3.4%	3.4%	4.1%	*4.0%*	*3.5%*	Retained to Com Eq	*3.5%*
78%	86%	77%	61%	60%	66%	71%	62%	56%	55%	*56%*	*58%*	All Div'ds to Net Prof	*63%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $504.9 mill. **Due in 5 Yrs** $206.7 mill.
LT Debt $419.2 mill. **LT Interest** $20.0 mill.
(LT interest earned: 4.2x; total int. cov.: 4.0x)
(40% of Cap'l)
Pension Assets-12/14 $306.3 mill.
Oblig. $390.6 mill.
Pfd Stock None

Common Stock 47,800,997 shs.
as of 2/9/15

MARKET CAP: $1.2 billion (Mid Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	38.8	27.5	19.6
Other	107.8	112.0	134.5
Current Assets	146.6	139.5	154.1
Accts Payable	46.8	55.1	59.4
Debt Due	136.3	54.7	85.7
Other	59.7	56.8	72.6
Current Liab.	242.8	166.6	217.7
Fix. Chg. Cov.	296%	301%	299%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	4.0%	7.0%	*5.0%*
"Cash Flow"	6.0%	6.5%	*5.5%*
Earnings	5.5%	4.0%	*7.5%*
Dividends	1.0%	1.5%	*7.0%*
Book Value	5.5%	4.5%	*5.5%*

Calendar	QUARTERLY REVENUES ($ mill.) E Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2012	116.8	143.6	178.1	121.5	560.0
2013	111.4	154.6	184.4	133.7	584.1
2014	110.5	158.4	191.2	137.4	597.5
2015	*115*	*165*	*195*	*140*	*615*
2016	*120*	*170*	*200*	*145*	*635*

Calendar	EARNINGS PER SHARE A Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2012	.03	.31	.56	.12	1.02
2013	.01	.28	.61	.12	1.02
2014	d.11	.36	.70	.24	1.19
2015	*Nil*	*.32*	*.73*	*.15*	*1.20*
2016	*Nil*	*.31*	*.74*	*.15*	*1.20*

Calendar	QUARTERLY DIVIDENDS PAID B ■ Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.154	.154	.154	.154	.62
2012	.1575	.1575	.1575	.1575	.63
2013	.16	.16	.16	.16	.64
2014	.1625	.1625	.1625	.1625	.65
2015	.1675				

BUSINESS: California Water Service Group provides regulated and nonregulated water service to 477,900 customers in 85 communities in the state of California. Accounts for over 94% of total customers. Also operates in Washington, New Mexico, and Hawaii. Main service areas: San Francisco Bay area, Sacramento Valley, Salinas Valley, San Joaquin Valley & parts of Los Angeles. Acquired Rio Grande Corp; West Hawaii Utilities (9/08). Revenue breakdown, '14: residential, 68%; business, 19%; industrial, 5%; public authorities, 3%; other 5%. '14 reported depreciation rate: 4.0%. Has 1,105 employees. President, Chairman, and CEO: Peter C. Nelson. Inc.: DE. Address: 1720 North First St., San Jose, CA 95112-4598. Tel.: 408-367-8200. Internet: www.calwatergroup.com.

State regulators (CPUC) have been working well with California Water Services during the region's historic drought. The more water it sells, the more revenues a water utility generates. Due to the ongoing lack of rainfall, the CPUC has implemented "decoupling." This mechanism encourages conservation, without having a major impact on a water utility's profits.

The company had a much better-than-expected fourth quarter. Fueled by rate relief implemented last year and reduced expenses, California Water's earnings per share doubled to $0.24, on a year-over-year basis in the December interim. This resulted in a hefty 17% bottom-line gain in 2014.

We expect profits to be flattish over the next two years. The bulk of the earnings gains resulting from higher rates were reflected in California Water's earnings in 2014. Based on state regulations, California water utilities can only file for adjustments for increased expenses once every three years. With most of the recent cost reductions probably not sustainable, we estimate that the company's share earnings will barely budge from last year's tally of $1.19, and come in at $1.20 for both 2015 and 2016.

The latest dividend hike was a bit of a disappointment. We had been looking for a 4.6% increase in the quarterly payout to $0.17 a share, instead it was only raised by 3.1% to $0.1675.

California Water's finances are in fine shape. The equity-to-total capital ratio was at an industry high of 60% at year-end 2014. Much of this can be attributed to a large equity offering in 2013. Capital expenditures to replace an aging pipeline infrastructure will probably increase in the years ahead. Because of the strong balance sheet, we don't anticipate any major equity offerings out to the late decade. Additional debt may be required, but we believe the utility's financial metrics will remain above the industry averages.

These shares are not of particular interest at this juncture. On the plus side, CWT's yield is higher than most of the stocks in the water industry. Over the pull to 2018-2020, however, the stock has below-average total return potential.

James A. Flood *April 17, 2015*

(A) Basic EPS. Excl. nonrecurring gain (loss): '00, (4¢); '01, 2¢; '02, 4¢; '11, 4¢. Next earnings report due mid-May. (B) Dividends historically paid in late Feb., May, Aug., and Nov. ■ Div'd reinvestment plan available. (C) Incl. intangible assets. In '14 : $7.3 mill., $0.15/sh. (D) In millions, adjusted for splits. (E) Excludes non-reg. rev.

Company's Financial Strength	B++
Stock's Price Stability	95
Price Growth Persistence	40
Earnings Predictability	90

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

CONNECTICUT WATER NDQ-CTWS

RECENT PRICE 36.82 | P/E RATIO 18.7 (Trailing: 19.2 Median: 22.0) | RELATIVE P/E RATIO 0.97 | DIV'D YLD 2.9% | VALUE LINE

TIMELINESS 3 Lowered 11/21/14
SAFETY 3 New 1/18/13
TECHNICAL 2 Raised 3/27/15
BETA .65 (1.00 = Market)

2018-20 PROJECTIONS

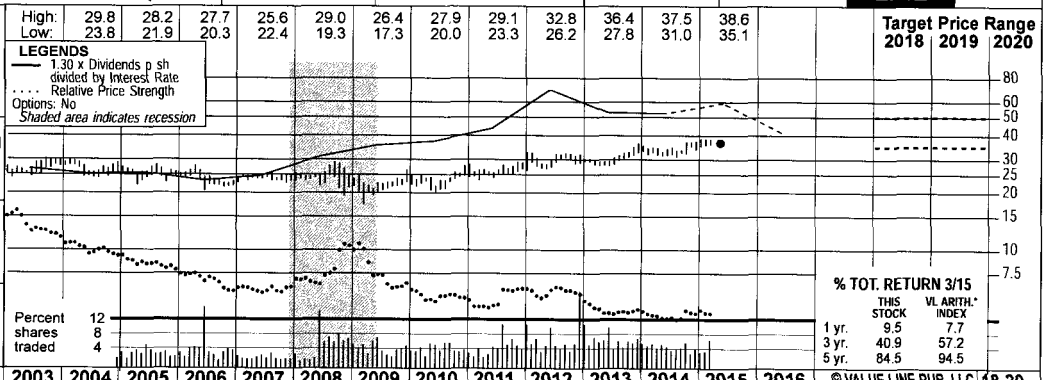
	Price	Gain	Ann'l Total Return
High	50	(+35%)	10%
Low	35	(-5%)	2%

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	0	0	0	0	0	0	0	0	0
Options	0	0	0	0	0	0	0	0	0
to Sell	0	0	0	0	0	0	0	0	0

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	40	50	36
to Sell	32	34	46
Hld's(000)	4304	4299	4296



1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
5.87	5.70	5.93	5.77	5.91	6.04	5.81	5.68	7.05	7.24	6.93	7.65	7.93	9.47	8.29	8.45	*8.75*	*9.00*	Revenues per sh	*12.50*
1.65	1.73	1.78	1.78	1.89	1.91	1.62	1.52	1.90	1.95	1.93	2.04	2.11	2.64	2.63	*3.00*	*3.20*	*3.35*	"Cash Flow" per sh	*3.60*
1.03	1.09	1.13	1.12	1.15	1.16	.88	.81	1.05	1.11	1.19	1.13	1.13	1.53	1.66	1.92	*2.00*	*2.10*	Earnings per sh A	*2.25*
.79	.79	.80	.81	.83	.84	.85	.86	.87	.88	.90	.92	.94	.96	.98	1.01	*1.05*	*1.09*	Div'd Decl'd per sh B■	*1.30*
1.42	1.43	1.86	1.98	1.49	1.58	1.96	1.96	2.24	2.44	3.28	3.06	2.61	2.79	3.02	4.11	*4.60*	*4.15*	Cap'l Spending per sh	*2.85*
8.61	8.92	9.25	10.06	10.46	10.94	11.52	11.60	11.95	12.23	12.67	13.05	13.50	20.95	17.92	18.84	*20.10*	*21.15*	Book Value per sh D	*24.15*
7.26	7.28	7.65	7.94	7.97	8.04	8.17	8.27	8.38	8.46	8.57	8.68	8.76	8.85	11.04	11.12	*11.20*	*11.35*	Common Shs Outst'g C	*12.00*
18.2	18.2	21.5	24.3	23.5	22.9	28.6	29.0	23.0	22.2	18.4	20.7	23.0	19.4	18.4	17.7	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*19.0*
1.04	1.18	1.10	1.33	1.34	1.21	1.52	1.57	1.22	1.34	1.23	1.32	1.44	1.23	1.03	.93			Relative P/E Ratio	*1.20*
4.2%	4.0%	3.3%	3.0%	3.0%	3.1%	3.4%	3.6%	3.6%	3.6%	4.1%	3.9%	3.6%	3.2%	3.2%	3.0%			Avg Ann'l Div'd Yield	*2.8%*
47.5	46.9	59.0	61.3	59.4	66.4	69.4	83.8	91.5	94.0	*98.0*	*102*	Revenues ($mill)	*150*
7.2	6.7	8.8	9.4	10.2	9.8	9.9	13.6	18.3	21.3	*23.0*	*24.0*	Net Profit ($mill)	*27.0*
--	23.5%	32.4%	27.2%	19.5%	35.2%	41.3%	32.0%	28.0%	*14.5%*	*18.0%*	*19.5%*	Income Tax Rate	*30.0%*
--	--	--	1.7%	--	--	--	1.7%	2.0%	2.4%	*2.5%*	*2.5%*	AFUDC % to Net Profit	*2.0%*
44.9%	44.4%	47.8%	46.9%	50.6%	49.5%	53.2%	49.0%	46.9%	45.7%	*45.5%*	*47.5%*	Long-Term Debt Ratio	*47.5%*
54.6%	55.1%	51.8%	52.7%	49.1%	50.2%	46.5%	50.8%	52.9%	54.2%	*54.5%*	*52.5%*	Common Equity Ratio	*52.5%*
172.3	174.1	193.2	196.5	221.3	225.6	254.2	364.6	373.6	386.8	*420*	*455*	Total Capital ($mill)	*550*
247.7	268.1	284.3	302.3	325.2	344.2	362.4	447.9	471.9	506.9	*535*	*560*	Net Plant ($mill)	*675*
5.0%	4.9%	5.5%	5.9%	5.5%	5.4%	4.9%	4.8%	5.9%	*6.4%*	*6.5%*	*6.5%*	Return on Total Cap'l	*6.0%*
7.5%	6.9%	8.7%	9.0%	9.3%	8.6%	8.3%	7.3%	9.2%	10.2%	*10.0%*	*10.0%*	Return on Shr. Equity	*9.5%*
7.6%	7.0%	8.7%	9.1%	9.4%	8.7%	8.3%	7.3%	9.2%	10.2%	*10.0%*	*10.0%*	Return on Com Equity	*9.5%*
.3%	NMF	1.6%	1.9%	2.3%	1.6%	1.4%	2.8%	3.8%	4.5%	*4.5%*	*4.5%*	Retained to Com Eq	*4.0%*
95%	105%	82%	79%	76%	81%	83%	62%	59%	53%	*53%*	*52%*	All Div'ds to Net Prof	*58%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $181.0 mill. **Due in 5 Yrs** $19.3 mill.
LT Debt $176.6 mill. **LT Interest** $7.0 mill.
(Total interest coverage: 4.4x)
(46% of Cap'l)
Leases, Uncapitalized: Annual rentals $.1 mill.
Pension Assets-12/14 $61.6 mill.
Oblig. $79.8 mill.

Pfd Stock $0.8 mill. **Pfd Divd** NMF

Common Stock 11,152,627 shs.
as of 3/1/15
MARKET CAP: $400 million (Small Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	13.2	18.4	2.5
Accounts Receivable	11.5	12.3	12.0
Other	11.7	16.2	21.7
Current Assets	36.4	46.9	36.2
Accts Payable	10.0	10.8	10.0
Debt Due	3.0	4.1	4.4
Other	2.9	7.8	9.2
Current Liab.	15.9	22.7	23.6
Fix. Chg. Cov.	408%	375%	375%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	4.0%	5.0%	*5.5%*
"Cash Flow"	3.0%	6.5%	*5.5%*
Earnings	2.5%	8.0%	*6.5%*
Dividends	1.5%	2.0%	*4.5%*
Book Value	6.0%	8.0%	*4.5%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	18.5	21.3	24.5	19.5	83.8
2013	19.7	22.6	27.6	21.6	91.5
2014	20.3	25.4	27.6	20.7	94.0
2015	*21.5*	*26.5*	*29.0*	*21.0*	*98.0*
2016	*22.5*	*27.5*	*30.0*	*22.0*	*102.0*

Calendar	EARNINGS PER SHARE A Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.22	.47	.67	.16	1.53
2013	.24	.39	.86	.17	1.66
2014	.27	.67	.76	.22	1.92
2015	*.35*	*.60*	*.80*	*.25*	*2.00*
2016	*.36*	*.62*	*.85*	*.27*	*2.10*

Calendar	QUARTERLY DIVIDENDS PAID B■ Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.233	.233	.238	.238	.942
2012	.238	.238	.2425	.2425	.962
2013	.2425	.2425	.2475	.2475	.98
2014	.2475	.2475	.2575	.2575	1.01
2015	.2575				

BUSINESS: Connecticut Water Service, Inc. is a non-operating holding company, whose income is derived from earnings of its wholly-owned subsidiary companies (regulated water utilities). In 2014, 93% of net income was derived from these activities. Provides water services to 400,000 people in 77 municipalities throughout Connecticut and Maine. Acquired The Maine Water Company, January, 2012; Biddeford and Saco Water, December, 2012. Incorporated: Connecticut. Has 265 employees. Chairman/President/Chief Executive Officer: Eric W. Thornburg. Officers and directors own 2.3% of the common stock; BlackRock, Inc. 7.0%; (4/15 proxy). Address: 93 West Main Street, Clinton, CT 06413. Telephone: (860) 669-8636. Internet: www.ctwater.com.

Connecticut Water Services will be hard-pressed to repeat last year's impressive performance. Share net rose 16% in 2014, thanks mostly to an agreement with regulators regarding a rebate from the IRS. Still, we estimate that the utility can string together two consecutive solid years in 2015 and 2016. Margins are improving as the company is successfully integrating two acquisitions made in 2012. Moreover, the Biddleford and Saco operation in Maine was recently granted a significant rate increase. As a result, we think Connecticut Water can still grow earnings 4%-5% per annum over the next two years.

Capital expenditures are scheduled to be large in the short term. In addition, to having to replace older pipes (like almost every other water utility), the company has agreed to supply water to two new customers. Funds are being spent to extend the infrastructure in Connecticut to service the town of Mansfield and the University of Connecticut's Storrs campus, which is the size of a small city. Overall, we expect the capital budget to average over $50 million a year through 2016, which represents a 10% increase over the relatively large outlays made in 2014. Starting in 2017, however, construction should take a breather.

The balance sheet is strong enough to handle the increased spending. The equity-to-total capital ratio will most likely decline from its very healthy level of 54.5% to 52.5% by year-end 2016. Despite the dip, this percentage is high for a water utility.

Dividend growth prospects have improved. Over the past five- and 10-year periods, the company has only raised its annual payout by 1.5% and 2.0%, respectively. This rate lagged the industry mean by a wide margin. We expect this gap to narrow substantially in the long term. Indeed, dividend hikes through late decade will probably average 4.5%.

Shares of Connecticut Water do not hold much appeal at their recent price. Despite having a high yield, the stock is expected to only perform in line with the market averages in the year ahead. Potential returns through late decade are even less attractive.

James A. Flood *April 17, 2015*

(A) Diluted earnings. Next earnings report due mid-May. Quarterly earnings do not add in 2012 due to rounding.
(B) Dividends historically paid in mid-March, June, September, and December. ■ Div'd reinvestment plan available.
(C) In millions, adjusted for split.
(D) Includes intangibles. In 2014: $31.7 million/$2.85 a share.

Company's Financial Strength	B+
Stock's Price Stability	85
Price Growth Persistence	50
Earnings Predictability	85

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

MIDDLESEX WATER NDQ-MSEX

RECENT PRICE 22.97 | P/E RATIO 19.6 (Trailing: 20.3 Median: 21.0) | RELATIVE P/E RATIO 1.02 | DIV'D YLD 3.4% | VALUE LINE

TIMELINESS 3 Lowered 4/11/14
SAFETY 2 New 10/21/11
TECHNICAL 2 Raised 4/3/15
BETA .75 (1.00 = Market)

2018-20 PROJECTIONS

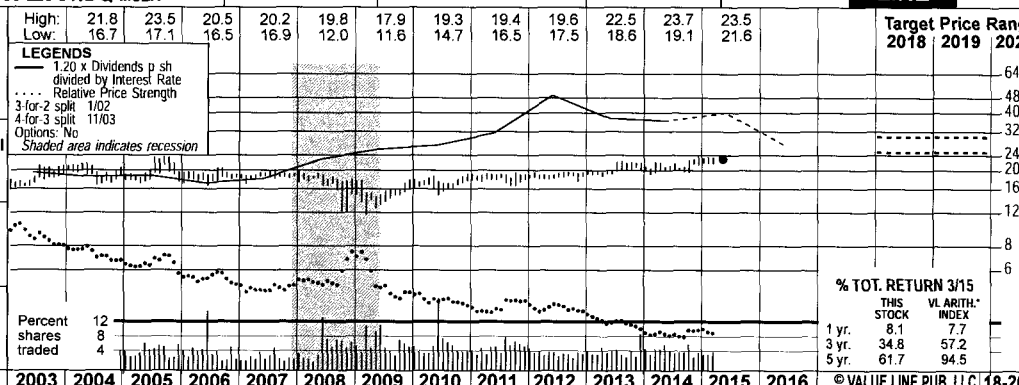
	Price	Gain	Ann'l Total Return
High	30	(+30%)	10%
Low	25	(+10%)	4%

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	2	0	0	0	1	0	1	0	0
Options	0	0	0	0	0	0	0	0	0
to Sell	1	0	0	0	1	0	0	0	1

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	41	32	39
to Sell	34	40	37
Hld's(000)	6463	6339	6372



1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
5.35	5.39	5.87	5.98	6.12	6.25	6.44	6.16	6.50	6.79	6.75	6.60	6.50	6.98	7.19	7.26	*7.40*	*7.70*	Revenues per sh	*9.10*
1.19	.99	1.18	1.20	1.15	1.28	1.33	1.33	1.49	1.53	1.40	1.55	1.46	1.56	1.72	*1.90*	*1.95*	*2.00*	"Cash Flow" per sh	*2.25*
.76	.51	.66	.73	.61	.73	.71	.82	.87	.89	.72	.96	.84	.90	1.03	1.13	*1.15*	*1.20*	Earnings per sh A	*1.35*
.60	.61	.62	.63	.65	.66	.67	.68	.69	.70	.71	.72	.73	.74	.75	.76	*.77*	*.78*	Div'd Decl'd per sh B■	*.85*
2.33	1.32	1.25	1.59	1.87	2.54	2.18	2.31	1.66	2.12	1.49	1.90	1.50	1.36	1.26	1.40	*1.80*	*2.00*	Cap'l Spending per sh	*2.00*
6.95	6.98	7.11	7.39	7.60	8.02	8.26	9.52	10.05	10.03	10.33	11.13	11.27	11.48	11.82	12.24	*12.75*	*13.25*	Book Value per sh	*14.30*
10.00	10.11	10.17	10.36	10.48	11.36	11.58	13.17	13.25	13.40	13.52	15.57	15.70	15.82	15.96	16.12	*16.25*	*16.25*	Common Shs Outst'g C	*17.00*
17.6	28.7	24.6	23.5	30.0	26.4	27.4	22.7	21.6	19.8	21.0	17.8	21.7	20.8	19.7	19.5	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*20.5*
1.00	1.87	1.26	1.28	1.71	1.39	1.46	1.23	1.15	1.19	1.40	1.13	1.36	1.32	1.11	1.01			Relative P/E Ratio	*1.30*
4.4%	4.2%	3.8%	3.7%	3.5%	3.4%	3.5%	3.7%	3.7%	4.0%	4.7%	4.2%	4.0%	4.0%	3.7%	3.5%			Avg Ann'l Div'd Yield	*3.1%*
74.6	81.1	86.1	91.0	91.2	102.7	102.1	110.4	114.8	117.1	*120*	*125*	Revenues ($mill)	*155*
8.5	10.0	11.8	12.2	10.0	14.3	13.4	14.4	16.6	18.4	*18.6*	*18.6*	Net Profit ($mill)	*23.0*
27.6%	33.4%	32.6%	33.2%	34.1%	32.1%	32.7%	33.9%	34.1%	*35.0%*	*34.5%*	*34.0%*	Income Tax Rate	*34.0%*
--	--	--	--	--	6.8%	6.1%	3.4%	1.9%	*1.0%*	*1.0%*	*1.5%*	AFUDC % to Net Profit	*2.5%*
55.3%	49.5%	49.0%	45.6%	46.6%	43.1%	42.3%	41.5%	40.4%	40.5%	*40.5%*	*42.0%*	Long-Term Debt Ratio	*43.5%*
41.3%	47.5%	49.6%	51.8%	52.1%	55.8%	56.6%	57.4%	58.7%	58.8%	*58.5%*	*57.5%*	Common Equity Ratio	*56.5%*
231.7	264.0	268.8	259.4	267.9	310.5	312.5	316.5	321.4	335.7	*350*	*375*	Total Capital ($mill)	*430*
288.0	317.1	333.9	366.3	376.5	405.9	422.2	435.2	446.5	465.4	*485*	*505*	Net Plant ($mill)	*550*
5.0%	5.1%	5.6%	5.8%	5.0%	5.7%	5.2%	5.4%	5.9%	*6.5%*	*6.5%*	*6.0%*	Return on Total Cap'l	*6.5%*
8.2%	7.5%	8.6%	8.6%	7.0%	8.1%	7.5%	7.8%	8.7%	9.3%	*9.0%*	*9.0%*	Return on Shr. Equity	*9.5%*
8.6%	7.8%	8.7%	8.9%	7.0%	8.2%	7.5%	7.8%	8.7%	9.3%	*9.0%*	*9.0%*	Return on Com Equity	*9.5%*
.6%	1.3%	1.8%	2.0%	.1%	2.1%	1.0%	1.4%	2.4%	3.0%	*3.0%*	*3.0%*	Retained to Com Eq	*3.5%*
94%	84%	79%	78%	98%	75%	87%	83%	73%	67%	*67%*	*65%*	All Div'ds to Net Prof	*63%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $160.9 mill. **Due in 5 Yrs** $49.8 mill.
LT Debt $136.0 mill. **LT Interest** $4.6 mill.
(LT interest earned: 6.0x)
(41% of Cap'l)

Pension Assets-12/14 $51.6 mill.
Oblig. $75.0 mill.
Pfd Stock $2.4 mill. **Pfd Div'd:** $.2 mill.

Common Stock 16,129,050 shs.
as of 2/28/15

MARKET CAP: $376 million (Small Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	3.0	4.8	2.7
Other	21.6	21.0	20.2
Current Assets	24.6	25.8	22.9
Accts Payable	3.8	6.3	6.4
Debt Due	11.1	33.8	24.9
Other	41.1	12.6	12.6
Current Liab.	56.0	52.7	43.9
Fix. Chg. Cov.	554%	697%	695%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	1.5%	1.0%	*6.5%*
"Cash Flow"	3.0%	1.5%	*5.5%*
Earnings	3.5%	1.5%	*5.0%*
Dividends	1.5%	1.5%	*2.0%*
Book Value	4.5%	3.0%	*2.5%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	23.5	27.4	32.4	27.1	110.4
2013	27.0	29.1	31.3	27.4	114.8
2014	27.1	29.2	32.7	28.1	117.1
2015	*28.0*	*30.0*	*33.0*	*29.0*	*120*
2016	*29.0*	*31.0*	*35.0*	*30.0*	*125*

Calendar	EARNINGS PER SHARE A Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.11	.23	.38	.17	.90
2013	.20	.28	.36	.19	1.03
2014	.20	.29	.42	.22	1.13
2015	*.21*	*.31*	*.43*	*.20*	*1.15*
2016	*.22*	*.32*	*.45*	*.21*	*1.20*

Calendar	QUARTERLY DIVIDENDS PAID B■ Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.183	.183	.183	.185	.73
2012	.185	.185	.185	.1875	.74
2013	.1875	.1875	.1875	.19	.75
2014	.19	.19	.19	.1925	.76
2015	.1925				

BUSINESS: Middlesex Water Company engages in the ownership and operation of regulated water utility systems in New Jersey, Delaware, and Pennsylvania. It also operates water and wastewater systems under contract on behalf of municipal and private clients in NJ and DE. Its Middlesex System provides water services to 60,000 retail customers, primarily in Middlesex County, New Jersey. In 2014, the Middlesex System accounted for 60% of operating revenues. At 12/31/14, the company had 282 employees. Incorporated: NJ. President, CEO, and Chairman: Dennis W. Doll. Officers & directors own 3.5% of the common stock; BlackRock Institutional Trust Co., 6.6% (4/15 proxy). Add.: 1500 Ronson Road, Iselin, NJ 08830. Tel.: 732-634-1500. Internet: www.middlesexwater.com.

Middlesex Water had a surprisingly good 2014. For the second straight year, the company was able to post a double-digit gain in earnings per share. This was impressive considering that the utility is still in recovery mode following the 2013 loss of two major customers — a Hess refinery and the borough of Sayreville.

Bottom-line gains should moderate. The rate relief that was granted in New Jersey and Delaware will not have as positive an impact on profits as was the case last year. On the positive side, an agreement to distribute water at the Dover Air Force Base (a major military installation) should provide a consistent source of revenues. Overall, we expect Middlesex's 2015 share net to barely rise, from $1.13 to $1.15 in 2015. Next year will probably be better, as we think per-share earnings can increase 4%, to $1.20.

We are not expecting Middlesex to change its remarkably consistent dividend policy through 2016. Since 2004, the utility has raised the payout by exactly $0.01 a share each and every year. With a dividend growth rate of 1.5% over both the past five- and 10-year periods, the company has lagged the industry mean by a substantial margin. When this tradition started, the dividend to net profits percentage was relatively high, meaning there was little room for increases. This figure fell to 57% in 2014, so Middlesex appears to have the flexibility to distribute a greater share of profits to shareholders.

The balance sheet may not be big, but it is strong. At the end of last year, Middlesex's equity-to-total capital ratio was close to 59%, the second highest in the industry. And, while this metric will most likely decline as debt is added to help fund the upgrading of the pipeline network, the utility's finances should remain very sound by late decade.

Middlesex stock has the highest yield of any member in the water industry. At 3.4%, the equity has a payout that is almost 80 basis points above the group average. Indeed, it is the only one that has a yield above 3%. Basically, investors are demanding a premium to own shares in this company. Despite the generous current income, the stock's potential returns through 2018-2020 are still subpar.

James A. Flood *April 17, 2015*

(A) Diluted earnings. May not sum due to rounding. Next earnings report due mid-May.
(B) Dividends historically paid in mid-Feb., May, Aug., and November. ■ Div'd reinvestment plan available.
(C) In millions, adjusted for splits.

Company's Financial Strength	B++
Stock's Price Stability	95
Price Growth Persistence	40
Earnings Predictability	80

To subscribe call 1-800-VALUELINE

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

SJW CORP. NYSE-SJW

RECENT PRICE 30.62 | P/E RATIO 24.3 (Trailing: 12.1 Median: 24.0) | RELATIVE P/E RATIO 1.26 | DIV'D YLD 2.6% | VALUE LINE

TIMELINESS 4 Lowered 12/19/14
SAFETY 3 New 4/22/11
TECHNICAL 2 Raised 3/27/15
BETA .80 (1.00 = Market)

2018-20 PROJECTIONS

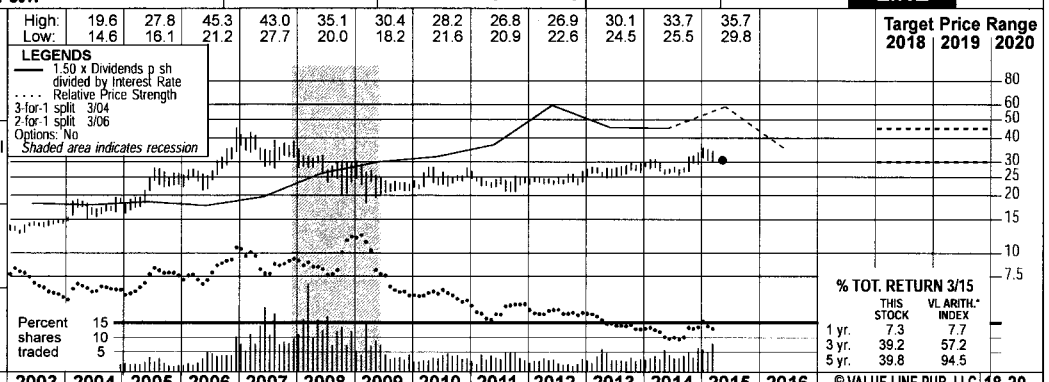
	Price	Gain	Ann'l Total Return
High	45	(+45%)	12%
Low	30	(Nil)	2%

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	1	1	0	1	1	0	0	1	0
Options	0	0	0	0	0	0	1	0	0
to Sell	0	0	0	0	1	0	1	0	0

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	45	38	49
to Sell	40	45	47
Hld's(000)	10965	10784	10867



1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
6.40	6.74	7.45	7.97	8.20	9.14	9.86	10.35	11.25	12.12	11.68	11.62	12.85	14.01	13.73	15.76	*14.15*	*14.05*	Revenues per sh	*17.60*
1.43	1.23	1.49	1.55	1.75	1.89	2.21	2.38	2.30	2.44	2.21	2.38	2.80	2.97	2.90	*4.50*	*3.45*	*3.55*	"Cash Flow" per sh	*3.90*
.87	.58	.77	.78	.91	.87	1.12	1.19	1.04	1.08	.81	.84	1.11	1.18	1.12	2.54	*1.35*	*1.40*	Earnings per sh [A]	*1.75*
.40	.41	.43	.46	.49	.51	.53	.57	.61	.65	.66	.68	.69	.71	.73	.75	*.78*	*.81*	Div'd Decl'd per sh [B] ■	*1.05*
1.77	1.89	2.63	2.06	3.41	2.31	2.83	3.87	6.62	3.79	3.17	5.65	3.75	5.67	4.68	*5.00*	*5.00*	*4.95*	Cap'l Spending per sh	*4.90*
7.88	7.90	8.17	8.40	9.11	10.11	10.72	12.48	12.90	13.99	13.66	13.75	14.20	14.71	15.92	17.75	*18.30*	*19.05*	Book Value per sh	*21.30*
18.27	18.27	18.27	18.27	18.27	18.27	18.27	18.28	18.36	18.18	18.50	18.55	18.59	18.67	20.17	20.29	*20.50*	*21.00*	Common Shs Outst'g [C]	*23.00*
15.5	33.1	18.5	17.3	15.4	19.6	19.7	23.5	33.4	26.2	28.7	29.1	21.2	20.4	24.3	11.0	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*22.0*
.88	2.15	.95	.94	.88	1.04	1.05	1.27	1.77	1.58	1.91	1.85	1.33	1.30	1.37	.58			Relative P/E Ratio	*1.40*
3.0%	2.1%	3.0%	3.4%	3.5%	3.0%	2.4%	2.0%	1.7%	2.3%	2.8%	2.8%	2.9%	3.0%	2.7%	2.7%			Avg Ann'l Div'd Yield	*2.8%*
						180.1	189.2	206.6	220.3	216.1	215.6	239.0	261.5	276.9	319.7	*290*	*295*	Revenues ($mill)	*405*
						20.7	22.2	19.3	20.2	15.2	15.8	20.9	22.3	23.5	51.8	*27.5*	*29.0*	Net Profit ($mill)	*40.0*
						41.6%	40.8%	39.4%	39.5%	40.4%	38.8%	41.1%	41.1%	38.7%	*32.5%*	*37.0%*	*36.0%*	Income Tax Rate	*38.0%*
						1.6%	2.1%	2.7%	2.3%	2.0%	--	--	--	2.0%	*1.0%*	*1.0%*	*1.0%*	AFUDC % to Net Profit	*1.5%*
						42.6%	41.8%	47.7%	46.0%	49.4%	53.7%	56.6%	55.0%	51.1%	51.6%	*52.5%*	*52.5%*	Long-Term Debt Ratio	*53.5%*
						57.4%	58.2%	52.3%	54.0%	50.6%	46.3%	43.4%	45.0%	48.9%	48.4%	*47.5%*	*47.5%*	Common Equity Ratio	*46.5%*
						341.2	391.8	453.2	470.9	499.6	550.7	607.9	610.2	656.2	744.6	*790*	*845*	Total Capital ($mill)	*1025*
						484.8	541.7	645.5	684.2	718.5	785.5	756.2	831.6	898.7	963.0	*1010*	*1065*	Net Plant ($mill)	*1200*
						7.6%	7.0%	5.7%	5.8%	4.4%	4.3%	4.9%	5.0%	5.0%	8.3%	*5.0%*	*5.0%*	Return on Total Cap'l	*5.5%*
						10.6%	9.7%	8.2%	8.0%	6.0%	6.2%	7.9%	8.1%	7.3%	14.4%	*7.5%*	*7.5%*	Return on Shr. Equity	*8.0%*
						10.6%	9.7%	8.2%	8.0%	6.0%	6.2%	7.9%	8.1%	7.3%	14.4%	*7.5%*	*7.5%*	Return on Com Equity	*8.0%*
						5.6%	5.2%	3.5%	3.3%	1.2%	1.2%	3.1%	3.3%	2.8%	10.1%	*3.0%*	*3.0%*	Retained to Com Eq	*3.5%*
						47%	46%	57%	59%	80%	80%	61%	59%	62%	28%	*58%*	*58%*	All Div'ds to Net Prof	*59%*

CAPITAL STRUCTURE as of 12/31/14
Total Debt $398.2 mill. **Due in 5 Yrs** $21.2 mill.
LT Debt $384.4 mill. **LT Interest** $18.1 mill.
(Total interest coverage: 2.9x) (52% of Cap'l)

Leases, Uncapitalized: Annual rentals $5.5 mill.

Pension Assets-12/14 $91.4 mill.
Oblig. $128.7 mill.

Pfd Stock None.

Common Stock 20,336,409 shs.
as of 2/13/15
MARKET CAP: $625 million (Small Cap)

CURRENT POSITION ($MILL.)	2012	2013	12/31/14
Cash Assets	2.5	2.3	2.4
Other	40.4	37.4	65.7
Current Assets	42.9	39.7	68.1
Accts Payable	8.5	12.6	7.0
Debt Due	20.7	23.0	13.8
Other	19.9	23.6	23.9
Current Liab.	49.1	59.2	44.7
Fix. Chg. Cov.	317%	268%	270%

ANNUAL RATES of change (per sh)	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	5.5%	4.0%	*4.0%*
"Cash Flow"	6.0%	4.0%	*4.5%*
Earnings	3.5%	.5%	*6.5%*
Dividends	4.5%	3.5%	*5.5%*
Book Value	5.5%	2.5%	*5.0%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	51.1	65.6	82.4	62.4	261.5
2013	50.1	74.2	85.2	67.4	276.9
2014	54.6	70.4	125.4	69.3	319.7
2015	*56.0*	*73.0*	*89.0*	*72.0*	*290*
2016	*57.0*	*74.0*	*90.0*	*74.0*	*295*

Calendar	EARNINGS PER SHARE [A] Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.06	.28	.53	.31	1.18
2013	.07	.37	.44	.24	1.12
2014	.04	.34	1.88	.28	2.54
2015	*.05*	*.40*	*.53*	*.37*	*1.35*
2016	*.05*	*.40*	*.57*	*.38*	*1.40*

Calendar	QUARTERLY DIVIDENDS PAID [B] ■ Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.173	.173	.173	.173	.69
2012	.1775	.1775	.1775	.1775	.71
2013	.1825	.1825	.1825	.1825	.73
2014	.1875	.1875	.1875	.1875	.75
2015	.1950				

BUSINESS: SJW Corporation engages in the production, purchase, storage, purification, distribution, and retail sale of water. It provides water service to approximately 229,000 connections that serve a population of approximately one million people in the San Jose area and 12,000 connections that serve approximately 36,000 residents in a service area in the region between San Antonio and Austin, Texas. The company offers nonregulated water-related services. Also owns and operates commercial real estate investments. Has about 395 employees. Officers & directors (including Nancy O. Moss) own 27.9% of outstanding shares. Chrm.: Charles J. Toeniskoetter. Inc.: CA. Address: 110 W. Taylor Street, San Jose, CA 95110. Tel.: (408) 279-7800. Int: www.sjwater.com.

SJW's main operating service area is in the midst of an historic drought. The vast majority of the utility's revenues are derived from its water operations in the thriving San Jose area of California. The lack of rain and snow in the mountains has led to the state placing severe restrictions on water usage for conservation purposes. This should result in a steep decline in demand for water. To date, regulators have worked with water utilities using a mechanism know as "decoupling." Basically, this process doesn't meaningfully penalize utilities for encouraging residents to reduce consumption.

SJW's earnings have been skewed. In 2014, the company's profits more than doubled due to a one-time event. The utility received a large payment in the third quarter for past expenses that it was forced to absorb. Since the funds were received as compensation for normal business expenses, we did not classify it as a nonrecurring event.

SJW's bottom line should post decent gains over the next two years. We think that the company's share net can reach $1.35 in 2015. If 2014 had been a normal year, the year-over-year comparison would have been favorable. Next year's per-share earnings will probably only show a modest $0.05-a-share increase to $1.40, however. During 2015 and 2016, opposite forces will be at work pulling the utility's profits in different directions. On the positive side, SJW will be earning a return on the funds spent modernizing its pipeline infrastructure. Conversely, margins may be restrained by the scarcity of surface water, which would force SJW to pay more to either extract more ground water or purchase it from other sources.

The recent dividend increase was adequate. Though the 4% hike was positive in that it was higher than the company's historical growth rate, we thought that there was room for a 5% raise. This would have put the company's growth rate more in line with the industry norm.

These shares are ranked to underperform the broader market averages in the year ahead. Moreover, total return potential over the next three- to five-year period is subpar, as well.

James A. Flood *April 17, 2015*

(A) Diluted earnings. Excludes nonrecurring losses : '03, $1.97; '04, $3.78; '05, $1.09; '06, $16.36; '08, $1.22; '10, $0.46. Next earnings report due mid-May. Quarterly earnings may not add due to rounding.
(B) Dividends historically paid in early March, June, September, and December. ■ Div'd reinvestment plan available.
(C) In millions, adjusted for stock splits.

Company's Financial Strength	B+
Stock's Price Stability	80
Price Growth Persistence	30
Earnings Predictability	70

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

YORK WATER NDQ-YORW

RECENT PRICE 24.01 | P/E RATIO 24.5 (Trailing: 27.0 Median: 25.0) | RELATIVE P/E RATIO 1.27 | DIV'D YLD 2.5% | VALUE LINE

TIMELINESS 3 Raised 3/27/15
SAFETY 2 New 7/19/13
TECHNICAL 2 Lowered 4/17/15
BETA .70 (1.00 = Market)

2018-20 PROJECTIONS

	Price	Gain	Ann'l Total Return
High	30	(+25%)	8%
Low	20	(-15%)	-1%

Insider Decisions

	M	J	J	A	S	O	N	D	J
to Buy	1	0	4	2	1	4	0	0	4
Options	0	0	0	0	0	0	0	0	0
to Sell	0	1	0	0	0	0	0	0	0

Institutional Decisions

	2Q2014	3Q2014	4Q2014
to Buy	29	30	32
to Sell	28	30	24
Hld's(000)	3603	3656	3767

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	© VALUE LINE PUB. LLC	18-20
High:					14.0	17.9	21.0	18.5	16.5	18.0	18.0	18.1	18.5	22.0	24.3	25.0				
Low:					11.0	11.7	15.3	15.5	6.2	9.7	12.8	15.8	16.8	17.6	18.8	21.1				
Revenues per sh	--	--	2.05	2.05	2.17	2.18	2.58	2.56	2.79	2.89	2.95	3.07	3.18	3.21	3.27	3.58	*3.85*	*4.00*	Revenues per sh	*4.75*
"Cash Flow" per sh	--	--	.59	.57	.65	.65	.79	.77	.86	.88	.95	1.07	1.09	1.12	1.19	*1.35*	*1.50*	*1.55*	"Cash Flow" per sh	*1.75*
Earnings per sh A	--	--	.43	.40	.47	.49	.56	.58	.57	.57	.64	.71	.71	.72	.75	.89	*.95*	*1.00*	Earnings per sh A	*1.15*
Div'd Decl'd per sh B	--	--	.34	.35	.37	.39	.42	.45	.48	.49	.51	.52	.53	.54	.55	.57	*.60*	*.63*	Div'd Decl'd per sh B	*.79*
Cap'l Spending per sh	--	--	.75	.66	1.07	2.50	1.69	1.85	1.69	2.17	1.18	.83	.74	.94	.76	1.10	*1.10*	*1.20*	Cap'l Spending per sh	*1.15*
Book Value per sh	--	--	3.79	3.90	4.06	4.65	4.85	5.84	5.97	6.14	6.92	7.19	7.45	7.73	7.98	8.15	*8.15*	*8.65*	Book Value per sh	*9.60*
Common Shs Outst'g C	--	--	9.46	9.55	9.63	10.33	10.40	11.20	11.27	11.37	12.56	12.69	12.79	12.92	12.98	12.83	*12.50*	*12.50*	Common Shs Outst'g C	*12.00*
Avg Ann'l P/E Ratio	--	--	17.8	26.9	24.5	25.7	26.3	31.2	30.3	24.6	21.9	20.7	23.9	24.4	26.3	23.6	*Bold figures are Value Line estimates*		Avg Ann'l P/E Ratio	*22.5*
Relative P/E Ratio	--	--	.91	1.47	1.40	1.36	1.40	1.68	1.61	1.48	1.46	1.32	1.50	1.55	1.48	1.24			Relative P/E Ratio	*1.40*
Avg Ann'l Div'd Yield	--	--	4.4%	3.3%	3.2%	3.1%	2.9%	2.5%	2.8%	3.5%	3.6%	3.5%	3.1%	3.1%	2.8%	2.5%			Avg Ann'l Div'd Yield	*3.0%*
Revenues ($mill)							26.8	28.7	31.4	32.8	37.0	39.0	40.6	41.4	42.4	45.9	*48.0*	*50.0*	Revenues ($mill)	*57.0*
Net Profit ($mill)							5.8	6.1	6.4	6.4	7.5	8.9	9.1	9.3	9.7	11.5	*12.0*	*12.5*	Net Profit ($mill)	*14.0*
Income Tax Rate							36.7%	34.4%	36.5%	36.1%	37.9%	38.5%	35.3%	37.6%	37.6%	29.8%	*29.5%*	*29.5%*	Income Tax Rate	*36.5%*
AFUDC % to Net Profit							--	7.2%	3.6%	10.1%	--	1.2%	1.1%	1.1%	.8%	1.3%	*1.5%*	*1.5%*	AFUDC % to Net Profit	*1.0%*
Long-Term Debt Ratio							44.1%	48.3%	46.5%	54.5%	45.7%	48.3%	47.1%	46.0%	45.1%	44.8%	*47.5%*	*47.0%*	Long-Term Debt Ratio	*48.0%*
Common Equity Ratio							55.9%	51.7%	53.5%	45.5%	54.3%	51.7%	52.9%	54.0%	54.9%	55.2%	*52.5%*	*53.0%*	Common Equity Ratio	*52.0%*
Total Capital ($mill)							90.3	126.5	125.7	153.4	160.1	176.4	180.2	184.8	188.4	189.4	*195*	*205*	Total Capital ($mill)	*220*
Net Plant ($mill)							155.3	174.4	191.6	211.4	222.0	228.4	233.0	240.3	244.2	253.2	*260*	*265*	Net Plant ($mill)	*280*
Return on Total Cap'l							8.4%	6.2%	6.7%	5.7%	6.2%	6.5%	6.4%	6.4%	6.5%	*7.4%*	*7.5%*	*7.5%*	Return on Total Cap'l	*8.0%*
Return on Shr. Equity							11.6%	9.3%	9.5%	9.2%	8.6%	9.8%	9.5%	9.3%	9.3%	11.0%	*11.5%*	*11.5%*	Return on Shr. Equity	*12.0%*
Return on Com Equity							11.6%	9.3%	9.5%	9.2%	8.6%	9.8%	9.5%	9.3%	9.3%	11.0%	*11.5%*	*11.5%*	Return on Com Equity	*12.0%*
Retained to Com Eq							3.0%	2.2%	1.7%	1.4%	1.9%	2.7%	2.5%	2.4%	2.4%	*4.0%*	*4.5%*	*4.5%*	Retained to Com Eq	*3.5%*
All Div'ds to Net Prof							74%	77%	82%	85%	78%	72%	73%	74%	74%	64%	*63%*	*63%*	All Div'ds to Net Prof	*69%*

Target Price Range

2018	2019	2020
64	48	40
32	24	20
16	12	8
6		

LEGENDS
1.10 x Dividends p sh divided by Interest Rate
.... Relative Price Strength
2-for-1 split 5/02
3-for-2 split 9/06
Options: No
Shaded area indicates recession

Percent shares traded: 12, 8, 4

% TOT. RETURN 3/15

	THIS STOCK	VL ARITH.* INDEX
1 yr.	22.2	7.7
3 yr.	51.6	57.2
5 yr.	103.2	94.5

CAPITAL STRUCTURE as of 12/31/14
Total Debt $84.8 mill. **Due in 5 Yrs** $30.5 mill.
LT Debt $84.8 mill. **LT Interest** $5.1 mill.
(Total interest coverage: 4.0x)
(45% of Cap'l)
Pension Assets 12/14 $30.6 mill.
Oblig. $40.9 mill.

Pfd Stock None

Common Stock 12,837,661 shs.
as of 3/9/14

MARKET CAP: $300 million (Small Cap)

CURRENT POSITION ($MILL.)

	2012	2013	12/31/14
Cash Assets	4.0	7.6	1.5
Accounts Receivable	6.4	3.8	4.0
Other	1.2	3.8	5.7
Current Assets	11.6	15.2	11.2
Accts Payable	1.1	1.8	1.6
Debt Due	.1	--	--
Other	4.3	6.0	4.3
Current Liab.	5.5	7.8	5.9
Fix. Chg. Cov.	414%	417%	417%

ANNUAL RATES of change (per sh)

	Past 10 Yrs.	Past 5 Yrs.	Est'd '11-'13 to '18-'20
Revenues	4.5%	3.0%	*5.5%*
"Cash Flow"	6.5%	6.5%	*6.5%*
Earnings	5.5%	5.0%	*6.5%*
Dividends	4.5%	2.5%	*5.0%*
Book Value	7.0%	5.0%	*3.0%*

QUARTERLY REVENUES ($ mill.)

Calendar	Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	9.6	10.4	11.0	10.4	41.4
2013	10.1	10.7	10.9	10.7	42.4
2014	10.6	11.8	12.0	11.5	45.9
2015	*11.0*	*12.0*	*12.5*	*12.5*	*48.0*
2016	*11.5*	*12.5*	*13.0*	*13.0*	*50.0*

EARNINGS PER SHARE A

Calendar	Mar.31	Jun. 30	Sep. 30	Dec. 31	Full Year
2012	.15	.17	.22	.18	.72
2013	.17	.18	.19	.21	.75
2014	.16	.22	.23	.28	.89
2015	*.19*	*.25*	*.26*	*.25*	*.95*
2016	*.20*	*.26*	*.28*	*.26*	*1.00*

QUARTERLY DIVIDENDS PAID B

Calendar	Mar.31	Jun.30	Sep.30	Dec.31	Full Year
2011	.131	.131	.131	.131	.524
2012	.134	.134	.134	.134	.535
2013	.138	.138	.138	.138	.552
2014	.1431	.1431	.1431	.1431	.572
2015	.1495	.1495			

BUSINESS: The York Water Company is the oldest investor-owned regulated water utility in the United States. It has operated continuously since 1816. As of December 31, 2014, the company's average daily availability was 35.2 million gallons and its service territory had an estimated population of 190,000. Has more than 65,100 customers. Residential customers accounted for 63% of 2014 revenues; commercial and industrial (29%); other (8%). It also provides sewer billing services. Incorporated: PA. York had 106 full-time employees at 12/31/14. President/CEO: Jeffrey R. Hines. Officers/directors own 1.1% of the common stock (4/15 proxy). Address: 130 East Market Street York, Pennsylvania 17401. Telephone: (717) 845-3601. Internet: www.yorkwater.com.

York Water had a strong finish in 2014. Share earnings came in at $0.28, $0.04 above our fourth-quarter estimate, which was actually a few cents higher than the Wall Street consensus. For the full year, the company was able to post a robust 19% year-over-year increase in the bottom line.

Earnings growth should moderate, but remain solid. The December interim's gains were due to a combination of a lower tax rate, better cost controls, and higher tariffs being in effect. Although the rate relief will not have as large an impact on profits going forward, we still expect York to benefit from a reduced tax burden and a successful cost-containment program. All told, we expect earnings per share to rise 7% this year, to $0.95, and increase by a nickel in 2016, to $1.00.

Capital spending has picked up. As is the case with almost all of its peers, the company is in the process of repairing and modernizing an aging pipeline and wastewater infrastructure. Last year, construction expenditures rose a hefty 40% as management targeted more funds for this purpose. We believe that the budget will remain near this level through the end of the decade.

The balance sheet is strong enough to handle these expenses. At the end of 2014, York's equity-to-total capital ratio stood at 55%, much higher than the industry norm. And, even though we expect this metric to weaken, we estimate that it will still be a healthy 52% in three to five years.

York shares are expected to perform in line with the broader market averages in the year ahead. True, the company's earnings outlook is improving and the stock's yield is 50 basis points higher than the typical stock followed by *Value Line.* However, these positive attributes appear to be already incorporated into the price of the stock. Indeed, the equity's long-term potential returns are unattractive as it is already trading well within our projected 2018-2020 Target Price Range. Those investors seeking safety, current income, and well-defined earnings, as well as good dividend growth, can probably find a better selection in the water utility industry.

James A. Flood *April 17, 2015*

(A) Diluted earnings. Next earnings report due mid-May.
(B) Dividends historically paid in mid-January, April, July, and October.
(C) In millions, adjusted for splits.

Company's Financial Strength	B+
Stock's Price Stability	90
Price Growth Persistence	55
Earnings Predictability	100

© 2015 Value Line Publishing LLC. All rights reserved. Factual material is obtained from sources believed to be reliable and is provided without warranties of any kind. THE PUBLISHER IS NOT RESPONSIBLE FOR ANY ERRORS OR OMISSIONS HEREIN. This publication is strictly for subscriber's own, non-commercial, internal use. No part of it may be reproduced, resold, stored or transmitted in any printed, electronic or other form, or used for generating or marketing any printed or electronic publication, service or product.

To subscribe call 1-800-VALUELINE

PMA-6

Arizona Water Company
Current Institutional Holdings and Individual Holdings
the Proxy Group of Eight Publicly Traded Water Companies

	[1] May 29, 2015 Percentage of Institutional Holdings	[2] May 29, 2015 Percentage of Individual Holdings (1)
Proxy Group of Eight Publicly Traded Water Companies		
American States Water Co.	70.205 %	29.80 %
American Water Works Co., Inc.	90.234	9.77
Aqua America, Inc.	52.14	47.86
California Water Service Group	73.036	26.96
Connecticut Water Service, Inc.	40.484	59.52
Middlesex Water Company	42.557	57.44
SJW Corporation	59.898	40.10
York Water Company	32.918	67.08
Average	57.68 %	42.32 %

Notes:
(1) (1 - column 1).

Source of Information: Bloomberg Professional, May 29, 2015

PMA-7

Arizona Water Company
Summary of Risk Premium Models for the
Proxy Group of Eight Publicly Traded Water Companies

	Proxy Group of Eight Publicly Traded Water Companies
Predictive Risk Premium Model ™ (PRPM™) (1)	11.59 %
Risk Premium Using an Adjusted Total Market Approach (2)	9.93 %
Average	10.76 %

Notes:
(1) From page 2 of this Exhibit.
(2) From page 3 of this Exhibit.

Arizona Water Company
Proxy Group of Eight Publicly Traded Water Companies
Indicated ROE
Derived by the Predictive Risk Premium Model (1)

Proxy Group of Eight Publicly Traded Water Companies	[1] LT Average Predicted Variance	[2] Spot Predicted Variance	[3] Average Predicted Variance	[4] GARCH Coefficient	[5] Predicted Risk Premium (2)	[6] Risk-Free Rate (3)	[7] Indicated ROE (4)
American States Water Co.	0.39%	0.44%	0.42%	1.66296	8.71%	3.69%	12.40%
American Water Works Co., Inc.	NM	NM	NM	NM	NM	3.69%	NM
Aqua America, Inc.	0.47%	0.32%	0.39%	2.22982	10.95%	3.69%	14.64%
California Water Service Group	0.31%	0.35%	0.33%	1.84347	7.55%	3.69%	11.24%
Connecticut Water Service, Inc.	0.28%	0.25%	0.27%	1.76572	5.87%	3.69%	9.56%
Middlesex Water Company	0.27%	0.33%	0.30%	1.9692	7.32%	3.69%	11.01%
SJW Corporation	0.42%	0.41%	0.42%	1.35495	7.05%	3.69%	10.74%
York Water Company	0.45%	0.38%	0.42%	1.95298	10.30%	3.69%	13.99%
						Average	11.94%
						Median	11.24%
					Average of Mean and Median		11.59%

Notes:

(1) The Predictive Risk Premium Model uses historical data to generate a predicted variance and a GARCH coefficient. The historical data used are the equity risk premiums for the first available trading month as reported by CRSP ® Data® 2012 through May 2015. Center for Research in Security Prices, The University of Chicago Booth School of Business and Bloomberg Professional Service.

(2) (1+(Column [1] * Column [2]) ^12) - 1.

(3) From note 2 of Exhibit PMA-8.

(4) Column [3] + Column [4].

Arizona Water Company
Indicated Common Equity Cost Rate
Through Use of a Risk Premium Model
Using an Adjusted Total Market Approach

Line No.		Proxy Group of Eight Publicly Traded Water Companies
1.	Prospective Yield on Aaa Rated Corporate Bonds (1)	4.75 %
2.	Adjustment to Reflect Yield Spread Between Aaa Rated Corporate Bonds and A Rated Public Utility Bonds	0.18 (2)
3.	Adjusted Prospective Yield on A Rated Public Utility Bonds	4.93 %
4.	Adjustment to Reflect Bond Rating Difference of Proxy Group	0.13 (3)
5.	Adjusted Prospective Bond Yield	5.06 %
6.	Equity Risk Premium (5)	4.87
7.	Risk Premium Derived Common Equity Cost Rate	9.93 %

Notes: (1) The average forecast of Moody's Aaa Rated Coroprate bonds per the consensus of nearly 50 economists reported in Blue Chip Financial Forecasts. (See pages 9 and 10 of this Exhibit. The projection is illustrated below:

Second Quarter 2015	3.80 %
Third Quarter 2015	4.00
Fourth Quarter 2015	4.20
First Quarter 2016	4.40
Second Quarter 2016	4.70
Third Quarter 2016	4.90
2017-2021	5.90
2022-2026	6.10
	4.75 %

(2) The average yield spread of A rated public utility bonds over Aaa rated corporate bonds of 0.18% from page 4 of this Exhibit.

(3) Adjustment to reflect the A2 / A3 Moody's LT issuer rating of the proxy group of eight publicly traded water companies as shown on page 6 of this Exhibit. The 13 basis point upward adjustment is derived by taking 1/6 of the spread between A2 and A3 Public Utility Bonds (1/6 * 0.76% = 0.13%) as derived from page 4 of this Exhibit.

(4) From page 7 of this Exhibit.

Arizona Water Company
Interest Rates and Bond Spreads for
Moody's Corporate and Public Utility Bonds

Selected Bond Yields

	[1] Aaa Rated Corporate Bond	[2] A Rated Public Utility Bond	[3] Baa Rated Public Utility Bond
Mar-15	3.64 %	3.74 %	4.51 %
Apr-15	3.52	3.75	4.51
May-15	3.98	4.17	4.91
Average	3.71 %	3.89 %	4.65 %

Selected Bond Spreads

A Rated Public Utility Bonds Over Aaa Rated Corporate Bonds:
0.18 % (1)

Baa Rated Public Utility Bonds Over A Rated Public Utility Bonds:
0.76 % (2)

Notes:
(1) Column [2] - Column [1].
(2) Column [3] - Column [2].

Source of Information:
Bloomberg Professional Service

Arizona Water Company
Comparison of Long-Term Issuer Ratingsfor the
Proxy Group of Eight Publicly Traded Water Companies

Proxy Group of Eight Publicly Traded Water Companies	Moody's Long-Term Issuer Rating May 2015		Standard & Poor's Long-Term Issuer Rating May 2015	
	Long-Term Issuer Rating	Numerical Weighting(1)	Long-Term Issuer Rating	Numerical Weighting(1)
American States Water Co. (2)	A2	6.0	A+	5.0
American Water Works Co., Inc. (3)	A3	7.0	A-	7.0
Aqua America, Inc. (4)	NR	--	A+	5.0
California Water Service Group (5)	NR	--	A+	5.0
Connecticut Water Service, Inc. (6)	NR	--	A	6.0
Middlesex Water Company	NR	--	A-	7.0
SJW Corporation (7)	NR	--	A	6.0
York Water Company	NR	--	A-	7.0
Average	A2/A3	6.5	A	6.0

Notes:

(1) From page 6 of this Exhibit.
(2) Ratings are those of Golden State Water Company.
(3) Ratings are those of Pennsylvania American Water and New Jersey American Water.
(4) Ratings are those of Aqua Pennsylvania, Inc.
(5) Ratings are those of California Water Service Co.
(6) Ratings are those of Connecticut Water Company.
(7) Ratings are those of San Jose Water Co.

Source Information: Moody's Investors Service
Standard & Poor's Global Utilities Rating Service

Numerical Assignment for Moody's and Standard & Poor's Bond Ratings

Moody's Bond Rating	Numerical Bond Weighting	Standard & Poor's Bond Rating
Aaa	1	AAA
Aa1	2	AA+
Aa2	3	AA
Aa3	4	AA-
A1	5	A+
A2	6	A
A3	7	A-
Baa1	8	BBB+
Baa2	9	BBB
Baa3	10	BBB-
Ba1	11	BB+
Ba2	12	BB
Ba3	13	BB-
B	14	B+
B2	15	B
B3	16	B-

Arizona Water Company
Judgment of Equity Risk Premium for
the Proxy Group of Eight Publicly Traded Water Companies

Line No.		Proxy Group of Eight Publicly Traded Water Companies
1.	Calculated equity risk premium based on the total market using the beta approach (1)	4.96 %
2.	Mean equity risk premium based on a study using the holding period returns of public utilities with A rated bonds (2)	4.77
3.	Average equity risk premium	4.87 %

Notes: (1) From page 8 of this Exhibit.
(2) From page 11 of this Exhibit.

Arizona Water Company
Derivation of Equity Risk Premium Based on the Total Market Approach
Using the Beta for
the Proxy Group of Eight Publicly Traded Water Companies

Line No.	Equity Risk Premium Measure	Eight Publicly Traded Water Companies
1.	Ibbotson Equity Risk Premium (1)	5.89 %
2.	Ibbotson Equity Risk Premium based on PRPM™ (2)	6.34
3.	Equity Risk Premium Based on Value Line Summary and Index (3)	5.05
4.	Equity Risk Premium Based on S&P 500 Companies(4)	8.47
5.	Conclusion of Equity Risk Premium (5)	6.44 %
6.	Adjusted Beta (6)	0.77
7.	Forecasted Equity Risk Premium	4.96 %

Notes:
(1) Based on the arithmetic mean historical monthly returns on large company common stocks from Ibbotson® SBBI® 2015 Market Report minus the arithmetic mean monthly yield of Moody's Aaa and Aa corporate bonds from 1926 - 2014. (12.07% - 6.18% = 5.89%).

(2) The Predictive Risk Premium Model (PRPM) is discussed in Ms. Ahern's accompanying direct testimony. The Ibbotson equity risk premium based on the PRPM is derived by applying the PRPM to the monthly risk premiums between Ibbotson large company common stock monthly returns minus the average Aaa and Aa corporate monthly bond yields, from January 1928 through April 2015.

(3) The equity risk premium based on the Value Line Summary and Index is derived from taking the projected 3-5 year total annual market return of 9.80% (described fully Ms. Ahern's direct testimony) and subtracting the average consensus forecast of Aaa corporate bonds of 4.75% (Shown on page 3 of this Exhibit). (9.80% - 4.75% = 5.05%).

(4) Using data from the Bloomberg Professional Service for the S&P 500, an expected total return of 13.22% was derived based upon expected dividend yields and long-term growth estimates as a proxy for capital appreciation. Subtracting the average consensus forecast of Aaa corporate bonds of 4.75% results in a expected equity risk premium of 8.47%. (13.22% - 4.75% = 8.47%).

(5) Average of lines 1 through 4.

(6) Average of mean and median beta from Exhibit PMA-8.

Sources of Information:

Stocks, Bonds, Bills, and Inflation - Ibbotson® SBBI® 2015 Market Report, Morningstar, Inc., 2015 Chicago, IL.
Industrial Manual and Mergent Bond Record Monthly Update.
Value Line Summary and Index
Blue Chip Financial Forecasts, June 1, 2015
Bloomberg Professional Services

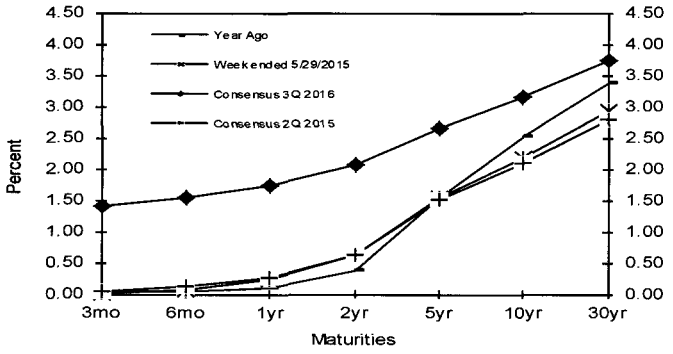
Consensus Forecasts Of U.S. Interest Rates And Key Assumptions[1]

	History								Consensus Forecasts-Quarterly Avg.					
	Average For Week Ending				Average For Month			Latest Q	2Q	3Q	4Q	1Q	2Q	3Q
Interest Rates	May 29	May 22	May 15	May 8	Apr.	Mar.	Feb.	1Q 2015	2015	2015	2015	2016	2016	2016
Federal Funds Rate	0.12	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.1	0.3	0.5	0.8	1.1	1.4
Prime Rate	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.3	3.3	3.5	3.8	4.1	4.5
LIBOR, 3-mo.	0.29	0.29	0.29	0.29	0.28	0.26	0.26	0.26	0.3	0.4	0.7	1.0	1.4	1.7
Commercial Paper, 1-mo.	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.1	0.3	0.5	0.9	1.2	1.5
Treasury bill, 3-mo.	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.0	0.2	0.5	0.8	1.1	1.4
Treasury bill, 6-mo.	0.08	0.08	0.09	0.08	0.09	0.11	0.07	0.09	0.1	0.3	0.6	0.9	1.2	1.5
Treasury bill, 1 yr.	0.24	0.23	0.24	0.24	0.23	0.25	0.22	0.22	0.3	0.5	0.8	1.1	1.4	1.7
Treasury note, 2 yr.	0.63	0.61	0.59	0.62	0.54	0.64	0.62	0.60	0.6	0.9	1.2	1.5	1.8	2.1
Treasury note, 5 yr.	1.54	1.54	1.54	1.54	1.35	1.52	1.57	1.49	1.5	1.7	2.0	2.2	2.4	2.7
Treasury note, 10 yr.	2.17	2.23	224	2.19	1.94	2.04	1.98	1.97	2.1	2.3	2.5	2.7	2.9	3.1
Treasury note, 30 yr.	2.94	3.02	3.02	2.91	2.59	2.63	2.57	2.55	2.8	3.0	3.2	3.4	3.6	3.7
Corporate Aaa bond	3.99	4.07	4.02	3.91	3.52	3.64	3.61	3.57	3.8	4.0	4.2	4.4	4.7	4.9
Corporate Baa bond	4.90	4.96	4.94	4.82	4.48	4.54	4.51	4.50	4.7	4.9	5.0	5.2	5.4	5.6
State & Local bonds	3.73	3.81	3.74	3.74	3.51	3.59	3.58	3.52	3.7	3.8	4.0	4.2	4.4	4.6
Home mortgage rate	3.87	3.84	3.85	3.80	3.67	3.77	3.71	3.73	3.8	4.0	4.2	4.5	4.7	4.9
	History								Consensus Forecasts-Quarterly					
	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q
Key Assumptions	2013	2013	2013	2014	2014	2014	2014	2015	2015	2015	2015	2016	2016	2016
Major Currency Index	76.4	76.7	76.0	77.1	76.6	77.8	82.6	89.4	90.4	90.9	91.6	91.7	91.6	91.3
Real GDP	1.8	4.5	3.5	-2.1	4.6	5.0	2.2	-0.7	2.6	3.2	3.0	2.7	2.8	2.8
GDP Price Index	1.2	1.7	1.5	1.3	2.1	1.4	0.1	-0.1	1.7	1.8	1.8	1.9	2.0	2.1
Consumer Price Index	-0.1	2.3	1.4	2.1	2.4	1.2	-0.9	-3.1	2.2	2.2	2.2	2.1	2.3	2.4

Forecasts for interest rates and the Federal Reserve's Major Currency Index represent averages for the quarter. Forecasts for Real GDP, GDP Price Index and Consumer Price Index are seasonally-adjusted annual rates of change (saar). Individual panel members' forecasts are on pages 4 through 9. Historical data for interest rates except LIBOR is from Federal Reserve Release (FRSR) H.15. LIBOR quotes available from *The Wall Street Journal*. Interest rate definitions are same as those in FRSR H.15. Treasury yields are reported on a constant maturity basis. Historical data for Fed's Major Currency Index is from FRSR H.10 and G.5. Historical data for Real GDP and GDP Chained Price Index are from the Bureau of Economic Analysis (BEA). Consumer Price Index (CPI) history is from the Department of Labor's Bureau of Labor Statistics (BLS).

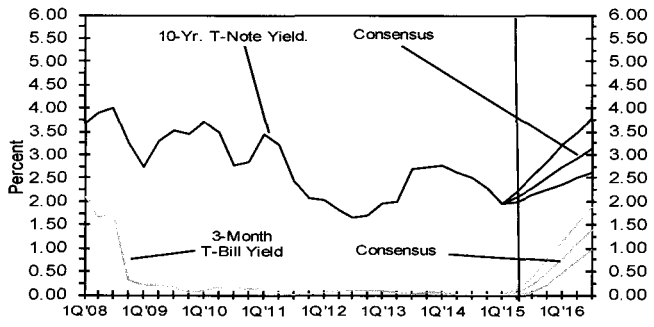
U.S. Treasury Yield Curve

Week ended May 29, 2015 and Year Ago vs.
2Q 2015 and 3Q 2016 Consensus Forecasts



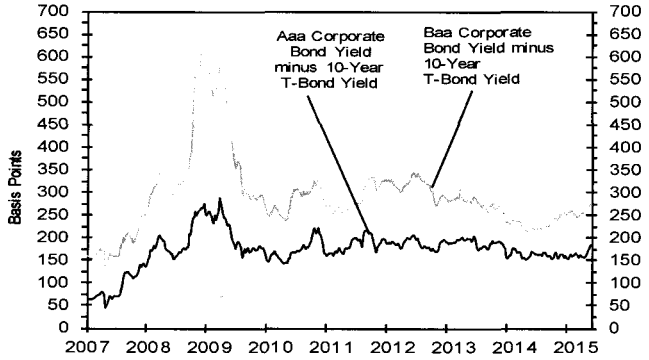
U.S. 3-Mo. T-Bills & 10-Yr. T-Note Yield

(Quarterly Average)



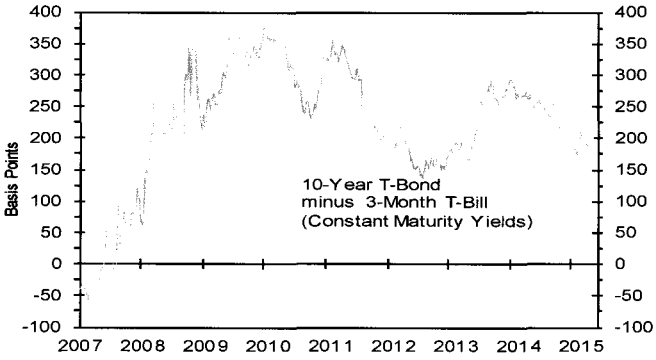
Corporate Bond Spreads

As of week ended May 29, 2015



U.S. Treasury Yield Curve

As of week ended May 29, 2015



Long-Range Estimates:

The table below contains results of our semi-annual long-range CONSENSUS survey. There are also Top 10 and bottom 10 averages for each variable. Shown are estimates for the years 2017 through 2021 and averages for the five-year periods 2017-2021 and 2022-2026. Apply these projections cautiously. Few economic, demographic and political forces can be evaluated accurately over such long time spans.

		Average For The Year					Five-Year Averages	
Interest Rates		**2017**	**2018**	**2019**	**2020**	**2021**	**2017-2021**	**2022-2026**
1. Federal Funds Rate	**CONSENSUS**	**2.5**	**3.3**	**3.5**	**3.6**	**3.7**	**3.3**	**3.5**
	Top 10 Average	3.1	4.0	4.2	4.3	4.2	4.0	4.0
	Bottom 10 Average	1.8	2.5	2.7	2.8	3.0	2.6	2.9
2. Prime Rate	**CONSENSUS**	**5.5**	**6.2**	**6.5**	**6.6**	**6.6**	**6.3**	**6.5**
	Top 10 Average	6.1	7.0	7.3	7.3	7.3	7.0	7.0
	Bottom 10 Average	4.7	5.3	5.6	5.8	5.9	5.5	5.8
3. LIBOR, 3-Mo.	**CONSENSUS**	**2.7**	**3.5**	**3.8**	**3.9**	**3.9**	**3.6**	**3.8**
	Top 10 Average	3.4	4.3	4.6	4.6	4.6	4.3	4.4
	Bottom 10 Average	1.9	2.7	2.9	3.1	3.1	2.7	3.0
4. Commercial Paper, 1-Mo.	**CONSENSUS**	**2.6**	**3.4**	**3.7**	**3.8**	**3.8**	**3.5**	**3.7**
	Top 10 Average	3.2	4.0	4.3	4.3	4.3	4.0	4.0
	Bottom 10 Average	2.1	2.8	3.0	3.2	3.2	2.9	3.3
5. Treasury Bill Yield, 3-Mo.	**CONSENSUS**	**2.4**	**3.1**	**3.4**	**3.5**	**3.5**	**3.2**	**3.4**
	Top 10 Average	3.2	3.9	4.2	4.3	4.2	3.9	4.0
	Bottom 10 Average	1.7	2.3	2.6	2.8	2.9	2.4	2.7
6. Treasury Bill Yield, 6-Mo.	**CONSENSUS**	**2.5**	**3.2**	**3.5**	**3.7**	**3.7**	**3.3**	**3.5**
	Top 10 Average	3.4	4.1	4.4	4.5	4.4	4.1	4.2
	Bottom 10 Average	1.8	2.4	2.7	2.9	3.0	2.6	2.8
7. Treasury Bill Yield, 1-Yr.	**CONSENSUS**	**2.8**	**3.5**	**3.7**	**3.8**	**3.8**	**3.5**	**3.7**
	Top 10 Average	3.6	4.3	4.5	4.6	4.5	4.3	4.4
	Bottom 10 Average	1.9	2.6	2.9	3.0	3.0	2.7	2.9
8. Treasury Note Yield, 2-Yr.	**CONSENSUS**	**3.0**	**3.6**	**3.9**	**4.0**	**4.0**	**3.7**	**3.9**
	Top 10 Average	3.9	4.4	4.7	4.8	4.8	4.5	4.6
	Bottom 10 Average	2.1	2.8	3.0	3.1	3.1	2.8	3.0
10. Treasury Note Yield, 5-Yr.	**CONSENSUS**	**3.4**	**3.9**	**4.1**	**4.3**	**4.3**	**4.0**	**4.2**
	Top 10 Average	4.1	4.7	5.1	5.2	5.2	4.8	5.0
	Bottom 10 Average	2.6	3.0	3.1	3.3	3.3	3.1	3.3
11. Treasury Note Yield, 10-Yr.	**CONSENSUS**	**3.7**	**4.2**	**4.4**	**4.6**	**4.6**	**4.3**	**4.5**
	Top 10 Average	4.5	5.1	5.5	5.7	5.8	5.3	5.6
	Bottom 10 Average	3.0	3.2	3.4	3.5	3.6	3.3	3.5
12. Treasury Bond Yield, 30-Yr.	**CONSENSUS**	**4.3**	**4.7**	**4.9**	**5.1**	**5.1**	**4.8**	**5.0**
	Top 10 Average	5.1	5.7	6.0	6.2	6.2	5.8	6.1
	Bottom 10 Average	3.4	3.7	3.8	4.0	4.0	3.8	3.8
13. Corporate Aaa Bond Yield	**CONSENSUS**	**5.4**	**5.8**	**5.9**	**6.1**	**6.1**	**5.9**	**6.1**
	Top 10 Average	6.0	6.5	6.8	7.0	7.1	6.7	6.9
	Bottom 10 Average	4.8	5.0	5.1	5.2	5.2	5.0	5.3
13. Corporate Baa Bond Yield	**CONSENSUS**	**6.1**	**6.6**	**6.8**	**6.9**	**6.9**	**6.7**	**6.9**
	Top 10 Average	6.9	7.4	7.8	8.0	8.0	7.6	8.0
	Bottom 10 Average	5.4	5.7	5.7	5.8	5.8	5.7	5.9
14. State & Local Bonds Yield	**CONSENSUS**	**4.9**	**5.1**	**5.3**	**5.4**	**5.4**	**5.2**	**5.3**
	Top 10 Average	5.6	5.9	6.1	6.2	6.2	6.0	6.1
	Bottom 10 Average	4.2	4.4	4.4	4.5	4.5	4.4	4.6
15. Home Mortgage Rate	**CONSENSUS**	**5.4**	**5.8**	**6.0**	**6.1**	**6.1**	**5.9**	**6.0**
	Top 10 Average	6.0	6.6	7.0	7.1	7.1	6.8	6.9
	Bottom 10 Average	4.7	4.9	5.0	5.2	5.2	5.0	5.0
A. FRB - Major Currency Index	**CONSENSUS**	**90.0**	**89.8**	**89.1**	**88.5**	**88.1**	**89.1**	**87.9**
	Top 10 Average	93.7	93.8	93.4	92.9	92.7	93.3	92.4
	Bottom 10 Average	86.4	85.8	84.7	84.2	83.5	84.9	83.4
		Year-Over-Year, % Change					Five-Year Averages	
		2017	**2018**	**2019**	**2020**	**2021**	**2017-2021**	**2022-2026**
B. Real GDP	**CONSENSUS**	**2.6**	**2.5**	**2.4**	**2.4**	**2.4**	**2.5**	**2.3**
	Top 10 Average	3.0	2.9	2.8	2.8	2.8	2.9	2.7
	Bottom 10 Average	2.2	2.1	2.0	1.9	2.0	2.0	2.0
C. GDP Chained Price Index	**CONSENSUS**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**
	Top 10 Average	2.3	2.5	2.4	2.4	2.4	2.4	2.4
	Bottom 10 Average	1.8	1.8	1.9	1.9	1.8	1.8	1.9
D. Consumer Price Index	**CONSENSUS**	**2.4**	**2.4**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
	Top 10 Average	2.7	2.7	2.7	2.6	2.5	2.6	2.5
	Bottom 10 Average	2.1	2.1	2.1	2.0	2.1	2.1	2.0

Arizona Water Company
Derivation of Mean Equity Risk Premium Based on a Study
Using Holding Period Returns of Public Utilities

Line No.		Over A Rated Moody's Public Utility Bonds (1)
1.	Arithmetic Mean Holding Period Returns on the Standard & Poor's Utility Index 1928-2014 (2):	10.69 %
2.	Arithmetic Mean Yield on Moody's A Rated Public Utility Yields 1928-2014	(6.48)
3.	Historical Equity Risk Premium	4.21 %
4.	Forecasted Equity Risk Premium Based on PRPM™ (3)	4.47
5.	Forecased Equity Risk Premium based on Projected Total Return on the S&P Utilities Index (4)	5.62
6.	Average of Historical and PRPM™ Equity Risk Premium	4.77 %

Notes: (1) Based on S&P Public Utility Index monthly total returns and Moody's Public Utility Bond average monthly yields from 1928-2014.

(2) Holding period returns are calculated based upon income received (dividends and interest) plus the relative change in the market value of a security over a one-year holding period.

(3) The Predictive Risk Premium Model (PRPM) is applied to the risk premium of the monthly total returns of the S&P Utility Index and the monthly yields on Moody's A rated public utility bonds from January 1928 - May 2015.

(4) Using data from Bloomberg Professional Service for the S&P Utilities Index, an expected return of 10.55% was derived based on expected dividend yields and long-term growth estimates as a proxy for market appreciation. Subtracting the expected A rated public utility bond yield of 4.93%, calculated on line 3 of page 3 of this Exhibit results in an equity risk premium of 5.62%. (10.55% - 4.93% = 5.62%)

Arizona Water Company
Indicated Common Equity Cost Rate Through Use
of the Traditional Capital Asset Pricing Model (CAPM) and Empirical Capital Asset Pricing Model (ECAPM)

Proxy Group of Eight Publicly Traded Water Companies	[1] Value Line Adjusted Beta	[2] Bloomberg Adjusted Beta	[3] Average Beta	[4] Market Risk Premium (1)	[5] Risk-Free Rate (2)	[6] Traditional CAPM Cost Rate	[7] ECAPM Cost Rate	[8] Indicated Common Equity Cost Rate (3)
American States Water Co.	0.70	0.83	0.77	7.41 %	3.69 %	9.40 %	9.82 %	
American Water Works Co., Inc.	0.70	0.58	0.64	7.41	3.69	8.43	9.10	
Aqua America, Inc.	0.70	0.79	0.75	7.41	3.69	9.25	9.71	
California Water Service Group	0.75	0.79	0.77	7.41	3.69	9.40	9.82	
Connecticut Water Service, Inc.	0.65	0.75	0.70	7.41	3.69	8.88	9.43	
Middlesex Water Company	0.75	0.79	0.77	7.41	3.69	9.40	9.82	
SJW Corporation	0.80	0.89	0.85	7.41	3.69	9.99	10.27	
York Water Company	0.70	0.93	0.82	7.41	3.69	9.77	10.10	
Average			0.76			9.31 %	9.76 %	9.54 %
Median			0.77			9.40 %	9.82 %	9.61 %
Average of Mean and Median			0.77					9.58 %

Notes:

(1) The market risk premium (MRP) is an average of four different measures. The first measure of the MRP derives the total return on the market by adding the thirteen-week average forecasted 3-5 year capital appreciation to the thirteen-week average expected dividend yield from Value Line Summary and Index. The projected risk-free rate (developed in Note 2) is then subtracted from the total return to arrive at the projected MRP. The second measure of MRP is based on the arithmetic mean of historical monthly return data of large company stocks less the income return on long-term government bonds from 1926-2014 as published by Morningstar, Inc. The third measure applies the PRPM to the Ibbotson historical data to derive a projected MRP. The fourth measure uses data from Bloomberg Professional Services to derive a total projected return on the S&P 500 by using expected dividend yields and long-term growth estimates as a proxy for capital appreciation. The projected risk-free rate is then subtracted from the projected total return to arrive at the projected MRP. The four measures of MRP are illustrated below:

Measure 1: Value Line Projected MRP (Thirteen weeks ending 5/29/15)		
Total projected return on the market 3 -5 years hence:	9.80	%
Projected Risk-Free Rate (described in Note 2):	3.69	
MRP based on Value Line Summary & Index:	6.11	%
Measure 2: Ibbotson Arithmetic Mean MRP (1926 - 2014)		
Arithmetic Mean Monthly Returns for Large Stocks 1926 - 2014:	12.07	%
Arithmetic Mean Income Returns on Long-Term Government Bonds:	5.23	
MRP based on Ibbotson Historical Data:	6.84	%
Measure 3: Application of the PRPM to Ibbotson Historical Data: (January1926 - April 2015)	7.15	%
Measure 4: Bloomberg Projected MRP		
Total return on the Market based on the S&P 500:	13.22	%
Projected Risk-Free Rate (described in Note 2):	3.69	
MRP based on Bloomberg data	9.53	%
Average MRP:	7.41	%

(2) For reasons explained in the direct testimony, the appropriate risk-free rate for cost of capital purposes is the average forecast of 30 year Treasury Bonds per the consensus of nearly 50 economists reported in Blue Chip Financial Forecasts. (See pages 9 and 10 of Exhibit PMA-7. The projection of the risk-free rate is illustrated below:

Second Quarter 2015	2.80 %
Third Quarter 2015	3.00
Fourth Quarter 2015	3.20
First Quarter 2016	3.40
Second Quarter 2016	3.60
Third Quarter 2016	3.70
2017-2021	4.80
2022-2026	5.00
	3.69 %

(3) Average of Column 6 and Column 7.

Sources of Information: Value Line Summary and Index
Blue Chip Financial Forecasts June 1, 2015
Stocks, Bonds, Bills, and Inflation - Ibbotson® SBBI® 2015 Market Report, Morningstar, Inc., 2015 Chicago, IL.
Bloomberg Professional Services

PMA-9

Arizona Water Company
Standard & Poor's Cash Flow/Leverage Analysis Ratios - Standard Volatility (1)

Financial Risk Profile	FFO / Debt (2) (%)	Debt / EBITDA (3) (x)	FFO / Cash Interest (4) (x)	EBITDA / Cash Interest (5) (x)	CFO / Debt (6) (%)	FOCF / Debt (7) (%)	DCF / Debt (8) (%)
Minimal	60+	1.5	13	>15	>50	40+	25+
Modest	45 - 60	1.5 - 2.0	9 - 13	10 - 15	35 - 50	25 - 40	15 - 25
Intermediate	30 - 45	2.0 - 3.0	6 - 9	6 - 10	25 - 35	15 - 25	10 - 15
Significant	***20 - 30***	***3.0 - 4.0***	4 - 6	***3 - 6***	***15 - 25***	10 - 15	5 - 10
Aggressive	12 - 30	4.0 - 5.0	***2 - 4***	2 - 3	10 - 15	***5 - 10***	***2 - 5***
Highly Leveraged	<12	>5.0	<2	<2	<10	<5	<2
Arizona Water Company	24.36% **(Significant)**	3.13x **(Significant)**	3.89x **(Aggressive)**	5.20x **(Significant)**	23.68% **(Significant)**	8.74% **(Aggressive)**	2.48% **(Aggressive)**

Table 3
Combining the Business and Financial Risk Profiles to Determining the Anchor

	Financial Risk Profile					
Business Risk Profile	**1 (minimal)**	**2 (modest)**	**3 (intermediate)**	**4 (significant)**	**5 (aggressive)**	**6 (highly leveraged)**
1 (excellent)	aaa / aa+	aa	a+ / a	a-	bbb	bbb- / bb+
2 (strong)	aa / aa-	a+ / a	a / bbb+	bbb	bb+	bb
3 (satisfactory)	a/a-	bbb+	bbb / bbb-	bbb- / bb+	bb	b+
4 (fair)	bbb / bbb-	bbb-	bb+	bb	bb-	b
5 (weak)	bb+	bb+	bb	bb-	b+	b / b-
6 (vulnerable)	bb-	bb-	bb- / b+	b+	b	b-

Notes:
(1) From Standard & Pooor's General: Corporate Methodology, November 20, 2013, pp. 5 & 53.
(2) Funds from operations / debt.
(3) Debt / earnings before interest, taxes, depreciation and amortization.
(4) Funds from operations / cash interest.
(5) Earnings before interest, taxes, depreciation and amortization / cash interest.
(6) Cash flows from operations / debt.
(7) Free operating cash flows / debt.
(8) Discretionary cash flows / debt.

Source of Information: http://www.standardandpoors.com/en_AP/web/guest/article/-/view/sourceId/8314109

Exhibit PMA-9

ARIZONA WATER COMPANY

Arizona Corporation Commission

Docket No. W-01445A-15-0277

2015

WESTERN GROUP

RATE HEARING

Direct Testimony

of

Fredrick K. Schneider

TABLE OF CONTENTS

I. Introduction and Qualifications 6

II. Purpose of Direct Testimony 9

III. Post-Test Year Plant Additions 10

A. Pinal Valley Service Area 11

i. Pinal Valley Water System – PWSID No. 11-009 11

ii. Coolidge Airport Water System – PWSID No. 11-707 29

iii. Tierra Grande Water System – PWSID No. 11-076 30

iv. Stanfield Water System – PWSID No. 11-012 31

B. White Tank Service Area 32

C. Phoenix Office 34

IV. Description of Company-Funded Construction Budgeting Procedures 36

V. Description of Company-Funded Utility Plant Additions For The Western Group . 39

A. Ajo Service Area 40

B. Pinal Valley Service Area 40

i. Pinal Valley Water System 40

ii. Coolidge Airport Water System 44

iii. Tierra Grande Water System 44

iv. Stanfield Water System 44

C. White Tank Service Area 44

D. Phoenix Office 45

VI. Additional Arsenic Removal Facilities and the Need to Continue the ACRM 46

VII. CAP Use Plan 48

A. Pinal Valley Service Area 48

B. White Tank Service Area 60

VIII. Aging Infrastructure and the Need for a System Improvement Benefits Mechanism ("SIB") 68

IX. Tank Maintenance Program 91

X. Nitrate Cost Recovery Mechanism ("NCRM") 97

APPENDICES AND EXHIBITS

Post-Test Year Plant Additions – Project Detail FKS-1
Pinal Valley Water Master Plan FKS-2
Well No. 34 Arsenic Removal Facility FKS-3
Pinal Valley Recharge and Recovery Application FKS-4
ADWR Determination of the Company's Application Administratively Complete FKS-5
Pinal Valley Recharge and Recovery Project Construction Schedule FKS-6
ASU Study: Parts of Metro Phoenix Area are Sinking FKS-7
Pinal Valley Recovery Well Permit FKS-8
City of Coolidge 2025 General Plan Update FKS-9
White Tank Recharge and Recovery Facility FKS-10
White Tank Recharge and Recovery Facility Construction Schedule FKS-11
Aging Infrastructure Replacement Plan FKS-12
EPA Condition Assessment of Ferrous Water Transmission and Distribution Systems FKS-13
Failure Modes and Mechanisms in Gray Cast Iron Pipe FKS-14
Failure Conditions of Asbestos Cement Water Mains FKS-15
AWWA Buried No Longer FKS-16
Storage Tank Maintenance Program FKS-17
US EPA Toxicity and Exposure Assessment FKS-18
USGS Probability of Nitrate Contamination of Groundwater in United States FKS-19
University of Arizona Nitrate Concentration Potential in Arizona Groundwater FKS-20
USGS Report on Water Quality in Central Arizona Basins FKS-21
2010 ADEQ Status of Water Quality Report – Groundwater Assessment FKS-22
Nitrate Removal Construction Cost Estimates FKS-23
Well Nos. 7, 27, 32 and 33 Project Descriptions and Cost Estimates FKS-24
Well No. 33 Operational and Maintenance Cost FKS-25

FIGURES

Figure 2-1 Pinal Valley Recharge and Recovery Facility Location/Service Area 52
Figure 2-2 Pinal Valley Recharge and Recovery Facility Conceptual Plan 53
Figure 2-3 Pinal Valley Service Area Water Production 57
Figure 2-4 Pinal Valley Service Area Groundwater Pumping Reduction 58
Figure 2-5 White Tank Recharge and Recovery Facility Proposed Location 62
Figure 2-6 White Tank Recharge and Recovery Facility Conceptual Plan 65
Figure 2-7 White Tank Service Area Water Production 67
Figure 2-8 White Tank Service Area Groundwater Pumping Reduction 67

ARIZONA WATER COMPANY

Direct Testimony of

Fredrick K. Schneider

I. Introduction and Qualifications

Q. PLEASE STATE YOUR NAME, EMPLOYER AND OCCUPATION.

A. My name is Fredrick K. Schneider. I am employed by Arizona Water Company (the "Company") as Vice President of Engineering. My business address is 3805 N. Black Canyon Highway, Phoenix, Arizona 85015.

Q. PLEASE DESCRIBE YOUR EDUCATIONAL BACKGROUND.

A. I graduated in 1990 with a Bachelor of Science degree in Hydrology from the College of Engineering and Mines at the University of Arizona, in Tucson, Arizona. Additionally, I have taken graduate level classes at the University of Phoenix.

Q. PLEASE DESCRIBE YOUR WORK EXPERIENCE.

A. In 1987, I began working for the United States Department of Agriculture performing chemical and granular gradation laboratory soils analysis. In 1988, I accepted a position with the City of Tucson as an Engineering Intern in its Engineering Department performing civil engineering site reviews. I later transferred to the City of Tucson's Water Department where I worked on groundwater modeling, environmental remediation and groundwater contamination investigation until I graduated from the University of Arizona in 1990.

Upon obtaining my degree in 1990, I joined Boyle Engineering Corporation ("Boyle") in Phoenix, Arizona as an Assistant Engineer and was later promoted to the position of Associate Engineer. Boyle provides consulting engineering services to the public and private sectors in the areas of water and wastewater. While employed by Boyle, I was involved in a variety of consulting assignments, including all phases of Water and Wastewater system planning and design,

reconnaissance level investigations, feasibility studies and construction phase services, including water and wastewater master planning, groundwater supply development, surface water supply development, storage reservoir design and construction, treatment facilities, pipeline systems and wastewater collection, treatment and disposal.

In 1995, I accepted a position with Wood, Patel and Associates ("Wood/Patel") in Phoenix, Arizona. While employed by Wood/Patel, my duties consisted of engineering design and project management for various water and wastewater pipeline feasibility analyses, evaluation of alternatives, cost estimating, detailed hydraulic analysis and master planning new developments ranging in size from several hundred to several thousand acres.

In 1998, I joined Citizens Water Resources ("Citizens") as a Senior Development Engineer and was later promoted to the position of Development Services Supervisor. While employed by Citizens, I negotiated development agreements, reviewed water and wastewater master plans and facility infrastructure plans, and was responsible for the inspection and approval of constructed facilities for projects within the metropolitan Phoenix area. I became an employee of Arizona American Water Company ("Arizona-American") when its parent company, American Water, purchased the water and wastewater assets of Citizens on January 15, 2001. Subsequently, I was promoted to the position of Development Services Manager, and was responsible for the same duties described above on a statewide basis. In 2003, I was promoted to the position of Manager of Arizona-American, moving from engineering to operations. In this capacity, I was responsible for all of the operations of Arizona-American's water and wastewater treatment facilities, distribution and collection facilities, and customer service. In May 2004, I was promoted to the position of Director of Engineering for American Water's Western Region, where my responsibilities included overseeing all capital planning and engineering activities

for American Water's operations in Arizona, California, Hawaii, New Mexico and Texas.

In October 2005, I joined Brown and Caldwell as an Associate. My duties included managing the Phoenix Infrastructure department, including design, project management and construction administration of water and wastewater infrastructure projects within the Metropolitan Phoenix Area.

In August 2007, I joined Arizona Water Company as Vice President of Engineering, where my responsibilities include capital planning, design, and construction management of all of the Company's engineering projects.

In July 2013, I took over responsibility for daily coordination and supervision of the Company's Administrative Services Department, which includes the Company's safety, water resources, water quality compliance and environmental compliance. In this role, I also support and oversee the Company's operations.

Q. ARE YOU A MEMBER OF ANY PROFESSIONAL ORGANIZATIONS?

A. Yes. I am a member of the American Water Works Association ("AWWA"), the Arizona Water Association, and American Society of Civil Engineers. I was also a member of the Infrastructure Replacement Group of the Blue Ribbon Panel on Sustainability, a panel formed to address water sustainability jointly chaired by the Arizona Corporation Commission (the "Commission"), the Arizona Department of Water Resources ("ADWR"), and the Arizona Department of Environmental Quality ("ADEQ").

Q. ARE YOU A REGISTERED PROFESSIONAL ENGINEER?

A. Yes. I have been a registered professional engineer in the State of Arizona since 1995.

Q. DO YOU HAVE ANY OTHER CERTIFICATIONS?

A. Yes. I am an ADEQ Grade 2 certified operator in Water and Wastewater Treatment and a Grade 3 certified operator in Water Distribution and Wastewater Collection.

Q. HAVE YOU TESTIFIED PREVIOUSLY BEFORE THE COMMISSION?

A. Yes. I have testified in rate proceedings and Certificate of Convenience and Necessity ("CCN") hearings before the Commission. In addition, I have testified in California before the California Public Utilities Commission and prepared pre-filed testimony in Hawaii and New Mexico. I testified in the Company's last four general rate case applications, including the Company's 2007 test year general rate case (Docket No. W-01445A-08-0440), the Company's adjusted 2010 test year Western Group general rate case (Docket No. W-01445A-10-0517), the Company's 2010 test year general Eastern Group rate case (Docket No. W-01445A-11-0310), and the Company's 2011 Northern Group general rate case (Docket No. W-01445A-12-0348).

II. Purpose of Direct Testimony

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY?

A. I address several engineering and operations related issues in this general rate case application for the Company's Western Group. Specifically, I address:

1. The critical and necessary post-Test Year plant additions which are, or will be completed and placed in service prior to the hearing in this case in the Ajo, Pinal Valley and White Tank service areas, and the reasons why such additions should be included in rate base in this proceeding.
2. The Company's planning and budgeting process for the construction of utility plant additions and improvements.
3. Company-funded utility plant additions since the last rate proceeding.

4. The Company's need to construct an additional arsenic removal facility in the Pinal Valley water systems and the Company's request to continue the arsenic cost recovery mechanism ("ACRM").
5. The Company's plan to construct the Pinal Valley Recharge and Recovery Facility and its request to continue collecting an off-site facilities fee for the purpose of funding this facility and related facilities.
6. The Company's plan to construct the White Tank Recharge and Recovery Facility in the White Tank service area and its request for a new off-site facilities fee to fund construction of this facility and related facilities.
7. The Company's work to reduce water loss in the Ajo, Pinal Valley and White Tank service areas and its request for a system improvement benefits ("SIB") mechanism to replace aging infrastructure.
8. The Company's tank maintenance program and associated costs in the Company's Ajo, Pinal Valley and White Tank service areas.
9. The Company's need to construct a nitrate removal facility in the Pinal Valley Service Area and its request for Commission authorization of a Nitrate Cost Recovery Mechanism ("NCRM").

The Western Group is comprised of the Ajo, Pinal Valley and White Tank service areas. The Pinal Valley service area is comprised of the Casa Grande, Coolidge Airport, Tierra Grande and Stanfield public water systems, which were consolidated for rate making purposes in Decision No. 71845.

III. Post-Test Year Plant Additions

Q. IS THE COMPANY PROPOSING TO INCLUDE POST-TEST YEAR PLANT ADDITIONS IN RATE BASE IN THIS PROCEEDING?

A. Yes. The test year for this general rate case is 2014. The Company proposes to include post-test year utility plant additions in rate base for the Ajo, Pinal Valley and White Tank service areas, as well as for the Company's Phoenix office and

meter shop. These utility plant additions include the revenue-neutral projects, identified by Work Authorization ("WA") number, which I describe in detail later in this section of my testimony. Exhibit FKS-1 also contains detailed project information, descriptions and supporting data for each post-test year plant addition. These projects are also shown in the Company's Application in the appendix to Schedule B-2, sponsored by Company witness Mr. Reiker.

Q. WHAT DO YOU MEAN BY "REVENUE-NEUTRAL" PROJECTS?

A. Revenue-neutral projects include only those items of utility plant required for the provision of service to existing customers served during the test year and does not include projects undertaken for the purpose of serving future customers or to expand system capacity.

Q. HAVE ANY OF THESE PROJECTS BEEN COMPLETED AND PLACED IN SERVICE?

A. Yes. As of the date of this pre-filed testimony, 23 of these projects have been completed and placed in service, as noted below. The Company will provide Staff and interveners with updates to the status and final cost of each project, including supporting documentation, as it is completed and placed in service.

Q. PLEASE SUMMARIZE THE PROJECTS THE COMPANY PROPOSES TO INCLUDE IN RATE BASE AS POST-TEST YEAR UTILITY PLANT ADDITIONS.

A. The Company proposes in this proceeding to include the following projects in rate base as post-test year plant:

A. <u>Pinal Valley Service Area</u>

i. <u>Pinal Valley Water System – PWSID No. 11-009</u>

WA 1-4806 – CONSTRUCT AN ARSENIC REMOVAL FACILITY AT WELL NO. 13.

Arsenic in Well No. 13 has increased from 8 to 14 parts per billion ("ppb"). The Company needs to construct an arsenic removal facility to comply with the

arsenic Maximum Contaminant Limit ("MCL") of 10 ppb as required by Safe Drinking Water Standards and to provide sufficient production capacity to satisfy water system demands. Company engineers analyzed the production capacity of the Coolidge portion of the Pinal Valley water system and determined that approximately 800 gpm of additional production capacity is required to satisfy system demands. The well was shut down until the Company could complete a treatment technology evaluation, construct an arsenic removal facility and place the arsenic removal facility in service. The Company will use a best available technology as recommended by the United States Environmental Protection Agency ("EPA") for removing arsenic. Historical arsenic results, treatment technology evaluation, cost estimates, construction drawings, photos, the proposal/contract, and design and construction schedules are included in Exhibit FKS-1. The total estimated cost to complete this project is $1,500,000 and the Company expects to complete and place the arsenic removal facility in service by May 23, 2016.

WA 1-5076 – LOWER AND REPLACE 460 LINEAR FEET ("LF") OF 6-INCH DIP WATER MAIN TO SERVE THE ARIZONA GRAIN DEPOT.

The Union Pacific Railroad constructed a second railroad track and is constructing a new railroad spur to serve Arizona Grain in Casa Grande. The Company's existing water main was in conflict with the proposed railroad spur and was inaccessible for maintenance and repairs. A water main break under the proposed railroad spur would cause significant damage to the railroad track and right-of-way and would require costly repairs at the Company's expense. To prevent this, Company engineers determined the water main must be replaced at a lower elevation and placed in a steel casing. Cost information, construction drawings, photos, the proposal/contracts, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $196,000 and was placed in service on September 3, 2014.

WA 1-5164 – REPLACE TWO MOTORS AND TWO BOOSTER PUMPS AT WELL NOS. 9 AND 10 BOOSTER PUMP STATION.

This booster pump station produces approximately 65% of the total water supplies produced in the Coolidge portion of the Pinal Valley water system. The existing booster pump station includes two boosters that have been in service for 29 years. This project is necessary to restore the pumping capacity of the booster pump station due to motor and pump age. When booster pump No. 2 was removed for inspection, the pump showed signs of extensive wear on the pump impellers, shaft and bearings. Company engineers determined that booster pump No. 1 also requires replacement because its production has decreased from 2,200 gpm to less than 1,900 gpm. As part of this project, the Company plans to replace both of the motors and pumps. Replacing both motors and both pumps will allow the Company to continue to provide adequate service during peak system demands of the Pinal Valley water system. Cost estimates, construction drawings, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $75,000 and the Company plans to place the booster pump stations in service on or about November 15, 2015.

WA 1-5165 – CONSTRUCT BLOCK WALLS AROUND WELL NOS. 21, 30, AND 31 IN PINAL VALLEY, INSTALL ACCESS GATES AND CONSTRUCT WATER RETENTION BASINS.

This project included the design, permit and construction of 833 LF of an 8-feet tall block wall, 238 LF of 6-feet tall block wall and three rolling gates at Well Nos. 21, 30 and 31 for security and access. The existing chain link fences were old no longer serviceable, were starting to fall over and did not provide adequate security to the sites. Construction of these block walls was necessary to screen the well sites from public view as part of the City of Casa Grande's beautification project. In addition to 1,071 LF of block walls, the Company

constructed a retention basin at both Well Nos. 31 and 26 to retain flush to waste water on-site and mitigate standing water off-site. Cost information, as well as the structural evaluation and analysis, construction drawings, photos, the proposal/contracts, and construction schedules are included in Exhibit FKS-1. The total estimated cost to complete this project is $418,000 and was placed in service on January 12, 2015.

WA 1-5167 – CONSTRUCT ARSENIC REMOVAL FACILITY AT VALLEY FARMS WELL NO. 2.

This project was completed and placed in service on June 30, 2015, at a total cost of $1,250,000. The Company constructed an arsenic removal facility at Valley Farms Well No. 2 because the arsenic concentration in the water increased to 16 ppb. The Company removed the well from service before the arsenic concentration reached the MCL of 10 ppb. Continued monitoring and sampling of the water show arsenic concentrations as high as 16 ppb. As a result of these high arsenic levels, blending with another source to comply with the arsenic MCL was not a viable option. EPA has determined the adsorptive process is a best available technology is a commonly used method for arsenic removal, and the Company has successfully operated over a dozen similar facilities. Accordingly, Company engineers determined that treating the water using adsorptive media is the best available technology. The arsenic removal facility design and permitting was completed and construction began in 2014. Cost estimates, construction drawings, photographs, the proposal/contract, and schedules for the ARF are included in Exhibit FKS-1.

WA 1-5168 – INSTALL FOUR 16-INCH GATE VALVES TO REPLACE THREE 16-INCH BUTTERFLY VALVES ALONG HIGHWAY 84 BETWEEN VIP BOULEVARD AND THORNTON ROAD.

This project is necessary to increase reliability and minimize service disruptions and water loss. While tying in a new water main extension on

Highway 84, the Company discovered three inoperable 16-inch butterfly valves between VIP Boulevard and Thornton Road in Casa Grande. This 16-inch water main provides service to five large industrial customers. In the event of a main break, service to the industrial park would be interrupted while the Company makes repairs. Because of the inoperable valves, additional time is required to isolate the area of the break and drain water from the main, resulting in increased water loss and a longer service interruption to the industrial park. Installing one additional gate valve and replacing the three inoperable butterfly valves will reduce service disruptions and water loss. Cost estimates, construction drawings, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $110,000 and was placed in service on July 20, 2015.

WA 1-5169 – CONSTRUCT 3,857 LF OF 12-INCH DUCTILE IRON PIPE ("DIP") TO REPLACE APPROXIMATELY 3,870 LF OF 6-INCH PVC ALONG OVERFIELD ROAD.

This project, completed and placed in service on May 21, 2015 at a total cost of $392,000, was necessary to reduce water loss and increase system reliability. Water loss in the Pinal Valley service area is currently more than 9% and has approached 10% in the past. Water mains in this portion of the Pinal Valley service area were constructed using thin walled PVC.[1] The existing water main and services had 13 recorded leaks since 2013. The Company estimates that before 2013 this water main had an additional 15 leaks. The number and increasing frequency of leaks shows that the condition of the water main has deteriorated and must be replaced to provide reliable service.

A 12-inch water main was required because the Company's Tariff Schedule No. TC-243 ("Terms & Conditions") requires water mains installed along section lines to be a minimum diameter of 12-inches. In addition, the

[1] These thin walled PVC water mains were installed prior to the Company's acquisition of the Woodruff water system

Company's Pinal Valley Water System Master Plan requires the installation of 12-inch water mains in this area. Cost information, construction drawings, photos, the placed in service notice, the proposal/contract, and schedules related to this project are included in Exhibit FKS-1. A copy of the Company's Pinal Valley Water Master Plan is also included in Exhibit FKS-2.

WA 1-5170 – RECONSTRUCT THE COTTONWOOD LANE STORAGE TANK AND BOOSTER PUMP STATION.

This project, completed and placed in service on May 27, 2015 at a total cost of $1,200,000, was necessary to correct structural defects in the rafters, roof plates and walls of a one million gallon water storage tank and to replace aging booster pumps located at the Company's Cottonwood Lane facility. Company engineers determined that the roof plate of the water storage tank had bowed upward causing parts of the walls to be pulled inward. This movement resulted in large dents, up to 9-inches deep, around the perimeter of the top 4 feet of the tank. The rafters were severely corroded, bent, twisted up to 8 degrees and displaced up to 12-inches. The flanges connecting the rafters to the roof were severely corroded with up to 1/8-inch in material loss. The roof plate was severely distorted, corroded and raised off of the rafters by up to 9-inches. Distortion on the roof exterior created locations for rain water and dirt to accumulate instead of properly draining off the roof. The center column was distorted, lifted and rotated approximately 6 degrees. The roof was no longer capable of sustaining the required loads to comply with AWWA Standard D100 for Welded Carbon Steel Tanks for Water Storage. The rafters, roof plates, eave angle and upper 4 feet of the tank wall were irreparably damaged and were completely replaced in this project. A new 24-inch roof vent and 18-inch overflow pipe were constructed to replace the old and undersized vent and overflow to comply with current AWWA standards.

In addition, three new booster pumps, one new discharge head and one new motor were installed to replace existing equipment at the booster pump station, which was originally constructed more than 50 years ago. Cost information, as well as the structural evaluation and analysis showing the severity of the tank structural condition, construction drawings, photos, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5171 – CONSTRUCT 2,789 LF OF 12-INCH DIP WATER MAIN TO REPLACE APPROXIMATELY 2,840 LF OF 12-INCH WATER MAIN ON COTTONWOOD LANE FROM ARIZOLA ROAD TO PEART ROAD.

This project, which was completed and placed in service on April 15, 2015 at a total cost of $517,000, was necessary to reduce water loss and increase system reliability. The existing water main had a total of 13 leaks and breaks, 3 of which occurred since 2013. Water main leaks and breaks along Cottonwood Lane (a major arterial roadway) flood the roadway and result in lane restrictions and significant traffic disruption. This project will reduce breaks and service disruptions and help reduce water loss in the Pinal Valley water system. Cost information, construction drawings, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5173 – INSTALL ELECTRICAL PANEL SAFETY IMPROVEMENTS AT 30 SITES IN THE PINAL VALLEY WATER SYSTEM.

This project includes relocating operational controls from the interior electrical panels to panel exterior doors, installing two starter reset plungers, one motor saver, 38 motor saver displays, and shielding over exposed conductors, and 75 disconnect switches for electrical panels and equipment at various sites throughout the Pinal Valley water system. Controls for operation and maintenance of well, tank, and booster stations are located inside electrical control panels. Logging operating parameters, recording error codes, and making operational adjustments require that electrical control panels are

energized. The Company's Energy Control Program prohibits employees from entering energized panels to protect employees from injury and to comply with the OSHA Control of Hazardous Energy Standard, 29 CFR 1910.147. The Company contracts with outside electrical contractors to perform this routine work. The proposed panel modifications allow Company Operators access to system controls, which will reduce Company's dependency on outside electrical contractors and system down time. Cost information, photos, the proposal/contracts, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $107,000 and was placed in service on December 31, 2014.

WA 1-5251 – PULL AND REPLACE THE PUMP, COLUMN PIPE, TUBE AND SHAFT, AND LOWER THE PUMP 100 FEET AT WELL NO. 33.

The Company recently lost all production at Well No. 33. This amounts to a loss of approximately 2.2 million gallons per day (MGD) of water. Company engineers determined that three joints of column pipe were split and 16 additional joints of column pipe require replacement because they were severely corroded and nearing the end of their service life. Additionally, 28 joints of oil tube and shaft had severe corrosion on the tube, threads, and butt joint, and numerous bearings are out of tolerance. The well casing is approximately 90% plugged and required brushing to restore full pumping capacity. Additionally, the nitrate concentration in Well No. 33 is above 9 mg/L and approaching the EPA's MCL of 10 mg/L. Spinner log testing and zonal sampling was completed to develop a plan to mitigate the increasing nitrate level and allow the Company to provide adequate service during peak system demands and will provide adequate back up capacity for the Pinal Valley water system. Based on analysis of the testing result, a packer was installed at 630 ft below land surface to limit the vertical migration of nitrates into the well. However, the packer is a temporary measure to reduce nitrate concentration in the well. A nitrate removal facility is necessary

and is discussed in detail in Section X of my testimony. Cost information, the well rehabilitation analysis, photos, and the proposal/contract and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $246,000 and was placed in service on January 22, 2015.

WA 1-5260 – REPLACE SODIUM HYPOCHLORITE TANK AT WELL NO. 29 ARSENIC REMOVAL FACILITY.

This project is necessary to replace a sodium hypochlorite chlorine tank at the Well No. 29 arsenic removal facility that is leaking because repairing the tank is not feasible. Sodium Hypochlorite (commonly referred to as bleach) is commonly used in drinking water applications for its ability to disinfect and maintain a residual level of disinfectant throughout the distribution system. Cost estimates, photos, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $25,000 and the Company plans to place the chlorine tank in service on or about August 28, 2015.

WA 1-5296 – REPLACE PUMP AND RELATED EQUIPMENT AT WELL NO. 19.

This project is necessary to restore the amount of water produced from Well No. 19 because production from this well has dropped more than 20% from approximately 2.4 MGD to less than 1.9 MGD, a sign of impending failure. Well No. 19 provides water supplies critical to meeting peak water demands in the Pinal Valley water system. After study of the well, Company engineers determined that the pump and related equipment needed to be replaced to restore the lost water production. Cost estimates, photos, well video logs, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $175,000 and the Company plans to place the well in service on or about August 28, 2015.

WA 1-5299 – CONSTRUCT A NEW ACCESS ROAD TO THE NITRATE REMOVAL FACILITY LOCATED AT WELLS NO. 9 AND 10.

Company operators currently access the Wells No. 9 and 10 booster pump station and nitrate removal facility on a daily basis using the existing dirt roads. However, during and after rain events, the existing dirt roads are not accessible by employees and large trucks and equipment. Access by large trucks and equipment is necessary to deliver chemicals and haul brine waste. Without these chemicals and waste hauling, the existing nitrate removal system could not be operated. Company engineers determined that a new access road is needed to provide direct, reliable access to the site from Arizona Boulevard. Cost estimates, construction drawings, photos, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $100,000 and the Company plans to complete the new access road on or about September 25, 2015.

WA 1-5301 – CONSTRUCT APPROXIMATELY 1,500 LF OF 12-INCH DIP ALONG HANCOCK TRAIL FROM WELL NO. 33 TO HACIENDA ROAD.

This project, completed and placed in service on June 6, 2015 at a total cost of $180,000, was needed in order to properly flush Well No. 33 upon startup and shutdown. It is industry standard for vertical turbine pumps, such as Well No. 33, to flush on start up and shutdown. Company operators increased the flush time of this well to reduce nitrate levels after startup. Prior to completing this project, this well routinely flushed to a retention basin located south of the site. After increasing the flush time, the retention basin is no longer large enough to contain the discharge. To avoid overflowing the retention basin onto the adjacent golf course, the Company constructed a flush line to an adjacent drainage area to flush the well without flooding the golf course. Cost estimates, construction drawings, photos, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5303 – INSTALL NITRATE ANALYZERS AND ELECTRICAL CONTROLS AT WELLS NO. 32 & 33.

This project, completed and placed in service on June 5, 2015 at a total cost of $174,000, was necessary to monitor nitrate levels at Wells No. 32 and 33 and to automatically turn off the wells if nitrate levels approach the EPA's MCL of 10 mg/L. Nitrate levels over the MCL have been known to cause a potentially fatal blood disorder in infants under six months of age called methemoglobinemia, or "blue-baby" syndrome, which causes a reduction in the oxygen carrying capacity of blood. This is discussed in detail in Section X of my testimony. An evaluation of historical water quality results for each of these wells shows a steady increase in nitrates over the past seven years. As a result, the Company determined that it was necessary to install nitrate analyzers at each well to monitor nitrate levels and automatic controls to shut the wells off to prevent water exceeding the nitrate MCL from being pumped into the distribution system. This project allows the Company to continue to provide a safe drinking water supply in the Pinal Valley service area until a nitrate removal facility is constructed for each well. Cost information, construction drawings, photos, the placed in service notice, water quality results, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5304 – INSTALL AN ADDITIONAL BOOSTER PUMP AT THE WELL NO. 27 BOOSTER PUMP STATION.

The Well No. 27 booster pump station supplies water to the Pinal Valley upper pressure zone, which includes the Central Arizona College campus. This booster pump station consists of a single booster pump with no backup. Consequently, when the pump failed twice in the past five years, water pressure in this portion of the Pinal Valley water system was lower than planned. Constructing a back up booster pump will allow the Company to maintain adequate water pressure in the event of a pump failure. Cost estimates, construction drawings, photos, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is

$175,000 and the Company plans to place the pump in service on or about October 30, 2015.

WA 1-5307 – CONSTRUCT A THIRD AUTO STRAINER AT COOLIDGE WELL NOS. 9 AND 10.

This project is necessary to remove sand from water pumped from Well Nos. 9 and 10. These wells were drilled by cable tool and do not have a gravel pack around the well casing to prevent sand from infiltrating the casing. As a result, these wells produce a large amount of sand. To correct this, in 2013 and included in this proceeding on test-year plant additions, the Company installed two 80-micron automatic strainers with provisions for a third strainer in the event that additional strainer capacity is needed. While the existing automatic strainers remove sand from the well water, at times sand production exceeds their capacity, resulting in premature plugging of the strainer screens. On average, Company operators expend one to two hours to disassemble, reassemble and clean the strainers twice per day. The additional capacity provided by the third automatic strainer will significantly reduce the number of times the strainers require disassembly and cleaning, resulting in a more reliable well and nitrate removal facility operation. Cost estimates, photos, the placed in service notice, the proposal/contract, and construction schedule for adding the third strainer are included in Exhibit FKS-1. The total estimated cost to complete this project is $40,000 and was placed in service on July 1, 2015.

WA 1-5329 – CONSTRUCT 85 LF OF 4-INCH WATER MAIN, REPLACE THREE 4-INCH GATE VALVES, TWO 4-INCH TEES AND ONE FIRE HYDRANT ON 4TH STREET BETWEEN CAMERON AND MORRISON AVENUES.

This project, placed in service on February 12, 2015, at a total cost of $24,000, was necessary to restore water service to customers located on 4th Street between Cameron and Morrison Avenues. A leak on this 4-inch main,

installed in 1929, saturated the asphalt sub-base and surrounding soil, requiring an emergency water main replacement to prevent further damage to the roadway. Cost information, photos, the placed in service notice, and the proposal/contract are included in Exhibit FKS-1.

WA 1-5332 – CONSTRUCT 140 LF OF 36-INCH DIP TO REPLACE 140 LF OF FAILED 36-INCH CONCRETE LINED CYLINDER ("CLC") TRANSMISSION MAIN ON CASA GRANDE MOUNTAIN SOUTH OF INTERSTATE 8.

This project, completed and placed in service on May 5, 2015 at a total cost of $300,000, was an emergency replacement of a 140 LF section of transmission main. The Arizona Department of Transportation notified the Company that water was running down Casa Grande Mountain onto Interstate 8. The Company discovered a 10-inch diameter hole in the 36-inch CLC, cracks in the exterior concrete coating, and corrosion of the steel cylinder. Installed in 1978, this 36-inch CLC main is the primary supply main to and from the Company's five million gallon storage tank located on Casa Grande Mountain. This storage tank represents approximately 30% of the Pinal Valley water system's total storage capacity.

Construction of a 12-inch bypass water main was necessary to keep the five million gallon storage tank in service during construction of the new 36-inch DIP transmission main. The 36-inch CLC main is paralleled by a 12-inch DIP transmission main, which is located above and adjacent to the 36-inch CLC. Excavation of the 36-inch CLC main exposed the 12-inch DIP transmission main. In order to safely excavate the 36-inch CLC main, the 12-inch DIP main needed to be temporarily removed from service and drained to prevent flooding of the excavation trench in the event of a break.

The remaining sections of the 36-inch CLC transmission main will be replaced in future years, as needed and are identified as necessary projects in the Company's infrastructure replacement plan in Exhibit FKS-12. Cost

estimates, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5339 – REPLACE FAILED WATER SERVICE LINE ON ARIZOLA BOULEVARD.

This project, completed and placed in service on June 21, 2015, at a total cost of $62,000, was an emergency service line replacement. This service line broke, damaging a portion of Arizona Boulevard (ADOT SR-87) south of Verde Lane. The Company replaced the water service line and constructed a temporary asphalt patch to replace the damaged asphalt. The Arizona Department of Transportation ("ADOT") required the Company to re-pave 50 feet of the highway on each side of the service line. Cost information, the ADOT permit, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5341 – REPLACE FAILED WATER SERVICE LINE ON PINAL AVENUE.

This project, completed and placed in service on June 20, 2015, at a total cost of $43,000, was an emergency service line replacement. This service line broke, damaging a portion of Pinal Avenue (ADOT SR-387). The Company replaced the water service line and constructed a temporary asphalt patch and sidewalk to replace the damaged asphalt and sidewalk. ADOT required the Company to re-pave 50 feet of the highway on each side of the service line. Cost information, the ADOT permit, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5344 – CONSTRUCT APPROXIMATELY 25 LF OF 8-INCH DIP WATER MAIN, INSTALL TWO VALVES TO REPLACE 25 LF OF 8-INCH WATER MAIN AND TWO GATE VALVES ON SECOND STREET.

This project, completed and placed in service on June 20, 2015 at a total cost of $27,000, was an emergency water main replacement. This water main broke, damaging a portion of Second Street. The Company constructed a new

water main to replace the failed water main, installed two new valves to replace two inoperable valves, and constructed a temporary asphalt patch to replace the damaged asphalt. The City of Casa Grande required the Company to re-pave a portion of the roadway which was damaged. Cost information, the City permit, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5345 – CONSTRUCT 13 LF OF 8-INCH DIP WATER MAIN TO REPLACE 13 LF OF 8-INCH WATER MAIN AT 1955 NORTH CASA GRANDE AVENUE.

This project, completed and placed in service on June 24, 2015 at a total cost of $62,000, was necessary to replace a portion of leaking 8-inch CA water main and to repair a damaged roadway, sidewalk, curb, and gutter. The City of Casa Grande required the Company to replace a 44 x 78 foot section of damaged asphalt and replace 28 LF of concrete sidewalk, curb and gutter in accordance with City specifications. Cost estimates, photos, the placed in service notice, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5348 – INSTALL A BACK-UP RADIO SYSTEM, SOLAR SHIELDS, FAN AND FILTER KIT, AND SURGE ARRESTOR AT THE BURGESS PEAK SUPERVISORY CONTROL AND DATA ACQUISITION ("SCADA") RADIO REPEATER.

This project is necessary to ensure the reliability of the Company's SCADA system in the Pinal Valley system. The Burgess Peak SCADA radio repeater ("Radio") has failed twice this year. On average, the Radio fails three times per year but most frequently during the summer and monsoon seasons. All communication between the Pinal Valley SCADA master computer and 17 other well, tank, treatment, and booster pump station sites are transmitted through this Radio. Whenever the Radio fails, Company operators and

management are unable to remotely monitor, control or receive alarms from these 17 sites and must operate the sites manually, including evenings, weekends and holidays. Company operators must remove and replace the failed Radio with a spare that is kept in the Pinal Valley office. The Radio must then be programmed and reconfigured by a consultant programmer. This process can take several days or more to complete, during which time the Company is unable to receive any alarms from the 17 sites. Failures to receive the critical alarms has caused unplanned tank overflows and critically low tank levels. Installation of an automatic, reliable back-up radio system will ensure that the Company is notified of an alarm during a primary Radio failure and the SCADA system will continue to operate until the failed radio is replaced. The Radio is located on top of a mountain and is subject to lightning strikes. The installation of a surge arrestor will reduce the number of Radio failures caused by lightning strikes and power surges during monsoon season. The installation of a solar shield and fan kit will increase equipment life by reducing temperatures in the equipment cabinet during the hot summer months. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $27,000 and the Company plans to place the Radio in service on or about August 14, 2015.

WA 1-5358 – REPLACE PUMP AND RELATED EQUIPMENT AT WELL NO. 26.

This project is necessary because the well pump failed. Company engineers determined that the pump and related equipment at Well No. 26 needs replacement. Well No. 26 is needed to meet peak water system demands. The well produces 2.2 MGD. Planned work includes pulling the pump, video inspecting the well, and replacing the well pump and related equipment. Prior to reinstalling the new pump, company engineers will inspect the existing oil tube and line shaft and replace all failed or unserviceable components. Company

engineers also plan to brush and bail the well prior to returning the well to service. Cost estimates, photos, well video logs, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $115,000 and the Company plans to place the well in service on or about September 4, 2015.

WA 1-5359 – REPLACE PUMP AND RELATED EQUIPMENT AT WELL NO. 27.

This project is necessary because Well No. 27 is the only well producing water in the upper zone of the Pinal Valley water system. Well No. 27 production has dropped from approximately 70% or 0.65 MGD to less than 0.22 MGD and no longer provides sufficient production capacity to meet peak system demands. Company engineers determined that the pump and related equipment at Well No. 27 requires replacement. Planned work includes pulling the pump, video inspecting the well, and replacing the well pump and related equipment. Prior to reinstalling the new pump, company engineers will inspect the existing oil tube and line shaft and replace all failed or unserviceable components. Company engineers also plan to brush and bail the well prior to returning the well to service. Well No. 27 has elevated levels of nitrates and requires nitrate removal. I discuss the need for nitrate removal in Section X of my direct testimony. In the mean time, to help mitigate the elevated nitrate levels, Company engineers plan to install a packer prior to returning the well to service to restrict water production from the upper portion of the aquifer, which has nitrate levels over EPA's MCL of 10 mg/L. Installing a packer will reduce nitrate levels in Well No. 27. However, the well must be blended with sources of supply from the Coolidge portion of the water system. Well No. 27 requires nitrate removal for its continued long term operation. Cost estimates, photos, well video logs, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to

complete this project is $200,000 and the Company plans to place the well in service on or about September 30, 2015.

WA 1-5361 – CONSTRUCT OVERFLOW AND REPLACE CATHODIC PROTECTION ON THE ELEVATED STORAGE TANK IN COOLIDGE.

This project was completed and placed in service on July 9, 2015 at a total cost of $70,000. While recoating the interior of the elevated storage tank, Company engineers determined the cathodic protection system had failed and needed to be replaced. It was necessary to replace one 8-inch inlet gate valve, one 4-inch drain valve. The Company also replaced the undersized 8-inch overflow line with a 16-inch overflow line in accordance with current AWWA standards. The overflow line was undersized and unable to sufficiently discharge water without over pressurizing and damaging the tank. Cost estimates, photos, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5362 – REPLACE PUMP AND RELATED EQUIPMENT AT WELL NO. 31.

Well No. 31 production has dropped from 1.7 MGD to 1.3 MGD and was showing signs of failure. Company engineers have determined that the pump and related equipment at Well No. 31 in the Pinal Valley service area requires replacement. Planned work includes pulling the pump, video inspecting the well, and replacing the well pump and related equipment. Prior to reinstalling the new pump, Company engineers will inspect the existing oil tube and line shaft and replace all failed or unserviceable components. Company engineers also plan to brush and bail the well prior to returning the well to service. Well No. 31 is needed to meet peak water system demands. Cost estimates, photos, well video logs, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $117,000 and the Company plans to place the well in service on or about September 27, 2015.

ii. Coolidge Airport Water System - PWSID No. 11-707

WA 1-5166 – INSTALL POINT OF USE ("POU") ARSENIC REMOVAL DEVICES AT 20 LOCATIONS IN THE COOLIDGE AIRPORT WATER SYSTEM.

The Coolidge Airport water system receives its water supply from two wells, Well Nos. 1 and 2. These wells produce water with an arsenic concentration of approximately 13 ppb, which exceeds the arsenic MCL of 10 ppb. The Coolidge Airport water system was previously classified by ADEQ as a transient, non-community water system. Because the number of customers now served by the Coolidge Airport water system, ADEQ now classifies the water system as a non-transient, non-community water system and must comply with Safe Drinking Water standards. The Coolidge Airport water system is 10 miles from the closest portion of the Pinal Valley distribution system. Therefore, interconnecting the two water systems is not economically feasible. ADEQ recommended that the Company install POU devices as a cost effective solution that eliminates the need to build an expensive arsenic removal facility mainly sized for fire flows. Company engineers determined that POU devices are a viable and least-cost alternative to constructing a centralized arsenic treatment facility. A copy of the January 27, 2015 letter from ADEQ, cost estimates, manufacture data sheets, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $80,000 and the Company plans to place the POU arsenic removal devices in service on or about September 30, 2015.

WA 1-5173 – INSTALL ELECTRICAL PANEL SAFETY IMPROVEMENTS AT 2 SITES IN THE COOLIDGE AIRPORT WATER SYSTEM.

This project includes relocating operational controls from the interior electrical panels to panel exterior doors, install one starter reset plunger, install one motor saver display, install shielding over exposed conductors, and install

three disconnect switches for electrical panels and equipment at two sites in the Coolidge Airport water system. Controls for operation and maintenance of well, tank, and booster stations are located inside electrical control panels. Logging operating parameters, recording error codes and making operational adjustments require that electrical control panels are energized. The Company's Energy Control Program prohibits employees from entering energized panels to protect employees from injury and to comply with the OSHA Control of Hazardous Energy Standard, 29 CFR 1910.147. The Company contracts with outside electrical contractors to perform this routine work. The proposed panel modifications allow Company Operators access to system controls which will reduce Company's dependency on outside electrical contractors and system down time. Cost information, photos, the proposal/contracts, and construction schedule are included in Exhibit FKS-1. This project was placed in service on December 31, 2014.

iii. **Tierra Grande Water System - PWSID No. 11-076**

WA 1-5173 – INSTALL ELECTRICAL PANEL SAFETY IMPROVEMENTS AT ONE SITE IN THE TIERRA GRANDE WATER SYSTEM.

This project includes relocating operational controls from the interior electrical panels to panel exterior doors, install three motor saver displays, install shielding over exposed conductors, and install three disconnect switches for electrical panels and equipment at one site in the Tierra Grande water system. Controls for operation and maintenance of well, tank, and booster stations are located inside electrical control panels. Logging operating parameters, recording error codes and making operational adjustments require that electrical control panels are energized. The Company's Energy Control Program prohibits employees from entering energized panels to protect from injury and to comply with the OSHA Control of Hazardous Energy Standard, 29 CFR 1910.147. The Company contracts with outside electrical contractors to perform this routine

work. The proposed panel modifications allow Company Operators access to system controls which will reduce Company's dependency on outside electrical contractors and system down time. Cost information, photos, the proposal/contracts, and construction schedule are included in Exhibit FKS-1. This project was placed in service on December 31, 2014.

iv. **Stanfield Water System - PWSID No. 11-012**

WA 1-5173 – INSTALL ELECTRICAL PANEL SAFETY IMPROVEMENTS AT TWO SITES IN THE STANFIELD WATER SYSTEM.

This project includes relocating operational controls from the interior electrical panels to panel exterior doors, install four motor saver displays, install shielding over exposed conductors, and install six disconnect switches for electrical panels and equipment at two sites in the Stanfield water system. Controls for operation and maintenance of well, tank, and booster stations are located inside electrical control panels. Logging operating parameters, recording error codes and making operational adjustments require that electrical control panels are energized. The Company's Energy Control Program prohibits employees from entering energized panels to protect employees from injury and to comply with the OSHA Control of Hazardous Energy Standard, 29 CFR 1910.147. The Company contracts with outside electrical contractors to perform this routine work. The proposed panel modifications allow Company Operators access to system controls which will reduce Company's dependency on outside electrical contractors and system down time. Cost information, photos, the proposal/contracts, and construction schedule are included in Exhibit FKS-1. This project was placed in service on December 31, 2014.

WA 1-5306 – INSTALL AN ADDITIONAL 30 HORSE POWER BOOSTER PUMP AND STARTER AND UPGRADE TRANSFORMERS AT THE STANFIELD BOOSTER PUMP STATION.

The Stanfield booster pump station supplies 100% of the water to the Stanfield water system. This booster pump station consists of one 10 HP pump and one 15 HP pump with a combined pumping capacity of 0.27 MGD. Both pumps are required in order to provide peak system demands and fire flow requirements, but they lack backup capacity in the event of a pump or motor failure. The Company requires at least one back-up pump at each booster pump station to maintain water service in the event of a pump failure. A new 30 HP pump provides backup capacity for the water system and increases the "firm" capacity of the booster pump station from 0.08 MGD, to 0.27 MGD, with the largest pump out of service. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $43,000 and the Company placed the booster pump in service on June 30, 2015.

B. <u>White Tank Service Area</u>

WA 1-5032 – CONSTRUCT PHASE 1 OF THE WHITE TANK SCADA SYSTEM.

This project, completed and placed in service on June 1, 2015 at a total cost of $327,000, was necessary to allow the Company to better operate production and treatment facilities in the White Tank water system. The Company currently has three employees that operate the White Tank water system, which is managed from the Pinal Valley office, located approximately 90 minutes away in Casa Grande. Currently, the water system has limited basic fault alarms and local controls.

The White Tank water system consists of five wells, two arsenic removal facilities, and one nitrate removal facility. Phase 1 of the SCADA system includes the installation of SCADA monitoring and control equipment at the Monte Vista arsenic removal facility, installation of a SCADA master computer, as well as a radio and antenna. The Monte Vista arsenic removal facility

removes arsenic from Well Nos. 2, 4, and 8. A Nitrate Removal Facility at Well No. 7 reduces the nitrate level from 40 mg/L to 18 mg/L before the water is pumped to the Monte Vista arsenic removal facility for blending with water treated from Well Nos. 2, 4, and 8. Operators will use the new SCADA system to trend daily tank levels, monitor well and blend plan status, and receive alarms when the system is not operating within established parameters. Constructing this SCADA system phase will allow management staff to monitor and control facilities in the White Tank system remotely from Casa Grande. Cost information, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5263 – INSTALL APPROXIMATELY 230 LF OF 6-INCH DIP AND ONE AIR RELIEF VALVE ALONG CITRUS ROAD.

This project, completed and placed in service on February 3, 2015 at a total cost of $52,000, was necessary to eliminate two dead end mains. Eliminating two dead end water mains creates a looped system that improves water quality by reducing water age improves fire flow, and stabilizes water system pressures. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5309 – REPLACE 16-INCH DUCTILE IRON FITTINGS AND BUTTERFLY VALVES AT THE BLUE HORIZON ARSENIC REMOVAL FACILITY.

This project was completed and placed in service on April 21, 2015 for a total cost of $54,000 to replace corroded pipes. Company operators must use corrosive chemicals in the arsenic treatment process, which corroded pipes at the Blue Horizon arsenic removal facility. Because this piping is critical to the facility's operation, it needed to be replaced. In order to protect against corrosion, the Company determined that the concrete lined fittings required replacement with ceramic epoxy lined fittings and the standard epoxy lined

valves required replacement with modified polyamine epoxy lined valves. This site is critical because it produces 50% of the water supply for the White Tank service area. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1.

WA 1-5360 – CONSTRUCT 12-INCH OVERFLOW AND NEW LADDER ON THE 500,000 STORAGE TANK AT BEAUTIFUL ARIZONA ESTATES TANK SITE.

While recoating the interior of the water storage tank, Company engineers noticed that the interior ladder failed and required replacement. A storage tank interior ladder is required so that operators and inspectors can access the tank to perform routine tank maintenance and inspections. Additionally, the existing 6-inch overflow is undersized because of increased production capacity in the White Tank service area. Constructing a 12-inch overflow line is required to comply with AWWA standards and to prevent over pressurizing and damage to the storage tank. This tank is critical because it provides 30% of the storage capacity to the Northern portion of the White Tank water system. Cost estimates, the proposal/contract, photos, and inspection documents are included in Exhibit FKS-1. The total estimated cost to complete this project is $20,000 and the Company plans to place the storage tank in service on or about August 31, 2015.

C. <u>Phoenix Office</u>

WA 1-5324 – REPLACE OBSOLETE PHONE SYSTEM IN THE PHOENIX, PINAL VALLEY, WHITE TANK AND AJO OFFICES.

This project is necessary to replace the Company's current phone system has failed at least four times in the past year and can no longer be repaired or serviced. The Company's current phone system is a 15 year old analog system that operates using Microsoft Windows NT. The manufacturer no longer provides support for the phone system, and Microsoft no longer supports Windows NT. Installing a new phone system will improve reliability. A new

phone system will also better integrate with future technologies. By upgrading to a Voice Over IP ("VOIP") system, the Company can transfer calls between the Phoenix office and its division offices, making customer call handling more efficient. Additionally, a VOIP system will allow employees to reroute calls to other division offices during busy periods to make more efficient use of customer service representatives. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The estimated total cost to complete this project is $85,000 and the Company plans to place the phone system in service on or before December 15, 2015.

WA 1-5325 – REPLACE OFFICE BUILDING SIGNS.

This project is necessary to install a new sign at the entrance to the parking lot for better visibility. The existing sign is located high on the building but is not visible from Indianola Avenue. This makes it difficult for customers and visitors to find by the office. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $31,000 and the Company plans to have the signs installed on or before December 15, 2015.

WA 1-5326 – REPLACE THE ANTI-VIRUS AND PATCH SERVERS AND MIGRATE ACTIVE DIRECTORY TO NEW SERVER.

This project is necessary to maintain the integrity, security and reliability of the Company's computer network. The patch and anti-virus servers are used to send software updates to user workstations and to run the company's anti-virus software. These servers are over six years old and need to be replaced.

Additionally, the Microsoft Active Directory Domain Service which authenticates and authorizes all users and computers in the network needs to be updated to a newer version in order to increase reliability of user access to the company's network. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this

project is $14,000 and the Company plans to place the computer software and servers in service on or before October 30, 2015.

WA 1-5327 – DESIGN AND IMPLEMENT A NEW COMPANY WEBSITE.

Customers use the company's website to find payment options, local office addresses, phone numbers, tariffs, Consumer Confidence Reports and to learn about water conservation. The current website has become difficult to maintain and is difficult for customers to navigate. Designing and implementing a new website will allow the company to fix these problems and allow it to offer new services to customers, such as e-billing. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-1. The total estimated cost to complete this project is $20,000 and the Company plans to have the website operational on or before December 15, 2015.

Q. IS THE COMPANY PROPOSING TO INCLUDE ANY ADDITIONAL POST-TEST YEAR PLANT IN RATE BASE NOT DESCRIBED ABOVE?

A. Yes. In addition to the projects described above, the Company proposes to include smaller post-test year projects, known as blanket projects, in rate base. Blanket projects are projects with short lead times that are managed by the division offices and reviewed on an aggregate basis by the Company's engineering department. The Company's proposed post-test year blanket projects for the Ajo, Pinal Valley, and White Tank service areas and for the Phoenix office and meter shop are reflected in the appendix to Schedule B-2 of the Company's Application, sponsored by Mr. Reiker.

IV. <u>Description of Company-Funded Construction Budgeting Procedures</u>

Q. HOW DOES THE COMPANY DETERMINE WHICH PROJECTS TO BUDGET IN A GIVEN YEAR?

A. Each year, the Company prepares the next year's construction budget for each of its water systems. Division managers prepare proposed construction budgets for utility plant additions in the water systems they manage as part of the budget

process. Each division manager identifies the water facilities needed to improve or maintain service to existing customers. For example, division managers propose construction project such as storage tanks, booster pump station replacements or upgrades, new wells, or replacement of water mains or water transmission lines. Division managers make recommendations based on the need to maintain safe, reliable and adequate water service.

Company engineers then review and analyze the proposed construction projects and further investigate and evaluate the need for each project. Company engineers develop preliminary schematics and cost estimates and collect data supporting for each project. Engineers also review current and projected water system demands and evaluate production, pumping, and storage capacities available to meet such demands. Among the factors Company engineers consider when reviewing proposed projects are compliance with applicable codes, ordinances, and safe drinking water standards, trends in source water quality, and changes in regulations that may affect continued compliance with drinking water standards.

Several days are scheduled each year for division managers, engineers, operations staff, and other Company managers to meet at each division office to review and discuss that Division Manager's proposed construction projects for the next year. Company engineers subsequently conduct on-site visits to review and discuss larger-scale construction projects. The Company's President, Division Manager's and engineers and I prioritize the proposed projects and a final construction budget is prepared and presented to the Company's Board of Directors for their review and approval.

Q. WHO DETERMINES HOW MUCH WILL BE ALLOCATED AND APPROVED FOR COMPANY-FUNDED PROJECTS?

A. The Company's Board of Directors establishes the annual construction budget for Company funded projects. Under normal circumstances, the construction budget

increases each year to reflect increasing costs of construction such as materials and labor, general inflation, and additional regulatory requirements. Since 2009, the Company's construction budget has increased steadily, reflecting improved economic conditions and increases in revenues. The Company's Board of Directors approved a construction budget of $18.3 million for calendar year 2015.

Q. HOW DO YOU PROCEED ONCE THE COMPANY'S CONSTRUCTION BUDGET IS APPROVED BY ITS BOARD OF DIRECTORS?

A. Once the Board of Directors approves the Company's construction budget, the Company prepares detailed construction plans for the utility plant additions and obtains the required regulatory permits and approvals. Once the Company receives the required permits and approvals, it releases the project to construction. Company engineers solicit competitive bids for infrastructure, such as booster pump stations, storage tanks, and new wells. The division managers solicit competitive bids from a list of qualified independent contractors for pipeline projects. The Company typically award these projects to the qualified contractors who submit the lowest bids.

Q. DOES THE COMPANY FUND THE COST OF INFRASTRUCTURE NEEDED TO SERVE NEW DEVELOPMENTS?

A. No. Developers fund the infrastructure needed to serve their projects through advances in aid of construction or contributions in aid of construction.

Q. ARE DEVELOPER ADVANCED FUNDS FOR WATER FACILITIES INCLUDED IN THE COMPANY'S ANNUAL CONSTRUCTION BUDGET?

A. No.

Q. HOW ARE DEVELOPERS' WATER FACILITY REQUIREMENTS DETERMINED AND BUDGETED?

A. The Company works with developers to determine the infrastructure needed to provide water service to their developments. Such infrastructure includes waterlines, fire hydrants, water services, and water meters. For larger

developments, the Company may also require water storage tanks, booster pump stations, wells, and water treatment plants. This infrastructure is included in main extension agreements between the Company and developers. Developers fund this infrastructure. Project timing is entirely dependent upon the developer's construction schedule. Because the Company does not fund these infrastructure requirements, it does not include developer advances or contributions in its annual construction budget.

V. Description of Company-Funded Utility Plant Additions For The Western Group

Q. PLEASE SUMMARIZE THE COMPANY-FUNDED UTILITY PLANT ADDED IN THE WESTERN GROUP SINCE DECEMBER 31, 2010, THE TEST YEAR UTILIZED IN THE LAST GENERAL RATE CASE FOR THE WESTERN GROUP.

A. From the adjusted test year in the Company's last Western Group general rate case through the adjusted December 31, 2014 test year in this proceeding, the Company funded construction projects in the Western Group are summarized below. Company funded utility plant additions were added to maintain and replace infrastructure, address water loss, resolve operational problems, and comply with safety regulations and Safe Drinking Water Act standards. A summary of the cost of these utility plant additions is provided in the following table:

ARIZONA WATER COMPANY Western Group Company-Funded Utility Plant Additions From 2011 through 2014[2]	
Ajo	$250,579
Pinal Valley	$24,248,976
White Tank	$2,314,448
Total	$26,814,003

The following is a summary of the major projects the Company has completed and placed in service since December 31, 2010, the adjusted test year in the last Western Group rate case:

A. Ajo Service Area

Plant Addition Summary for PWSID No. 10-003	
WA No.	**Project Description**
4919	Replace the booster pumps and related equipment at the Ocotillo Booster Pump Station.
5034	Install SCADA System at the Ocotillo Booster Pump Station.
5035	Replace the obsolete handheld meter reading devices.

B. Pinal Valley Service Area

i. Pinal Valley Water System – (11-009)

Plant Addition Summary for PWSID No. 11-009	
WA No.	**Project Description**
4617	Construct a 2 MG water storage tank, 4,800 GPM booster pump station, and related appurtenances at the Arizona City storage tank and booster pump station site.
4702	Construct 127 LF of 8-inch DIP, 2,185 LF of 6-inch DIP, and 37 LF of 4-inch DIP water main to replace 155 LF of 8-inch CI, 50 LF of 6-inch CA, 1,946 LF of 4-inch CI, and 280 LF of 4-inch CA water main along Florence Street between Main Street and Florence Boulevard as part of the City of Casa Grande downtown street improvement project.

[2] Excludes post-test year plant included in rate base in the previous rate proceeding (test year ended December 31, 2010) and includes post-test year plant requested in this proceeding.

4704	Construct a permanent post pH adjustment system including a new sodium hydroxide chemical storage tank and redundant chemical injection pumps to replace the chemical storage tank, injection pump, and controls at the Pinal Valley Well No. 28 arsenic removal facility.
4772	Construct 2,144 LF of 12-inch C-900 and 4,193 LF of 6-inch C-900 water main to replace 6,510 LF of 4-inch and 370 LF of 6-inch CA water main and replace 162 service connections along Lincoln, Seagoe, and Elm Avenues.
4773	Construct 1,312 LF of 12-inch C-900 and 1,115 LF of 6-inch C-900 water main to replace 2,400 LF of 6-inch CA water main with along Vah Ki Inn Road and Moore Road.
4774	Construct 2,614 LF of 12-inch DIP and 1,532 LF of 16-inch DIP water main from Pinal Valley Well No. 28 to the Arizona City storage tank and booster pump station site.
4802	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 23.
4803	Pull and replace the pump, motor, and related appurtenances at Pinal Valley Well No. 14.
4804	Install a 16-inch control valve and related fittings at the Casa Grande Mountain 5 MG water storage tank.
4807	Construct grading and drainage improvements at the Valley Farms storage tank site.
4846	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 7.
4850	Construct 92 LF of 6-inch DIP water main to replace 92 LF of 6-inch CA water main along Geronimo Drive.
4854	Construct 200 LF of 10-inch C-900 water main to replace 200 LF of 10-inch CA water main along La Palma Road south of Windsor Road.
4861	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 29.
4876	Construct 13 LF of 6-inch DIP water mains to replace 13 LF of 6-inch CA water main along McMurray Boulevard at Crane Street.
4911	Replace two base station radios, six remote desk sets, and four radios, reprogram seven radios and purchase two new handheld radios to comply with FCC narrowband requirements.
4912	Construct a surge anticipator valve and related appurtenances at the Coolidge Well Nos. 9 and 10 booster pump station.
4915	Construct entrained air removal system and sanitary seal at Pinal Valley Well No. 17. Pull and replace the pump and related appurtenances.
4943	Pull and replace the pump motor and related appurtenances at Pinal Valley Well No. 20.
4955	Construct 13 LF of 6-inch DIP water main to replace 13 LF of 6-inch CA water main at McMurray Boulevard and Houck Street.
4958	Construct 3 LF of 4-inch DIP water main to replace 3 LF of 4-inch CI water main at the intersection of 1st Street and Dry Lake Street.

4961	Replace nitrate analyzer at Pinal Valley Well No. 27.
4967	Construct 18 LF of 12-inch DIP water main to replace 18 LF of 12-inch DIP water main along Cottonwood Lane between Desert Willow Avenue and Arizola Road.
4972	Construct 39 LF of 6-inch DIP water main to replace 39 LF of 6-inch CA water main at McMurray Boulevard and Crane Street.
4979	Purchase 4.38 acres of vacant land at the northeast corner of Highway 84 and Thornton Road in the City of Casa Grande's Industrial Park to store company materials.
4985	Purchase 8.88 acres at the southeast corner of Cottonwood Lane and Peart Road in Casa Grande to construct water storage tanks, arsenic removal facility, well, and booster pump station.
4988	Construct 340 LF of 6-inch DIP water main to replace 325 LF of 4-inch CI water main along First Street between Picacho and Dry Lake Street.
5017	Construct a sludge dewatering filter at the Cottonwood Lane arsenic removal facility.
5019	Construct two variable frequency drive motor controllers, replace electric utility service and electric service entrance section at the Coolidge Well Nos. 9 and 10, booster pump station.
5023	Construct automatic cleaning filtration system at the Coolidge Well Nos. 9 and 10 site.
5024	Construct a 950 GPM booster pump station, hydropneumatic tank, and related appurtenance at the Valley Farms storage tank site.
5025	Replace 3,062 linear feet of old deteriorated and failing 4-inch and 6-inch concrete asbestos water main with 6-inch ductile iron water main and replace 68 service connections in the Rancho Grande Subdivision, Phase 1.
5026	Replace 2,791 LF of deteriorated and failing 2-inch GS, 3-inch CA, 4-inch CA, and 6-inch CA water mains with 326 LF of 6-inch DIP and 2,563 LF of 8-inch DIP and replace 34 service connections along McMurray Boulevard between Schultz Street and Pinal Avenue.
5027	Install a 150kW generator at the Arizona City storage tank and booster pump station site.
5028	Purchase a set of Leak Finder RT leak noise correlators for leak detection in the Pinal Valley system.
5029	Construct 380 LF of 8 ft tall C.M.U. wall and gates to replace the chain link fence and slump block wall at Pinal Valley Well No. 25.
5031	Construct a perimeter fence around the Highway 84 and Thornton Road/ material storage yard.
5075	Construct 174 LF of 6-inch DIP water main to replace 174 LF of 6-inch DIP water main and 6-inch PVC water main at UPRR Rail Road Crossing.
5079	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 30.
5080	Pull and replace booster pump No. 2 and related appurtenances at the Henness Booster Pump Station.

5087	Pull and replace the pump, motor, and related appurtenances at Pinal Valley Well No. 21.
5095	Install a 2-inch domestic service along Colorado Street to serve the Odyssey Charter School.
5118	Replace 4,334 LF of old deteriorated and failing 4-inch and 6-inch CA water main with 6-inch DIP water main and replace 76 service connections in the Rancho Grande Subdivision, Phase 2.
5122	Construct a line stop and 16-inch gate valve on the 16-inch CA water main at the southwest corner of Gila Bend Highway and VIP Boulevard.
5123	Pull and replace the pump, motor, and related appurtenances at Pinal Valley Well No. 25.
5127	Replace the mechanical seal, pump shaft, and bearings in pump No. 1 and install a temporary plug in water storage tank to control flow at the Cottonwood Lane Booster Pump Station.
5176	Purchase no-lead Brass compliant meters.
5195	Replace a leaking fire hydrant at the SRP Substation.
5198	Construct 13 LF of 10-inch DIP water main to replace 13 LF of 10-inch CA water main along McMurray Boulevard and Gilbert Avenue.
5200	Pull and replace pump, modify on-site piping, and construct a flush-to-waste line at Coolidge Well No. 10.
5204	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 10.
5205	Construct 5 LF of 6-inch DIP water main to replace 5 LF of 6-inch DIP water main on Sand Hills Court.
5208	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 28.
5211	Remove and reinstall media to replace 840 failing nozzles and replace the interior coating in six vessels at the Pinal Valley Well No. 28 Arsenic Removal Facility.
5215	Pull and replace pump and related appurtenances at Pinal Valley Well No. 14.
5224	Expand the Henness Road booster pump station to a firm capacity of 6,000 gpm. Construct 24-inch DIP suction and discharge manifolds to replace 16-inch DIP and install a surge anticipator valve.
5236	Remove and reinstall media to replace 604 failing nozzles and replace the interior coating in four Vessels at the Pinal Valley Well No. 29 Arsenic Removal Facility.
5239	Replace one 1-inch leaking copper service with one 1-inch copper service at 512 E. Cottonwood Lane.
5264	Pull and replace the pump, motor, and related appurtenances at Pinal Valley Well No. 32.
5265	Pull and replace the pump and related appurtenances at Pinal Valley Well No. 7.

ii. **Coolidge Airport Water System (PWSID No. 11-707)**

Plant Addition Summary for PWSID No. 11-707	
WA No.	**Project Description**
4768	Construct 3,430 LF of 12-inch DIP water main to replace 3,680 LF of 6-inch PVC water main from the Airport booster pump station to Coolidge Airport Road South of Boeing Avenue.

iii. **Tierra Grande Water System (PWSID No. 11-076)**

Plant Addition Summary for PWSID No. 11-076	
WA No.	**Project Description**
4801	Pull and replace the pump, motor and related appurtenances at Tierra Grande Well No.3.

iv. **Stanfield Water System (PWSID No. 11-012)**

Plant Addition Summary for PWSID No. 11-012	
WA No.	**Project Description**
4951	Purchase the existing Envirogen arsenic and nitrate removal facility at the Stanfield site and replace resin media in 13 vessels.
5020	Install a nitrate analyzer, electrical controls and control valve at Stanfield Well No. 1.
5062	Pull and replace the pump, motor, and related appurtenances at Stanfield Well No. 1.
5098	Replace the plenum and relocate the tank fill line on the brine tank at the Stanfield arsenic and nitrate removal Facility.

C. **White Tank Service Area**

Plant Addition Summary for PWSID No. 07-128	
WA No.	**Project Description**
4808	Construct 400 LF of 8-inch DIP water main on 191st Avenue

	between Melvin Street and Van Buren Street.
4810	Construct 254 LF of 6-inch DIP, 264 LF of 8-inch DIP and 70 LF of 12-inch DIP water main to replace 588 LF of 6-inch, 8-inch and 12-inch water mains along Jackrabbit Trail.
4917	Reconstruct backwash tank overflow and construct grading/drainage improvements at Monte Vista site and install equipment shade canopies at Golightly and Monte Vista Sites. Isolate the transmission main that runs from Golightly Well No. 7 site to Monte Vista site.
4918	Construct 560 LF of HDPE casing, 1,560 LF of 12-inch DIP, 230 LF of 8-inch DIP, and 230 LF of 6-inch DIP water main to replace approximately 1,860 LF of CA water main on Perryville Road at the Interstate 10 Interchange.
4948	Pull and replace the pump, motor and related appurtenances at White Tank Well No. 2.
5033	Replace two handheld meter reading devices.
5060	Pull and replace the pump, motor and related appurtenances at White Tank Well No. 8.
5061	Pull and replace the pump, motor and related appurtenances at White Tank Well No. 4.
5073	Replace electrical wire from the service entrance section to the starter and from the starter to the motor at White Tank Well No. 9.
5119	Replace conduit and wire between terminal box and RTU at the White Tank Well No. 7 Nitrate Removal Facility.
5193	Install an alarm system and security lighting at White Tank Well No. 9.
5209	Replace eight water services along 193rd Drive and 193rd Avenue between Thomas Road and Catalina Drive.
5234	Pull and replace the pump and related appurtenances at White Tank Well No. 10.

D. **Phoenix Office**

Plant Addition Summary for Phoenix Office	
WA No.	**Project Description**
5186	Replace the engineering department computer server.
5187	Replace two domain controller servers and the exchange email server.
5188	Purchase additional office furniture and reconfigure existing space to accommodate two additional employees. Purchase cubical partitions and furniture for new workstations.

VI. Additional Arsenic Removal Facilities and the Need to Continue the ACRM

Q. DOES THE COMPANY NEED TO CONSTRUCT ADDITIONAL ARSENIC REMOVAL FACILITIES IN THE WESTERN GROUP?

A. Yes. The Company needs to construct an arsenic removal facility for Pinal Valley Well No. 34 to reduce arsenic levels from 40 ppb to under the federally mandated MCL of 10 ppb to comply with Safe Drinking Water standards. The Arizona City portion of the Pinal Valley water system currently has one source of supply, Well No. 28, which serves more than 4,700 customers. When Well No. 28 has a well pump failure, water is pumped from limited well supplies in Casa Grande to Arizona City by the Tanger booster pump station. The Tanger booster pump station and transmission line have capacity to provide up to 1.2 MGD to Arizona City but do not have sufficient capacity to supply the max day demand of 1.9 MGD in Arizona City. Therefore, an additional source of supply is required in Arizona City. If a new source of supply is not added to the Arizona City portion of the Pinal Valley water system, during the summer time, customers will experience low pressures, poor water quality or may not have water.

Constructing an arsenic removal facility to utilize Well No. 34 increases water supply reliability by adding a second source of supply in this portion of the Pinal Valley water system. The Company will use one of the best available technologies for arsenic removal as recognized by the EPA, similar to the more than 20 ARFs the Company currently owns and operates.

Q. IS THE COMPANY REQUESTING COMMISSION APPROVAL TO RECOVER THESE ADDITIONAL COSTS UNDER THE ARSENIC COST RECOVERY MECHANISM ("ACRM")?

A. Yes. In Decision No. 73144, the Commission authorized continuation of the ACRM in the Company's Pinal Valley service area. The Company requests the Commission authorize continuation of the ACRM in this proceeding. Mr. Harris discusses the Company's request in detail in Section II of his direct testimony.

Q. WHERE IS THE COMPANY PLANNING TO CONSTRUCT THE ARSENIC REMOVAL FACILITY FOR WELL NO. 34?

A. Adequate space is not available at the Well No. 34 site to construct an arsenic removal facility. Therefore, the arsenic removal facility will be constructed at the Arizona City storage tank and booster pump station site, where there is adequate space.

Q. ARE ADDITIONAL TRANSMISSION MAINS REQUIRED TO CONVEY GROUNDWATER TO THE NEW ARSENIC REMOVAL FACILITY?

A. Yes. A 3,400 LF 12-inch DIP transmission main is required to move water from Well No. 34 to the Arizona City storage tank and booster pump station site, where the arsenic removal facility will be constructed.

Q. WILL THIS ARSENIC REMOVAL FACILITY BENEFIT THE ENTIRE PINAL VALLEY WATER SYSTEM?

A. Yes. By constructing an arsenic removal facility at Well No. 34, the Company can pump water from the Arizona City area to the Casa Grande area, thereby providing an additional source of water supply to the Pinal Valley water system. Cost estimates, the proposal/contract, and construction schedule are included in Exhibit FKS-3.

Q. WHEN WILL THE COMPANY COMPLETE CONSTRUCTION OF THIS ARSENIC REMOVAL FACILITY?

A. The Company anticipates this project will be completed and placed in service on or before December 31, 2016. The estimated cost to construct for the Pinal Valley Well No. 34 arsenic treatment facility is $3,400,000.

Q. DO ANY OTHER WATER SOURCES IN THE WESTERN GROUP REQUIRE TREATMENT FOR ARSENIC?

A. No. The Company monitors all of its sources of supply to ensure compliance with Safe Drinking Water Standards, including the federally-mandated arsenic MCL.

Q. HOW IS THE COMPANY PROPOSING TO RECOVER THE COSTS ASSOCIATED WITH THE PINAL VALLEY WELL NO. 34 ARSENIC REMOVAL FACILITY?

A. As mentioned above, the Company requests continuation of the ACRM in this proceeding for the purpose of recovering the costs to construct and operate the ARF at Well No. 34 and the cost of other arsenic removal facilities the Company may need to construct in the Pinal Valley and White Tank service areas prior to its next Western Group rate case. As Mr. Harris describes in detail in Section II of his direct testimony, the Company will experience a significant negative effect on its financial performance without the ability to recover a portion of the costs associated with this federally mandated ARF investment through the ACRM.

Q. ARE THERE OTHER REASONS THE COMPANY REQUIRES THE CONTINUATION OF THE WESTERN GROUP ACRM?

A. Yes. In addition to the arsenic removal facility noted above, the Company requests the continuation of the ACRM to recover its cost of removing arsenic from the treatment plants listed as post-test year plant additions which require twelve months of operating costs prior to recovering those actual costs. Specifically, these ARF's are Valley Farms Well No. 2, Pinal Valley Well No. 13 and the POU devices at the Company's Coolidge Airport water system.

VII. CAP Use Plan

A. Pinal Valley Service Area

Q. HOW MUCH CAP WATER DOES THE COMPANY HAVE UNDER SUBCONTRACT WITH THE CAP FOR USE IN THE PINAL VALLEY SERVICE AREA?

A. The Company holds annual CAP water allocations totaling 10,884 acre-feet ("AF") in the Pinal Valley service area. The Company delivered 1,928 AF of CAP water to customers for non-potable use in 2014.

Q. HAS THE COMPANY PREPARED A PLAN TO PUT THE UNUSED PORTION OF ITS PINAL VALLEY CAP ALLOCATION TO USE?

A. Yes. The Company's plan is outlined in the Pinal Valley 2015 CAP Use Plan, filed in this docket. The Pinal Valley 2015 CAP Use Plan was filed on August 7, 2015 in this docket and is sponsored by Mr. Garfield. The Pinal Valley 2015 CAP Use Plan is an update to the Company's CAP Water Use Plan ("2006 CAP Use Plan") filed in Docket No. W-01445A-04-0650, on December 29, 2006 as required in Decision No. 68302. In the 2006 CAP Use Plan, the Company contemplated constructing a 10 million gallon per day ("MGD") surface water treatment plant at an estimated cost, in 2006 dollars, ranging from $34 million to $66 million.

Q. HAS THE COMPANY UPDATED THIS 2006 ESTIMATED COST?

A. Yes. In the Company's 2010 test year Western Group rate case, I provided an updated cost estimate of $82 million to design and construct a 10 MGD surface water treatment plant. In 2014, after further refinements to design specifications and a general increase in equipment, materials, and construction costs, that estimate increased to $94 million. The Company has developed a far less costly and more efficient means of delivering much needed CAP water to the Company's Pinal Valley customers.

Q. WHAT DOES THE COMPANY'S PINAL VALLEY 2015 CAP USE PLAN RECOMMEND?

A. The Pinal Valley 2015 CAP Use Plan outlines the Company's plan to deliver CAP water to its customers through recharge and recovery beginning in 2015. The estimated construction cost to construct the Pinal Valley recharge and recovery facility is approximately $5.8 million, making it a practical, cost-effective and financially feasible alternative to treatment and direct delivery of CAP water.

Q. WILL THE COMPANY ACHIEVE ANY COST SAVINGS UNDER THE PINAL VALLEY 2015 CAP USE PLAN?

A. Yes. In addition to the $357,500 grant the Company received from ADWR's Water Management Assistance Program, the Company's Pinal Valley 2015 CAP Use Plan achieves the following cost savings:

- Construction cost savings of $88 million
- Operating cost savings of $2.4 million per year
- Customer savings of $17.5 million per year
- Residential customer savings of more than $24 per month or a savings of 84 percent.

Q. WHAT IS RECHARGE AND RECOVERY?

A. Recharge and recovery involves the intentional recharge of water into an aquifer system for intended recovery and beneficial use as an element of long-term water resource management.[3] Under ADWR's recharge and recovery program, water can be stored at either underground storage facilities or groundwater savings facilities. Underground storage facilities are constructed typically using recharge (or spreading) basins where water directly recharges the groundwater aquifer through infiltration. Other type methods of underground storage facilities, such as shallow wells (vadose zone) or deep injection wells, are used when recharge basins are impractical or technically not feasible.

Q. PLEASE DESCRIBE THE COMPANY'S PLANNED PINAL VALLEY RECHARGE AND RECOVERY FACILITY, AS OUTLINED IN THE PINAL VALLEY 2015 CAP USE PLAN.

A. The Company's Pinal Valley recharge and recovery facility will consist of recharge basins and the infrastructure necessary to deliver CAP water to these basins. The Company will eventually drill recovery wells on-site to deliver recovered CAP water to customers throughout the Pinal Valley service area. In the meantime, the Company will obtain permits for its existing Pinal Valley wells so that it may receive stored water through them.

[3] Southwest Hydrology. May/June 2008. University of Arizona.

Q. WHERE DOES THE COMPANY PLAN TO CONSTRUCT THE PINAL VALLEY RECHARGE AND RECOVERY FACILITY?

A. A map showing the location of the Pinal Valley recharge and recovery facility is shown below in Figure 2-1. A conceptual plan showing the recharge basins and the facility's connection to the CAP canal is shown below in Figure 2-2.

Figure 2 – 1 Pinal Valley Recharge and Recovery Facility Location and Pinal Valley Service Area

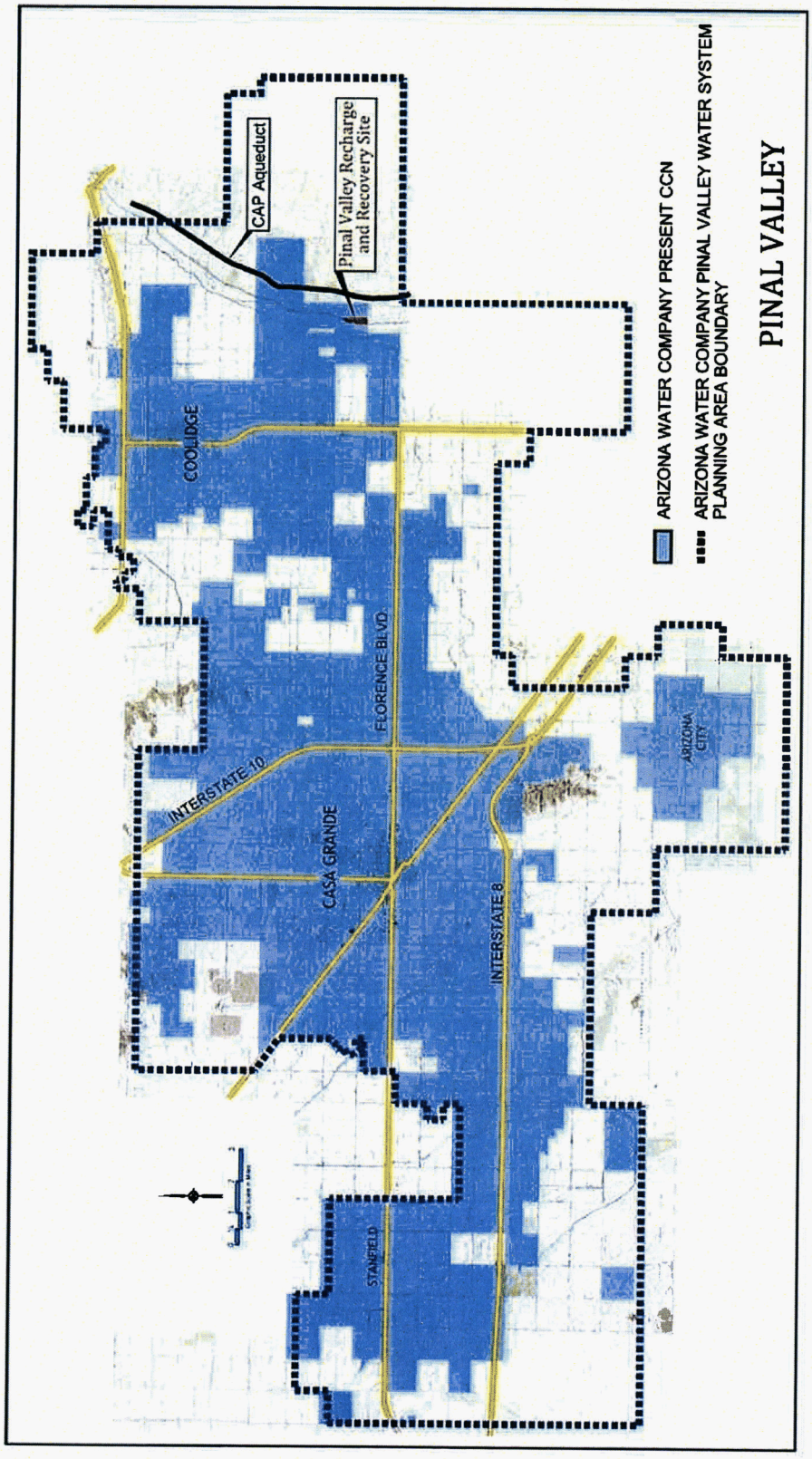
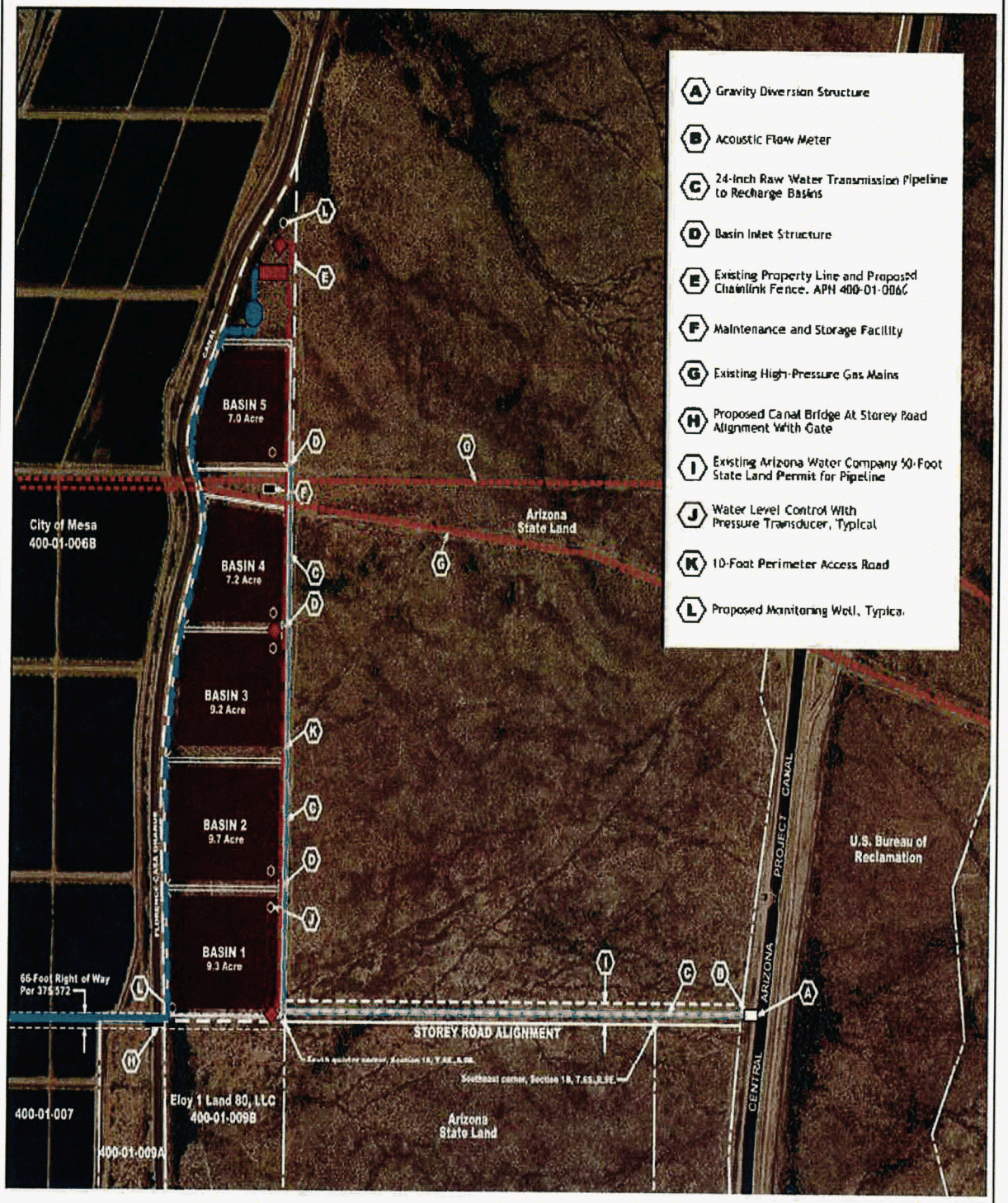


Figure 2 – 2 Pinal Valley Recharge and Recovery Facility Conceptual Plan



Q. DOES THE COMPANY'S PLAN COMPLY WITH ARIZONA POLICY?

A Yes. As explained by Mr. Garfield in Section III of his direct testimony, the Company's plan to use CAP water to serve its customers through recharge and

recovery complies with Arizona's public policy on water storage and water savings. Mr. Garfield also discusses how the Company's plan addresses and mitigates over-reliance on groundwater in the Pinal Active Management Area ("AMA") and the resulting threat to the sustainability of water supplies in the area.

Q. WHAT IS THE STATUS OF THE COMPANY'S PINAL VALLEY RECHARGE AND RECOVERY FACILITY?

A. On March 12, 2014, Company engineers prepared a Request for Proposal ("RFP") from qualified hydrogeological and engineering firms. After an extensive review of the proposals and interviewing the individuals who would be responsible for the project analysis, modeling, application, permitting and design, the Company selected the team of Clear Creek and Associates and Carollo Engineers to complete the necessary work.

The project commenced on May 21, 2014, and on December 19, 2014, the Company completed and submitted to ADWR its Application to Construct an Underground Storage Facility and a Water Storage Permit. On May 28, 2015, ADWR notified the Company that it had completed its review of the Company's applications and supporting analyses and determined that both applications were Administratively Complete. Copies of the Company's application to construct the Pinal Valley recharge and recovery facility, water storage permit are included in Exhibit FKS-4. Copy of ADWR's determination is included in Exhibit FKS-5.

Q. WHAT IS THE NEXT STEP?

A. Because ADWR determined the applications are administratively complete, ADWR provided a public notice to surrounding landowners and regulatory agencies and published the notice in the local newspaper. The last of these notices were published on June 4, 2015 and on June 11, 2015. The public comment period closed on June 26, 2015. Once the Company receives ADWR's comments, the Company will proceed with a 60-day pilot recharge project to verify and validate the study's recharge estimates.

Q. HAS THE COMPANY COORDINATED WITH THE CENTRAL ARIZONA WATER CONSERVATION DISTRICT ("CAWCD") AND CAP TO CONSTRUCT THE NECESSARY FACILITIES TO CONVEY CAP WATER TO THE RECHARGE BASINS?

A. Yes. The Company has met with CAWCD and CAP to discuss the necessary facilities necessary and how the Company will utilize the facilities to recharge and recover CAP water. The Company will submit its preliminary design to CAWCD and CAP in September 2015.

Q. HOW IS THE COMPANY PLANNING TO DELIVER WATER FROM THE CAP CANAL TO THE RECHARGE BASINS?

A. The Company has studied the hydraulics of conveying water from the CAP canal to the recharge basins and determined that water can be conveyed from the CAP canal to the recharge basins by gravity and without the use of large pumps and pumping equipment. In the company's effort to minimize the long term cost of recharging CAP water, it determined that water can be siphoned from the canal and then conveyed through a 24-inch transmission main to the recharge basins without continuous pumping, thereby reducing construction, operating, and maintenance costs.

Q. WHAT IS THE COMPANY'S SCHEDULE TO COMPLETE PINAL VALLEY RECHARGE AND RECOVERY FACILITY?

A. A detailed design, permitting, construction and start-up schedule is included as Exhibit FKS-6. The company's schedule is summarized in the following table:

Pinal Valley Recharge and Recovery Facility Schedule Summary	
ACTIVITY	**DURATION**
ADWR Permitting	Nine months ending September 2015.
Facility Design and CAP Permitting	Nine months. Begin July 2015 and complete April 2016.
Bidding	Solicit bids May 2016.
Award of Contract	June 2016.
Construction	Six months with a completion date of December 2016.

Q. HOW WILL THE COMPANY FUND THE PINAL VALLEY RECHARGE AND RECOVERY FACILITY?

A. The Company is funding the design and construction of the Pinal Valley Recharge and Recovery Facility primarily with offsite facility fees, which are recorded as contributions in aid of construction and excluded from rate base, thereby keeping customer rates low.

Q. DOES THE COMPANY HAVE THE NECESSARY PERMITS IN PLACE TO STORE CAP WATER GROUNDWATER SAVINGS FACILITIES REFERENCED IN MR. GARFIELD'S TESTIMONY?

A. Yes. On August 22, 2014, the Company received the necessary ADWR Water Storage Permits. Those permit numbers are shown below.

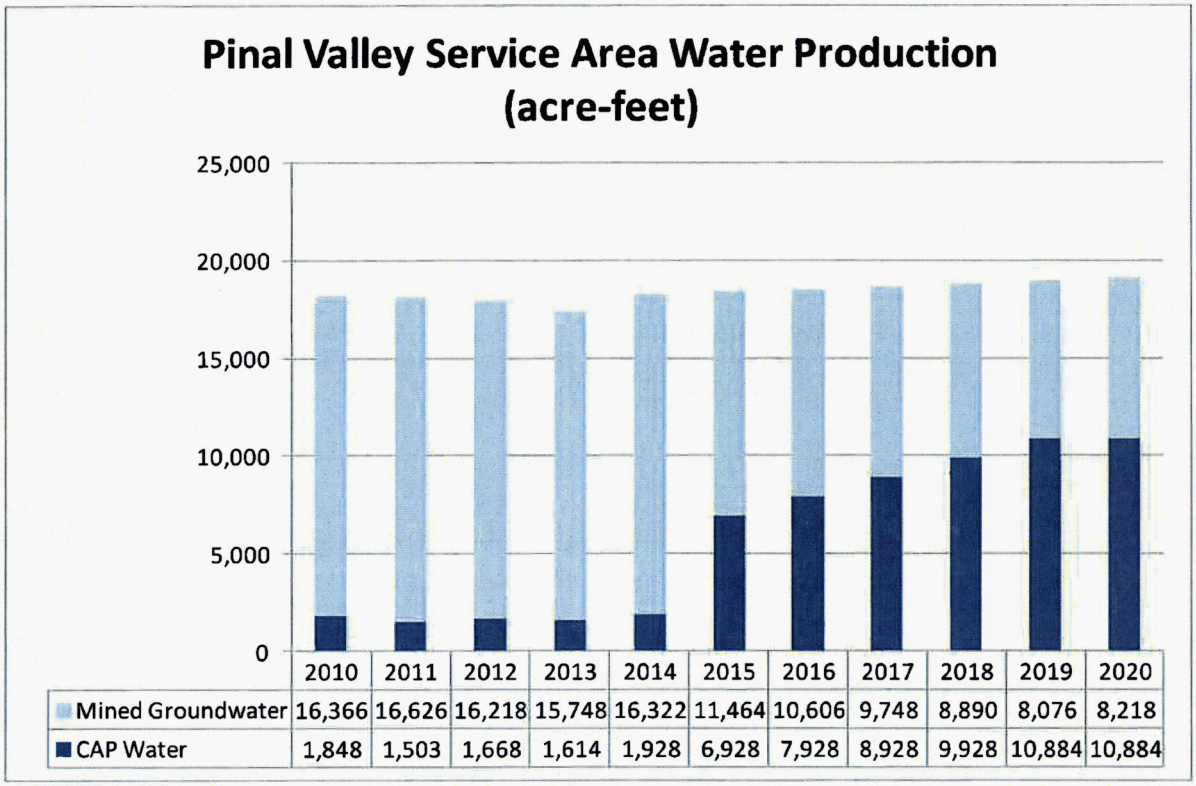
Groundwater Savings Facility	ADWR Water Storage Permit Number
CAIDD	73-531382.0700
MSIDD	73-531381.0700
HIDD	73-534489.0800

Q. WHAT EFFECT WILL RECHARGE AND RECOVERY HAVE ON GROUNDWATER PUMPING UNDER THE PINAL VALLEY 2015 CAP USE PLAN?

A. The Company's 2014 Pinal Valley service area water production totaled 18,214 acre-feet, with pumped groundwater making up nearly 90% of all water

production. Implementing the Pinal Valley 2015 CAP Use Plan will increase the amount of CAP water used through recharge and recovery delivered to customers, thereby reducing the amount of mined groundwater pumped by 50%, as shown below:

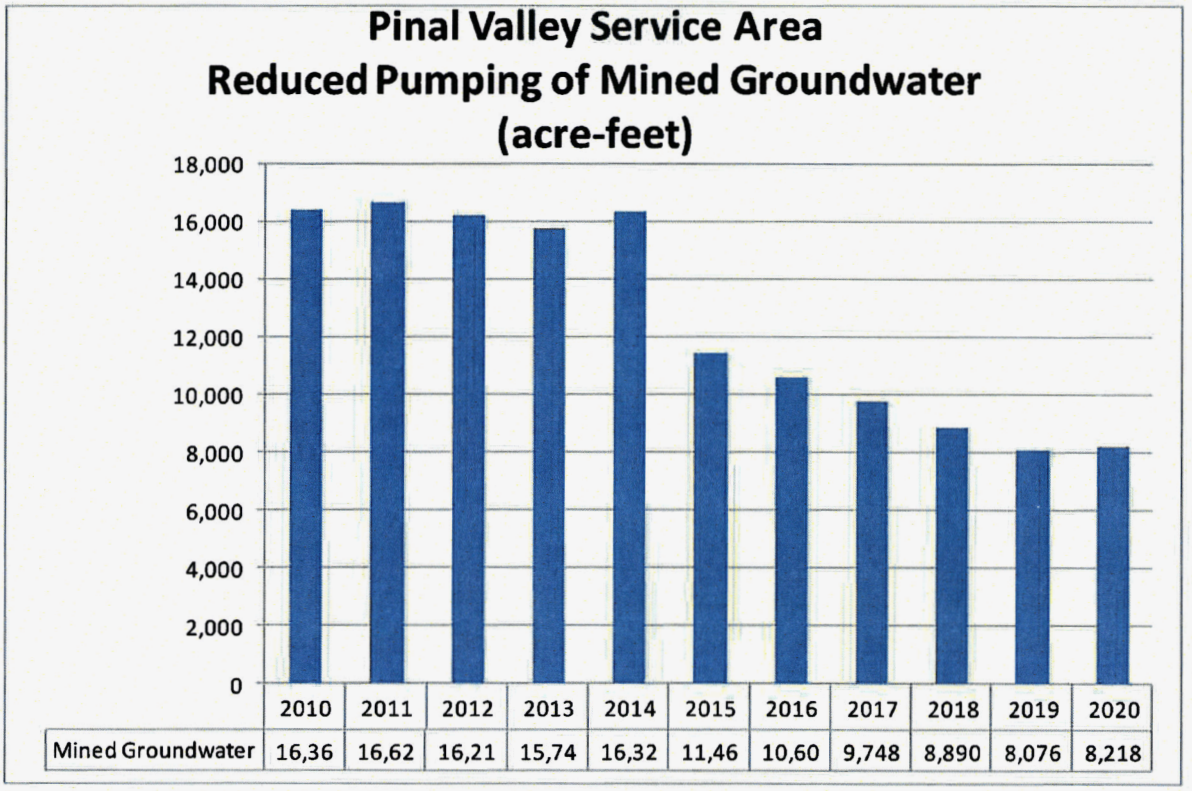
Figure 2 – 3 Pinal Valley Service Area Water Production



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mined Groundwater	16,366	16,626	16,218	15,748	16,322	11,464	10,606	9,748	8,890	8,076	8,218
CAP Water	1,848	1,503	1,668	1,614	1,928	6,928	7,928	8,928	9,928	10,884	10,884

Under the Pinal Valley 2015 CAP Use Plan, the Company will reduce pumping of mined groundwater by over 8,000 acre-feet by 2019, as shown below.

Figure 2 – 4 Pinal Valley Service Area Groundwater Pumping Reduction



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mined Groundwater	16,36	16,62	16,21	15,74	16,32	11,46	10,60	9,748	8,890	8,076	8,218

Over the next ten years, the Company will recharge nearly 8,000 acre-feet of CAP water per year, saving nearly 80,000 acre feet of groundwater by 2024.

Q. WHAT IS MINED GROUNDWATER?

A. Mined groundwater is the withdrawal or removal of groundwater over a period of time that exceeds the recharge rate of the supply aquifer.

Q. DOES MINING GROUNDWATER CAUSE PROBLEMS?

A. Mining groundwater over a long duration can cause several problems. Mining groundwater can lead to land subsidence and earth fissures. On August 12, 2015, the Arizona Republic published an article regarding an Arizona State University study, in cooperation with ADWR, evaluating the efforts of mining groundwater. ADWR stated that "Land subsidence has been happening in

Arizona since the early 1900s with parts of Maricopa and Pinal Counties subsiding more than 18 feet since then".[4] The study also concluded that fissures can threaten canals, utility lines, water mains, storm drains and sewers. A copy of the Arizona Republic article in included in Exhibit FKS-7.

Q. HOW DOES THE COMPANY PLAN TO RECOVER STORED CAP WATER?

A. The Company will initially recover stored CAP water through its 39 existing wells located throughout the Pinal Valley service area. As the area near the recharge and recovery site develops, the Company plans to recover stored CAP water from recovery wells constructed at or near the recharge and recovery site. The Company will then deliver that water to the Pinal Valley service area through a 36-inch transmission main. The Company will construct on-site recovery wells as needed to satisfy water system production needs and to meet recovery objectives as previously shown in Figures 2-3 and 2-4.

Q. HAS THE COMPANY APPLIED FOR AND RECEIVED RECOVERY WELL PERMITS FROM ADWR?

A. Yes. On June 9, 2015, ADWR issued Recovery Well Permit No. 74-224234.0000 permitting the Company's 39 Pinal Valley service area wells as recovery wells. A copy of the recovery well permit is included in Exhibit FKS-8.

Q. WAS THE COMPANY'S RECHARGE AND RECOVERY PLAN ADOPTED BY ANY PUBLIC AGENCIES?

A. Yes. The City of Coolidge incorporated the Company's Pinal Valley Recharge and Recovery Facility into the City of Coolidge 2025 General Plan Update dated June 23, 2014. A copy of the City of Coolidge 2025 General Plan Update in included in Exhibit FKS-9.

[4] Arizona Republic Article, August 12, 2015 ASU Study: Parts of metro Phoenix area are sinking, Anne Ryman.

Q. HOW AND WHEN WAS THE PLAN ADOPTED?

A. The City of Coolidge Planning and Zoning Commission approved the 2025 General Plan Update on May 7, 2014. The City Council approved the plan on June 23, 2014 and the voters approved the plan on November 4, 2014.

B. <u>White Tank Service Area</u>

Q. HOW MUCH CAP WATER DOES THE COMPANY HAVE UNDER SUBCONTRACT WITH THE CAP FOR USE IN THE WHITE TANK SERVICE AREA?

A. The Company holds a CAP allocation totaling 968 acre-feet per year for its White Tank service area.

Q. HAS THE COMPANY OUTLINED A PLAN TO PUT THE UNUSED PORTION OF ITS WHITE TANK CAP ALLOCATION TO USE?

A. Yes. The Company's plan is outlined in the White Tank 2015 CAP Use Plan, filed in this docket on August 7, 2015.

As explained in the White Tank 2015 CAP Use Plan, the Company has developed a far less costly and more efficient means of delivering much needed CAP water to customers in the White Tank service area.

Q. HOW DOES THE COMPANY PLAN TO DELIVER CAP WATER TO CUSTOMERS IN THE WHITE TANK SERVICE AREA?

A. The Company plans to deliver CAP water to its customers through recharge and recovery. The estimated construction cost related to the Company's White Tank recharge and recovery facility is $2.6 million, making it a practical, cost-effective alternative to treatment and direct delivery of CAP water.

Q. WILL THE COMPANY ACHIEVE ANY COST SAVINGS UNDER THE WHITE TANK 2015 CAP USE PLAN?

A. Yes. The Company's White Tank 2015 CAP Use Plan achieves the following cost savings:

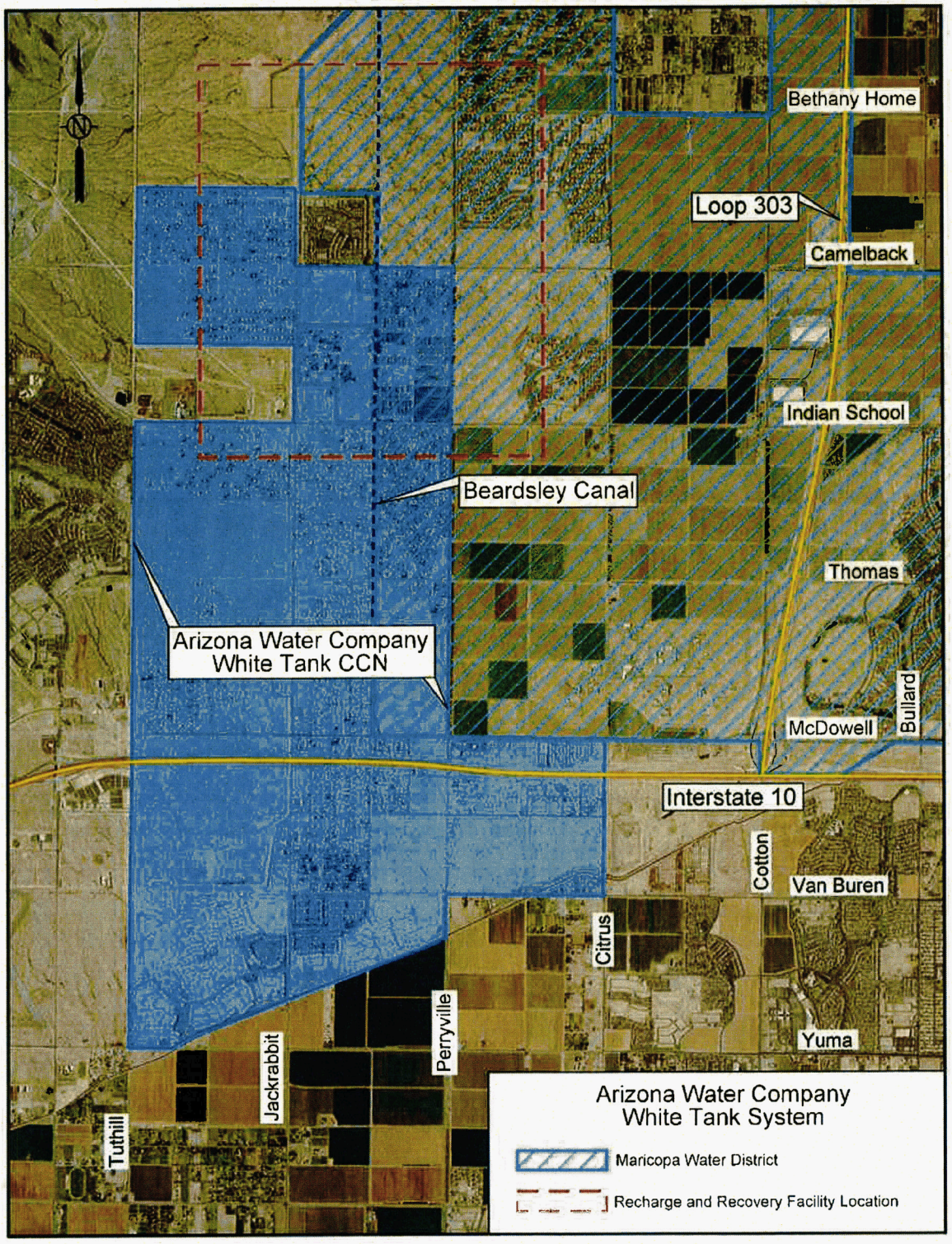
- Construction cost savings of $8.6 million

- Operating cost savings of $180,000 per year
- Customer savings of $1.6 million per year
- Residential customer savings of more than $33 per month or a savings of 77 percent

Q. WHAT IS THE STATUS OF THE COMPANY'S WHITE TANK RECHARGE AND RECOVERY PROJECT?

A. Company engineers completed the conceptual design and facility sizing of the White Tank CAP recharge and recovery facility. Also, Company engineers identified several sites in or near the Company's White Tank water system. A map showing the possible locations of the White Tank recharge and recovery facility is shown below in Figure 2-5. A conceptual plan showing the recharge basins and the facility's connection to the Maricopa Water District Canal is shown below in Figure 2-6. The Company's facility sizing, estimated cost of construction and annual operation and maintenance cost are included in Exhibit FKS-10.

Figure 2 – 5 White Tank Recharge and Recovery Facility Proposed Location



Q. HOW IS THE COMPANY PLANNING TO DELIVER WATER FROM THE CAP CANAL TO ITS RECHARGE BASINS?

A. Company engineers evaluated options and determined that working with Maricopa Water District ("MWD") to wheel the Company's CAP water, using MWD's existing canal, is the most cost-effective solution. Company engineers discussed this possibility with MWD, and MWD representatives have indicated their support.

Q. HOW WILL THE COMPANY FUND THE WHITE TANK RECHARGE AND RECOVERY FACILITY?

A. The Company is planning to fund the design and construction of the White Tank Recharge and Recovery Facility primarily with offsite facilities fees, which are recorded as contributions in aid of construction and excluded from rate base, thereby keeping customer rates low.

Q. DOES THE COMPANY HAVE AN OFFSITE FACILITIES FEE FOR THE WHITE TANK SERVICE AREA?

A. No. However, the Company is requesting Commission approval of a new off-site facilities fee for the White Tank service area, as discussed in more detail by Mr. Harris in Section V of his direct testimony.

Q. WHAT IS THE AMOUNT OF THE COMPANY'S PROPOSED OFF-SITE FACILITIES FEE?

A. As discussed in Section V of Mr. Harris' direct testimony, the proposed off-site facilities fee tariff is $2,500 for each new service connection with a 5/8 x 3/4-inch meter. The amount of the Facilities Fee increases for larger meter sizes. The proposed Off-Site Facilities Fee tariff is included in Mr. Harris' direct testimony as Exhibit JDH-6.

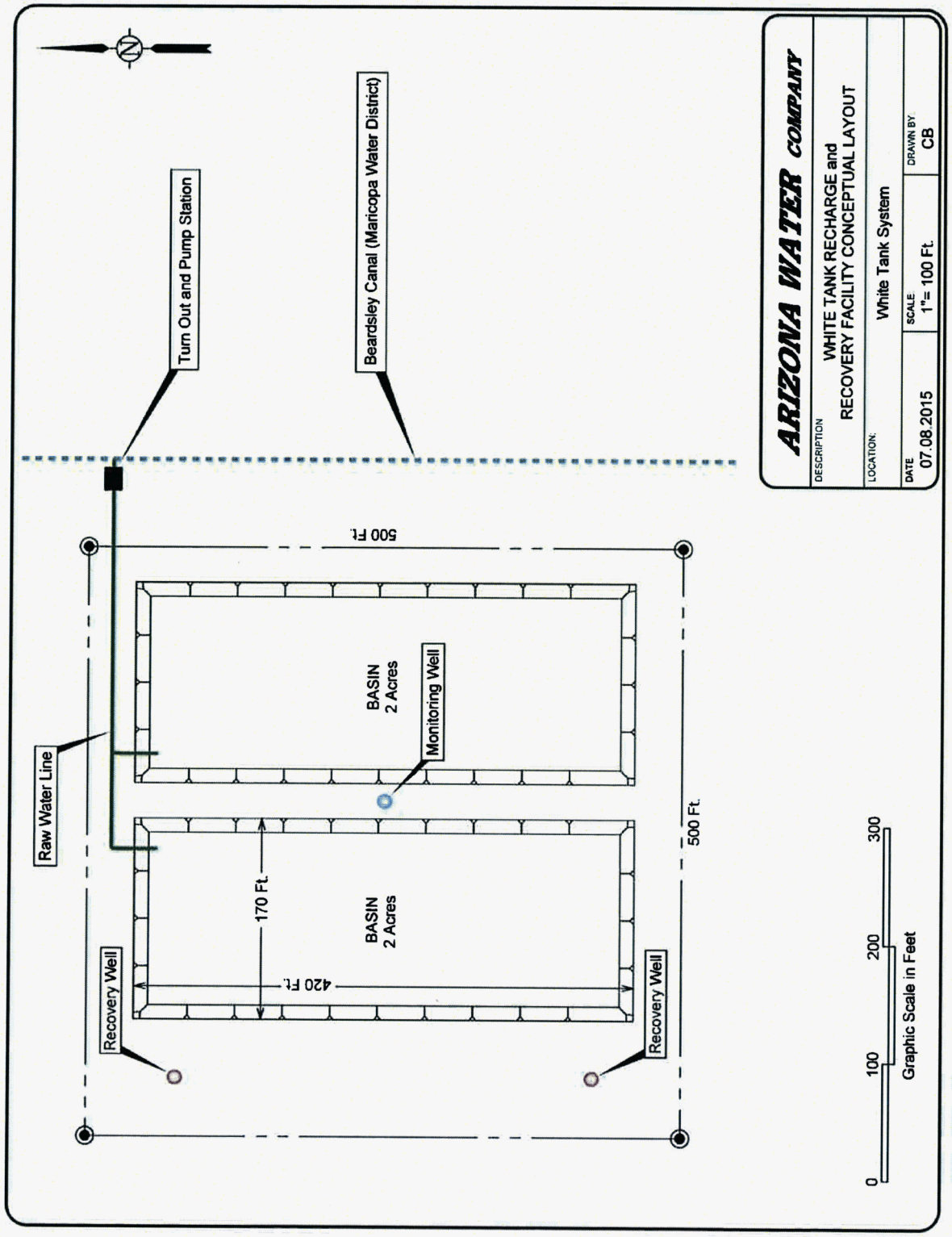
Q. WHAT IS THE COMPANY'S SCHEDULE TO COMPLETE THE RECHARGE BASINS?

A. A detailed design, permitting, construction and start-up schedule for this work is included as Exhibit FKS-11. In summary, the Company's schedule is shown below.

White Tank Recharge and Recovery Facility Schedule Summary	
ACTIVITY	**DURATION**
Real Property Acquisition	9 months after approval of the Company's requested Off-Site Facilities Fee.
ADWR Permitting	9 months.
Facility Design and MWD Permitting	9 months.
Bidding and award of contract	2 months.
Construction	6 months.
	Total Duration = 35 months

If the funds from the offsite facilities fees will not fund the project based on the above schedule, the Company proposes to fund the necessary construction using Company funds and collect post in-service AFUDC until sufficient offsite facilities fees are collected. This is discussed in more detail in Section V of Mr. Harris' testimony.

Figure 2 – 6 White Tank Recharge and Recovery Facility Conceptual Plan



Q. DOES THE COMPANY HAVE THE NECESSARY PERMITS IN PLACE TO STORE CAP WATER IN MARICOPA WATER DISTRICT'S GROUNDWATER SAVINGS FACILITY DESCRIBED IN MR. GARFIELD'S TESTIMONY?

A. Yes. On August 22, 2014, the Company received the necessary ADWR Water Storage Permit, permit No. 73-558246.1500.

Q. WHAT ELSE HAS THE COMPANY DONE TO PREPARE TO STORE CAP WATER FOR THE WHITE TANK WATER SYSTEM?

A. On April 7, 2015, per the Company's request, CAWCD sent the Company a letter stating that CAWCD consents to allow the Company to store its CAP Water at both the CAWCD Agua Fria Constructed Recharge Project and their Hieroglyphic Mountains Recharge Project. On May 1, 2015, the Company applied for the necessary ADWR Water Storage Permit to store CAP Water at both of these recharge sites. On June 5, 2015, the Company sent CAP a Letter of Intent to store the Company's CAP Water at two existing facilities owned by CAWCD. On June 16, 2015, ADWR determined the Company's Agua Fria permit was administratively complete. On June 19, 2015, ADWR determined the Company's Hieroglyphic Mountain permit was administratively complete. This provides the Company with several options to store CAP water until the Company's White Tank Recharge and Recovery Facility is complete.

Q. WHAT EFFECT WILL RECHARGE AND RECOVERY HAVE ON FUTURE WATER SUPPLIES UNDER THE COMPANY'S 2015 CAP USE PLAN?

A. The Company's 2014 water production in its White Tank system totaled 1,319 acre-feet, with pumped groundwater making up 100% of all water production, as shown below in Figure 2-7. Implementing the White Tank 2015 CAP Use Plan will begin recharging, recovering and delivering of CAP water to customers, thereby reducing the need to pump mined groundwater by 55%, as shown below. The Company will reduce its pumping of mined groundwater by 968 acre-feet by 2020, as shown below in Figure 2-8.

Figure 2 – 7 White Tank Service Area Water Production

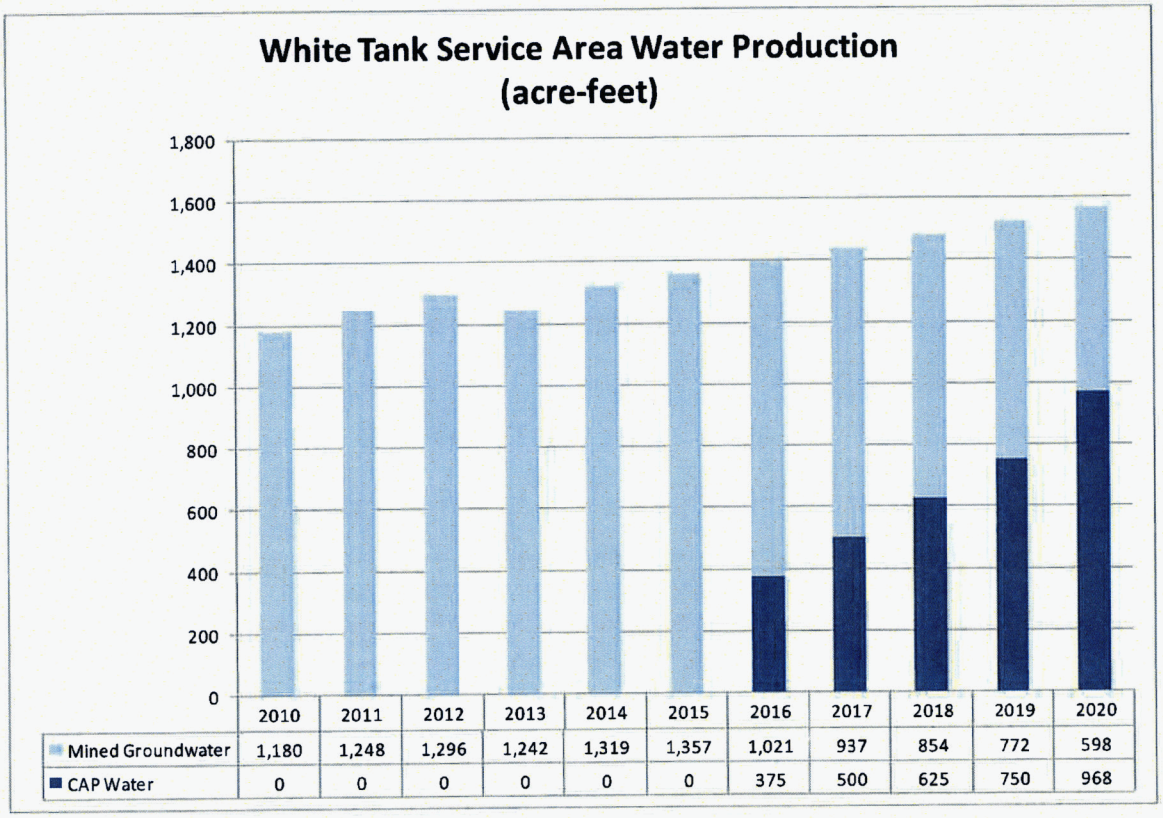
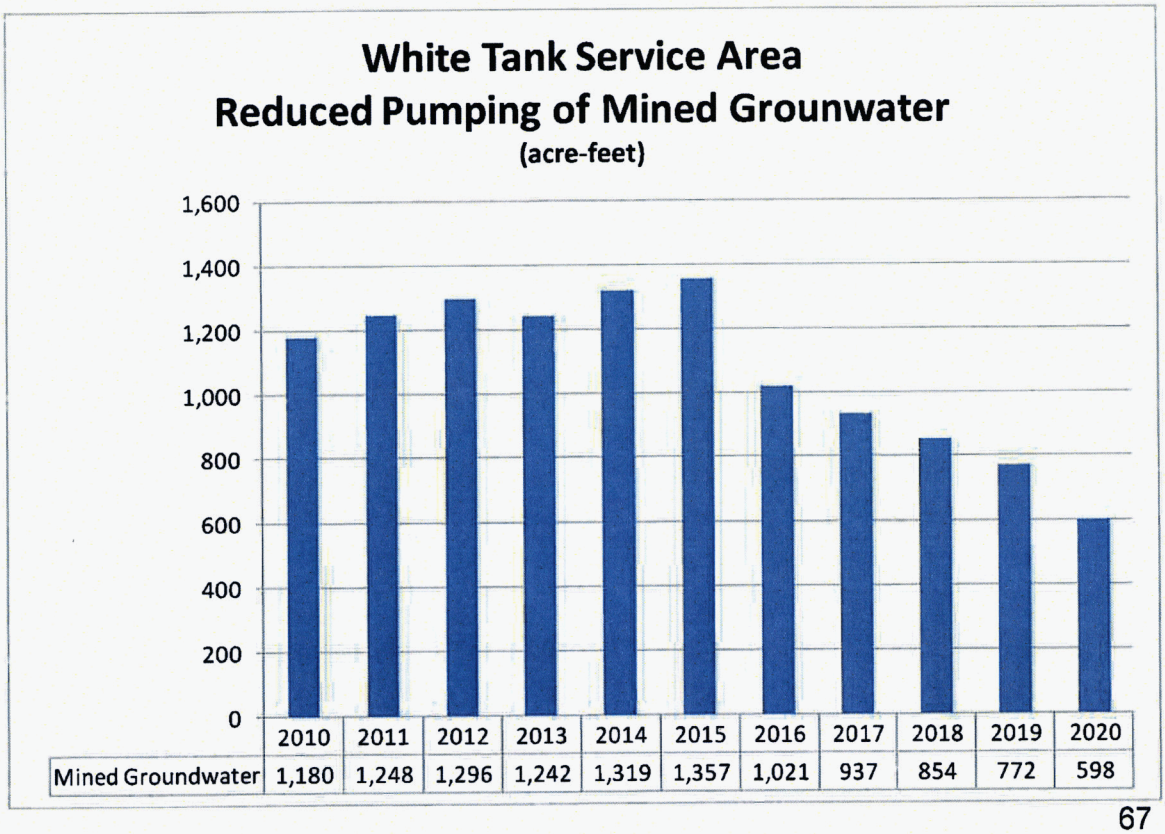


Figure 2 – 8 White Tank Service Area Groundwater Pumping Reduction



Over the next ten years, the Company will recharge nearly 800 acre-feet of CAP water per year, and by 2024, will have saved nearly 8,000 acre feet of groundwater under this plan.

Q. HOW DOES THE COMPANY PLAN TO RECOVER STORED CAP WATER?

A. The Company will initially recover stored CAP water from any of its seven existing wells located throughout the White Tank service area. As the White Tank recharge and recovery site develops, the Company plans to recover stored CAP water from additional recovery wells at the recharge and recovery site. The Company will construct on-site recovery wells as needed to satisfy water system production needs and to meet recovery objectives as shown in Figures 2-7 and 2-8.

Q. HAS THE COMPANY APPLIED FOR RECOVERY WELL PERMITS FROM ADWR?

A. Yes. On May 12, 2015, the Company applied for the necessary ADWR permits to permit all seven of the Company's existing White Tank service area wells as recovery wells.

Q. DOES THE COMPANY PLAN TO FUND THE CONSTRUCTION OF ADDITIONAL RECOVERY WELLS WITH OFF SITE FACILITIES FEES?

A. Yes. The Company intends to use funds from its proposed off-site facilities fee to fund additional recovery wells as well as transmission and distribution mains, storage tanks and booster stations needed to pump treat, store, and ultimately provide safe, reliable and adequate water service and to transition to sustainable supplies.

VIII. Aging Infrastructure and the Need for a System Improvement Benefits Mechanism ("SIB")

Q. DID THE COMMISSION ESTABLISH A WATER LOSS STANDARD FOR THE COMPANY?

A. Yes. In Decision No. 71845. The Commission ordered the Company to reduce water loss for each of its water systems to less than ten percent.

Q. HAVE YOU REVIEWED WATER LOSS FOR THE COMPANY'S WESTERN GROUP OF WATER SYSTEMS?

A. Yes. As of December 2014, water loss in the Company's Western Group of water systems remains below the Commission-mandated ten percent limit. Water loss for each of the six Western Group water systems is shown in the following table:

Water Loss for each Western Group of Water Systems			
System	**PWS ID No.**	**Calendar Year 2013 Reported Water Loss**	**Calendar Year 2014 Reported Water Loss**
Ajo	10-003	6.14%	5.98%
Coolidge Airport	11-707	21%	5.11%
Pinal Valley	11-009	8.32%	9.26%
Tierra Grande	11-076	5.55%	3.96%
Stanfield	11-012	7.24%	6.18%
White Tank	07-128	3.40%	4.24%

Q. IS THE COMPANY COMPLYING WITH THE COMMISSION'S ORDER?

A. Yes. As shown in the table above, all water systems in the Western Group have water loss less than ten percent.

Q. DOES THE COMPANY'S WESTERN GROUP OF WATER SYSTEMS HAVE A SIB?

A. No. In the Company's previous Western Group rate case, the Commission did not authorize a SIB. However, in the Company's most recent Eastern and Northern Group rate case proceedings, the commission approved and authorized a SIB.

Q. IS THE COMPANY REQUESTING A SIB MECHANISM IN THIS PROCEEDING FOR ITS WESTERN GROUP OF WATER SYSTEMS?

A. Yes.

Q. WHY IS A SIB NECESSARY FOR THE WESTERN GROUP OF WATER SYSTEMS WHEN WATER LOSS IS LESS THEN 10 PERCENT?

A. Water loss in those water systems is trending upward as shown in the above table. It is more efficient and cost effective to keep water loss below ten percent by replacing aging infrastructure in a timely fashion rather than let water loss increase above ten percent before beginning to replace failing infrastructure. The Company's plan identified the need to increase the rate of replacing aging infrastructure, however this level of investment will have a significant negative effect on the Company's financial performance without the SIB mechanism that the Commission developed to allow water utilities to recover a portion of the cost of these replacements on a more timely basis.

Q. HAVE YOU PREPARED AN ANALYSIS OF AGING INFRASTRUCTURE IN THE WESTERN GROUP?

A. Yes. The Company prepared "Aging Infrastructure Replacement Plan for the Company's Western Group of Water Systems" in 2015, attached to this testimony as FKS-12, which provides a comprehensive analysis outlining the historical, current and anticipated future efforts and requirements to effectively replace aging infrastructure in the Company's Western Group of water systems. The analysis shows approximately 318,300 LF of water main, or approximately 7.3 percent of the mains in the Western Group of water systems are in need of replacement including 4,110 service lines. This analysis is based on a complete review of the documented water main and service line leak, break and repair history, summarized in Appendix 6.2 of Exhibit FKS-12. The specific replacement projects are identified in Appendix 6.3 of Exhibit FKS-12. The Company estimates that replacing these failing water mains and service lines will cost $55.8 million. Each year, as the number of water mains and service lines that exceed their useful service lives increases, so will the associated costs of

replacing the water mains and service lines, making it more difficult for the Company to keep up.

Q. WILL THESE WATER MAIN AND SERVICE LINE REPLACEMENTS HELP TO MAINTAIN WATER LOSS TO LESS THAN 10 PERCENT?

A. Yes. These projects replace aging and failing water mains and service lines, which are prone to leaks and breaks, with new infrastructure that is less susceptible to leaks. These waterline replacements are needed to reduce the rising costs of repairing leaks and comply with the Commission's order to keep water loss below ten percent. The Company is prepared to increase the rate of replacement of aging and failing water mains and service lines, but needs Commission's support and rate increases to do so.

Q. CAN THE COMPANY CURRENTLY FUND THE REPLACEMENT OF AGING INFRASTRUCTURE NEEDED TO MANAGE WATER LOSS TO LESS THAN 10 PERCENT?

A. No. Not without adequate rate relief and not without an effective cost-recovery mechanism such as the SIB mechanism, which the Commission adopted in the Company's Eastern and Northern Group rate cases. This is discussed in more detail in Mr. Garfield and Mr. Harris' direct testimony.

Q. HOW DOES THE COMPANY PLAN TO CONTINUE TO REPLACE AGING INFRASTRUCTURE?

A. By implementing the Commission adopted SIB mechanism. The SIB allows the Company to replace aging water mains and service lines as it becomes necessary, rather than waiting until the next test year. As with the SIB the Commission adopted in the Eastern and Northern Group rate cases, the SIB will allow the Company to limit water loss by replacing aging infrastructure in a cost effective and timely manner. The Western Group's need for the SIB mechanism is discussed in more detail in Mr. Garfield and Mr. Harris' direct testimony.

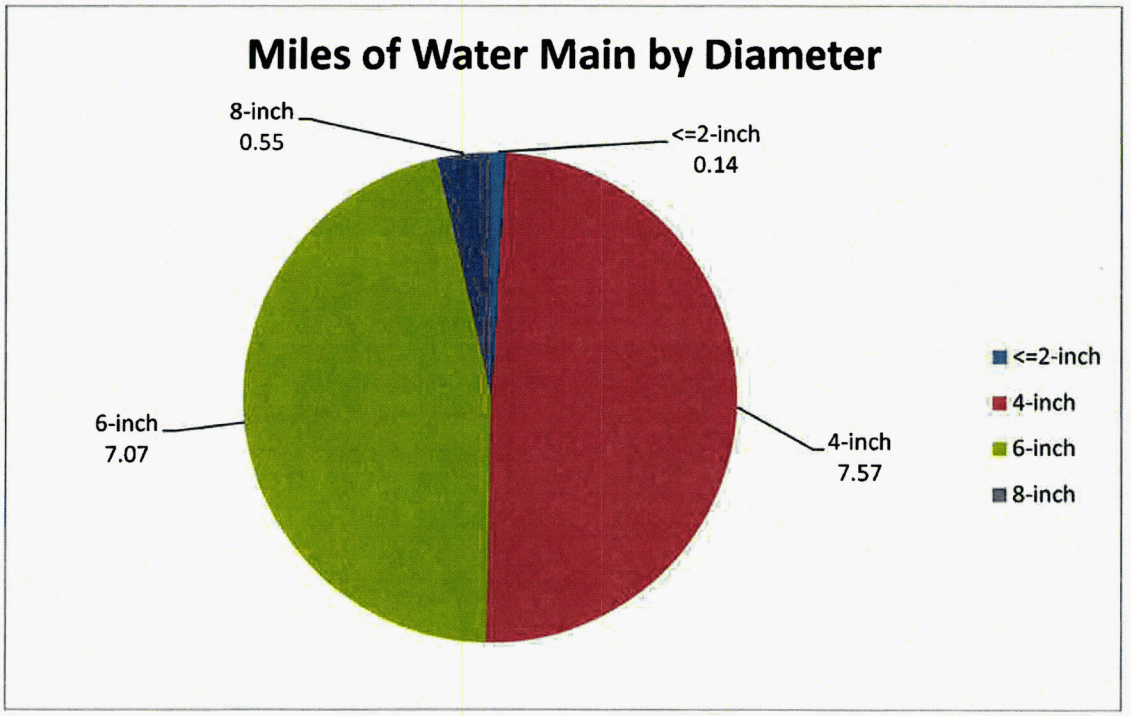
Q. THROUGH THE ANALYSIS OF AGING INFRASTRUCTURE COMPLETED BY THE COMPANY, WHAT WERE THE FINDINGS?

Ajo Service Area

The Ajo Service Area experienced a significant amount of customer growth during the 1960s and, with that growth, came the installation of a large number of cement asbestos ("CA") water mains as well as the installation of polybutylene and polyethylene ("poly") water service lines. Unfortunately, poly service lines have proven to become brittle and split longitudinally. Repairing this type of service line is difficult and normally leads to their full replacement when leaks are discovered. Planned service line replacements reduce or eliminate damage to asphalt roadways and concrete curb, gutter and sidewalk which significantly decreases the cost compared to unplanned replacements. Leaking service lines often damage asphalt roadways and concrete curb, gutter and sidewalks which increases the cost of the unplanned service line replacement. These unplanned service line replacements typically cost more than $10,000 each and can cost $60,000 or more if the leak occurred in ADOT right-of-way. Failing poly service lines are still in service and require replacement in the very near future. Without these replacements, water losses are expected to increase.

The following three sets of charts and tables show the miles of water mains in service size, material type and decade installed within the Ajo Service Area, respectively.

Ajo Service Area - Miles of Water Main by Diameter

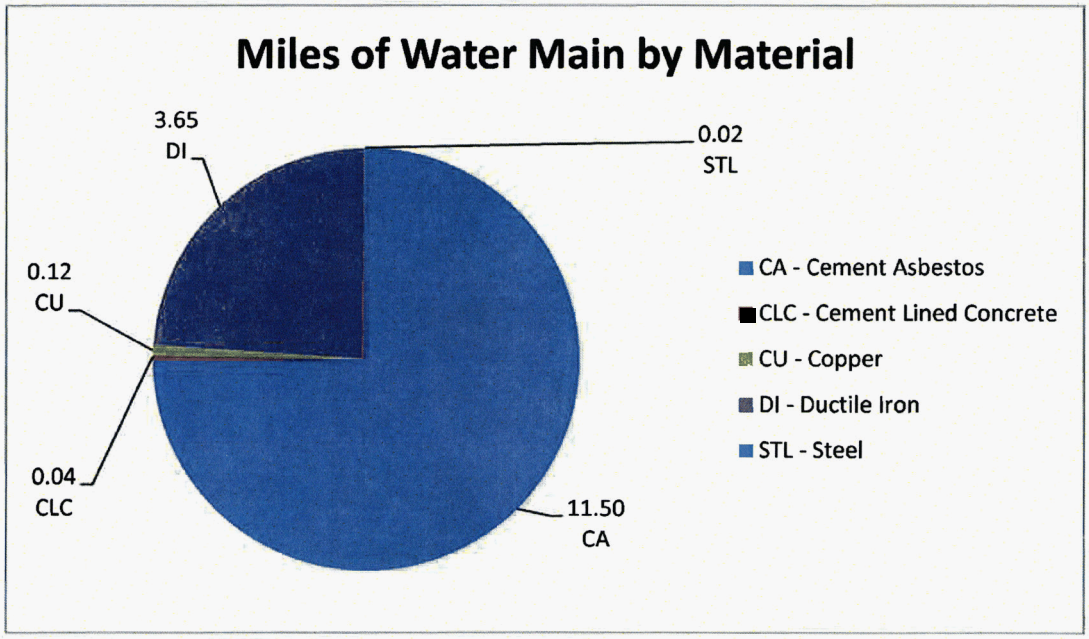


Diameter	Miles of Water Main
<=2-inch	0.14
4-inch	7.57
6-inch	7.07
8-inch	0.55

The table above shows that 8 miles or over 40,700 LF of water mains in service today are less than six inches in diameter.

The chart and table below show miles of water mains currently in service by material type. A majority of the water mains are CA.

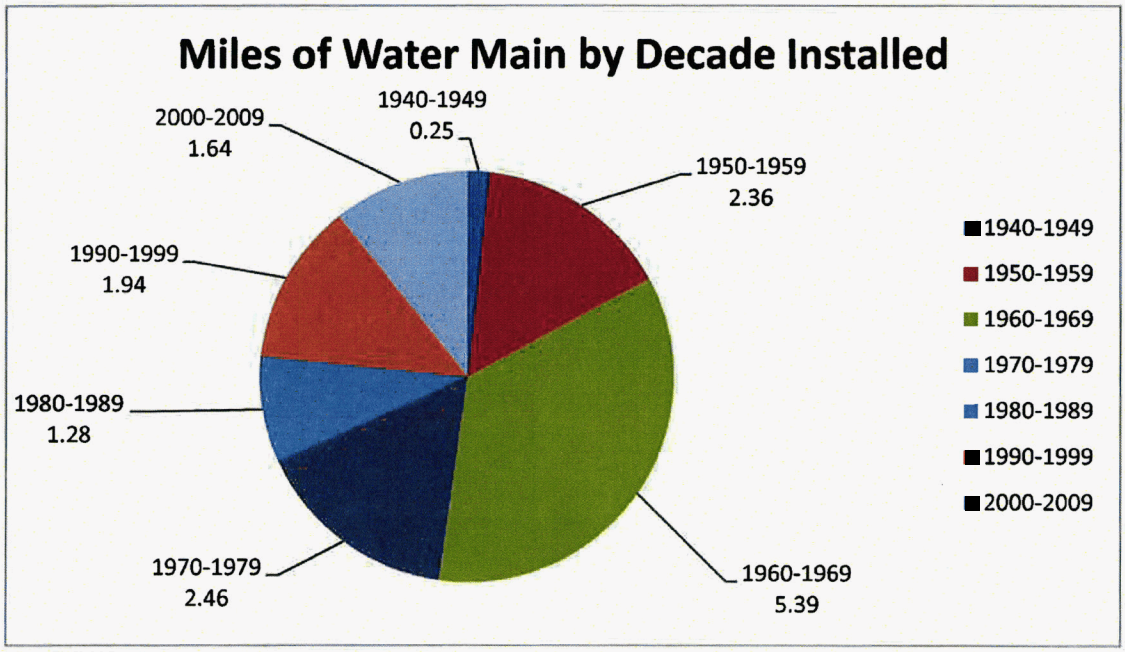
Ajo Service Area - Miles of Water Main by Material



Material Type	Miles of Water Main
Cement Asbestos	11.50
Cement Lined Concrete	0.04
Copper	0.12
Ductile Iron	3.65
Steel	0.02

The chart and table below show the miles of water mains installed by decade and still in service. Seventeen percent or nearly 14,000 LF of water mains currently in service were installed prior to 1960 and are over 55 years old. Much of these water mains are at or reaching the end of their useful service lives and require replacement in the future.

Ajo Service Area - Miles of Water Main by Decade Installed



Decade Installed	Miles of Water Main
1940-1949	0.25
1950-1959	2.36
1960-1969	5.39
1970-1979	2.46
1980-1989	1.28
1990-1999	1.94
2000-2009	1.64
2010-2019	0

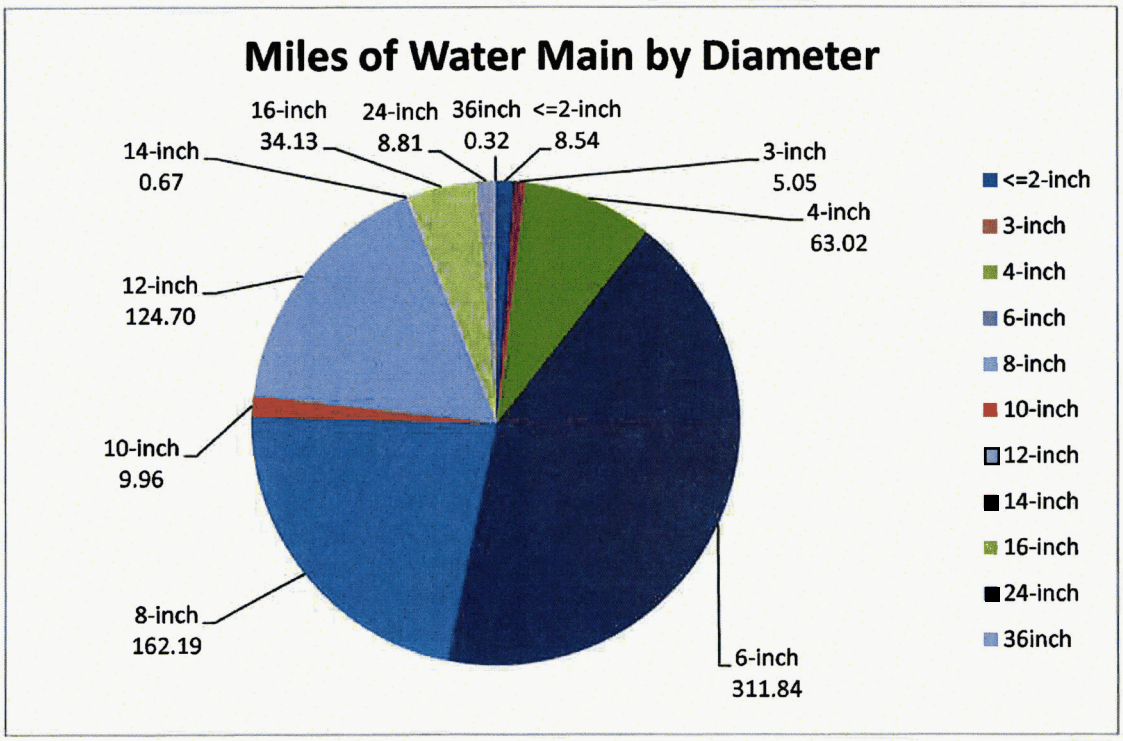
Pinal Valley Service Area

A review of the Pinal Valley Service Area shows that many of the water mains have been in service since the early 1920s, and are well past their useful service life. Many of these old water mains, some as small as 2-inch, do not comply with today's minimum standards. Because of their age and industry practices at the time, modern corrosion protection was not available when cast iron, galvanized steel and steel water mains were installed and, as a result, are susceptible to numerous leaks, which are difficult to detect, locate and repair.

The Pinal Valley Service Area experienced a significant amount of customer growth during the mid-1970s and, with that growth, came the installation of a large number of CA water mains as well as poly water service lines. Unfortunately, poly service lines have proven to become brittle and split longitudinally. Repairing this type of service line is difficult and normally leads to their full replacement when leaks are discovered. Planned service line replacements reduce or eliminate damage to asphalt roadways and concrete curb, gutter and sidewalk which significantly decreases the cost compared to unplanned replacements. Leaking service lines often damage asphalt roadways and concrete curb, gutter and sidewalks which increases the cost of the unplanned service line replacement. These unplanned service line replacements typically cost more than $10,000 each and can cost $60,000 or more if the leak occurred in ADOT right-of-way. Thousands of poly service lines are still in service and require replacement in the very near future. Without these replacements, water losses are expected to increase.

The following three sets of charts and tables show the miles of water main in service by size, material type and decade installed within the Pinal Valley Service Area, respectively.

Pinal Valley Service Area - Miles of Water Main by Diameter

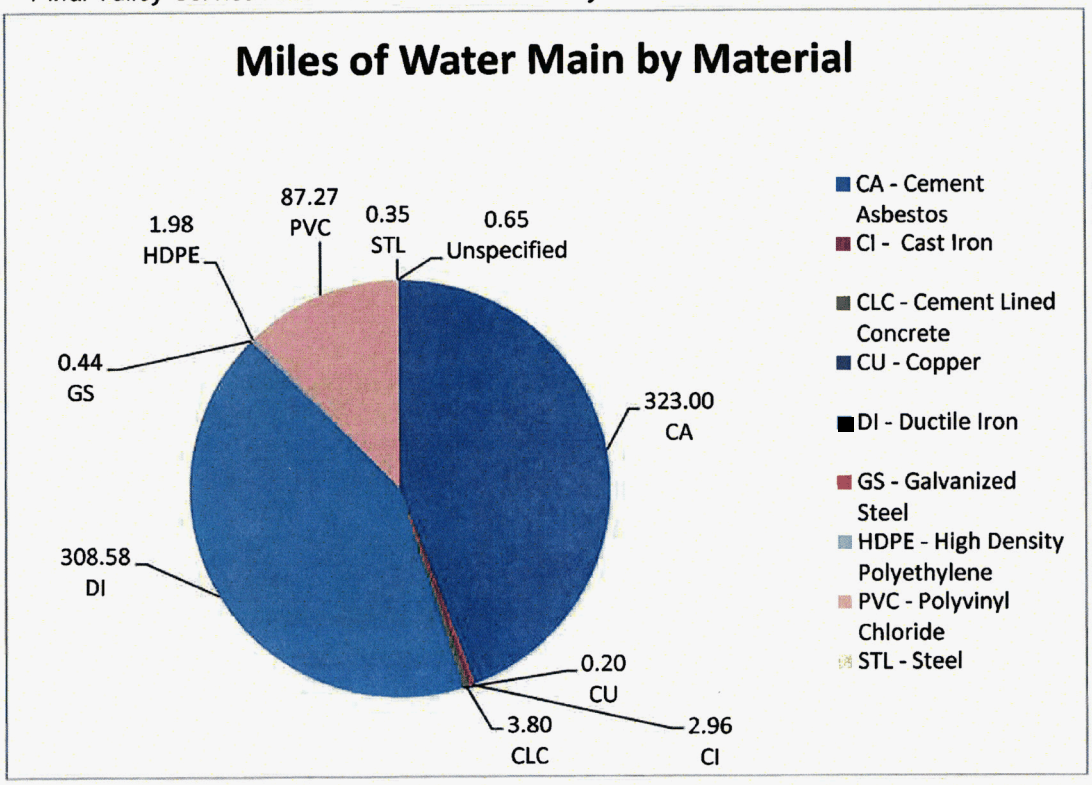


Diameter	Miles of Water Main	Diameter	Miles of Water Main
<=2-inch	8.54	12-inch	124.70
3-inch	5.05	14-inch	0.67
4-inch	63.02	16-inch	34.13
6-inch	311.84	24-inch	8.81
8-inch	162.19	36-inch	0.32
10-inch	9.96		

The table above shows that 77 miles or over 404,500 LF of water mains in service today are less than six inches in diameter.

The chart and table below show miles of water mains currently in service by material type. A majority of the water mains are CA. Nearly 20,000 LF of water mains are constructed of cast iron, galvanized steel and steel.

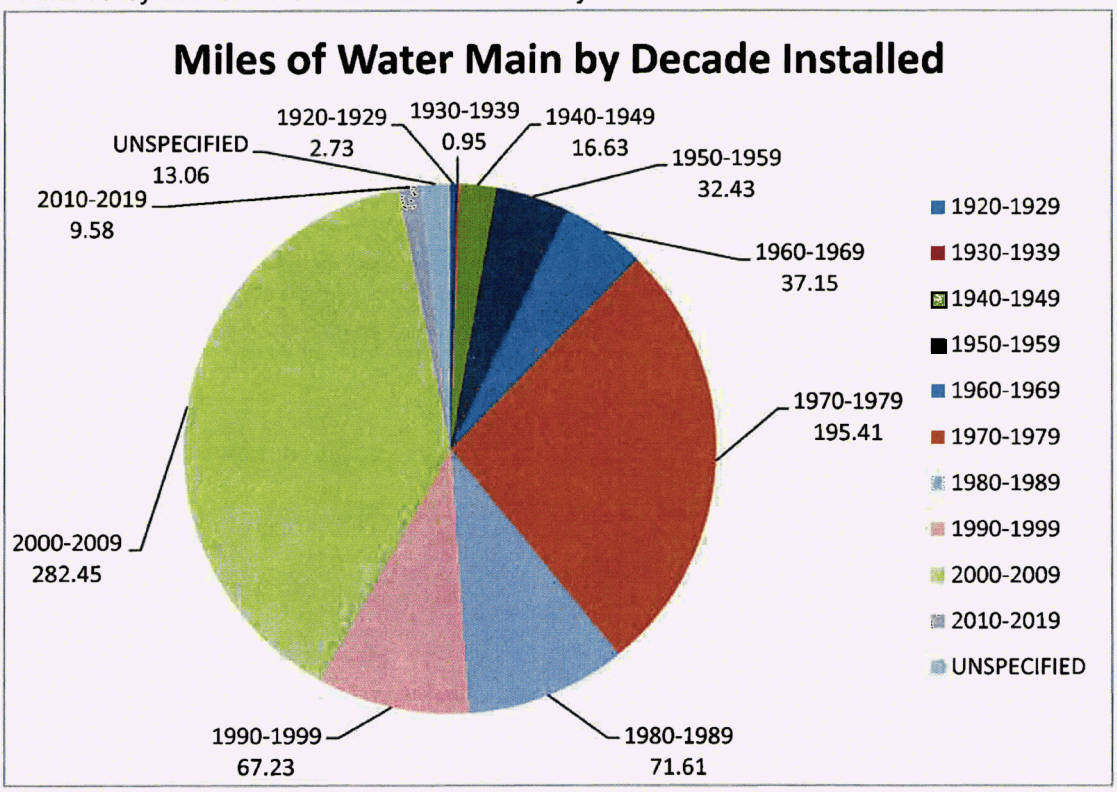
Pinal Valley Service Area - Miles of Water Main by Material



Material Type	Miles of Water Main	Material Type	Miles of Water Main
Cement Asbestos	323.00	Galvanized Steel	0.44
Cast Iron	2.96	High Density Polyethylene	1.98
Cement Lined Concrete	3.80	Polyvinyl Chloride	87.27
Copper	0.20	Steel	0.35
Ductile Iron	308.58	Unspecified	0.65

The chart and table below show the miles of water mains installed by decade and still in service. Three percent or over 107,000 LF of water mains currently in service, were installed prior to 1950 and are over 65 years old. Much of these water mains are at or reaching the end of their useful service lives and require replacement.

Pinal Valley Service Area - Miles of Water Main by Decade Installed



Decade Installed	Miles of Water Main	Decade Installed	Miles of Water Main
1920-1929	2.73	1980-1989	71.61
1930-1939	0.95	1990-1999	67.23
1940-1949	16.63	2000-2009	282.45
1950-1959	32.43	2010-2019	9.58
1960-1969	37.15	Unspecified	13.06
1970-1979	195.41		

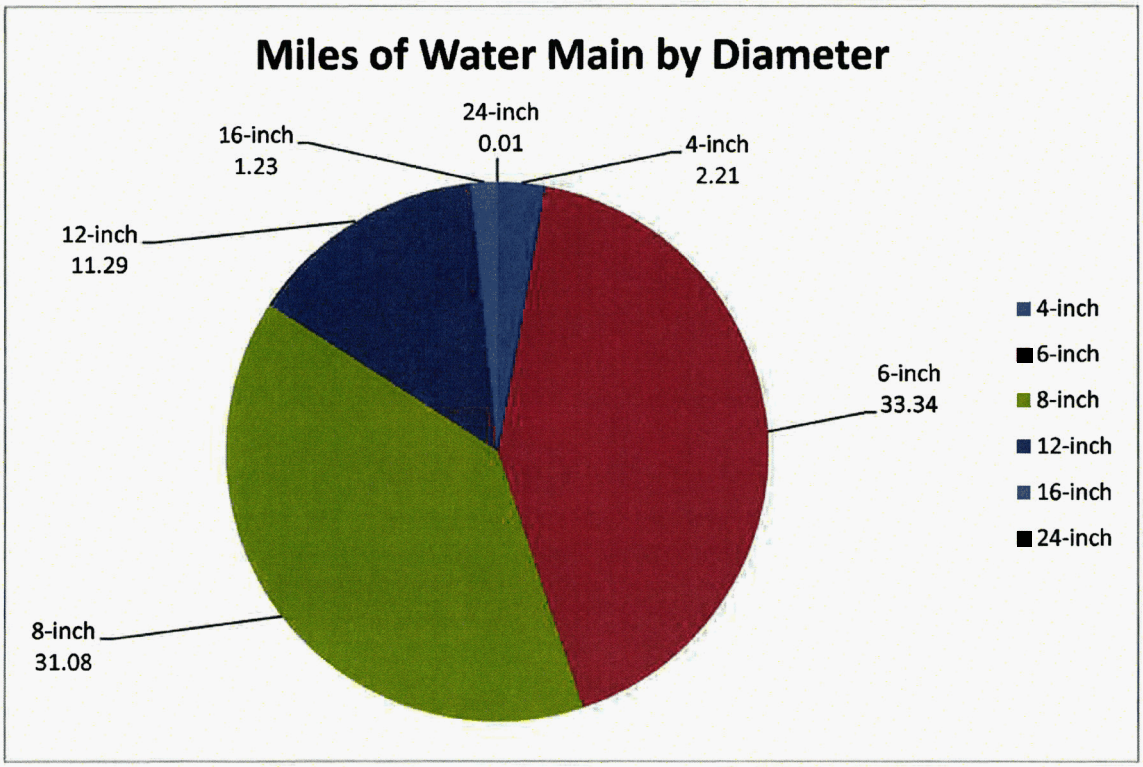
White Tank Service Area

The White Tank Service Area experienced a significant amount of customer growth during the mid-1970s and, with that growth, came the

installation of a large number of CA water mains as well as poly water service lines. Unfortunately, poly service lines have proven to become brittle and split longitudinally. Repairing this type of service line is difficult and normally leads to their full replacement when leaks are discovered. Planned service line replacements reduce or eliminate damage to asphalt roadways and concrete curb, gutter and sidewalk which significantly decreases the cost compared to unplanned replacements. Leaking service lines often damage asphalt roadways and concrete curb, gutter and sidewalks which increases the cost of the unplanned service line replacement. These unplanned service line replacements typically cost more than $10,000 each and can cost $60,000 or more if the leak occurred in ADOT right-of-way. It is estimated that several hundred poly service lines are still in service and require replacement in the very near future. Without these replacements, water losses are expected to increase.

The following three sets of charts and tables show the miles of water mains in service by size, material type and decade installed within the White Tank Service Area, respectively.

White Tank Service Area - Miles of Water Main by Diameter

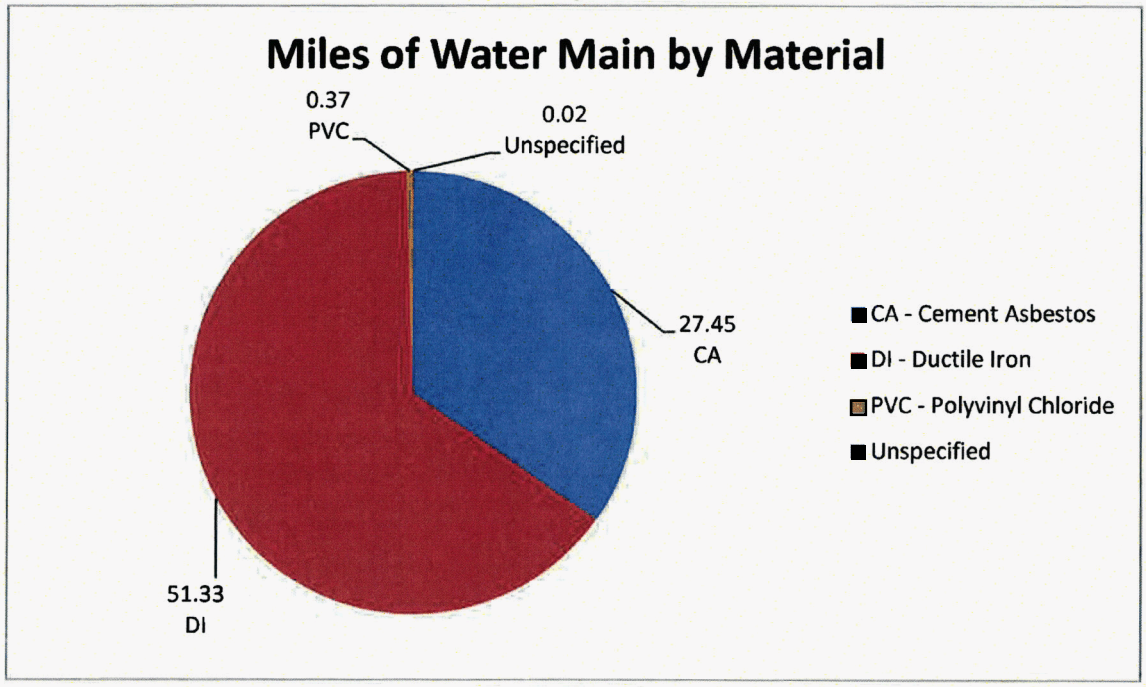


Diameter	Miles of Water Main
4-inch	2.21
6-inch	33.34
8-inch	31.08
12-inch	11.29
16-inch	1.23
24-inch	0.01

The table above shows that 2 miles or over 11,600 LF of water mains in service today are less than six inches in diameter.

The chart and table below show miles of water mains currently in service by material type. A majority of the water mains are either ductile iron or CA.

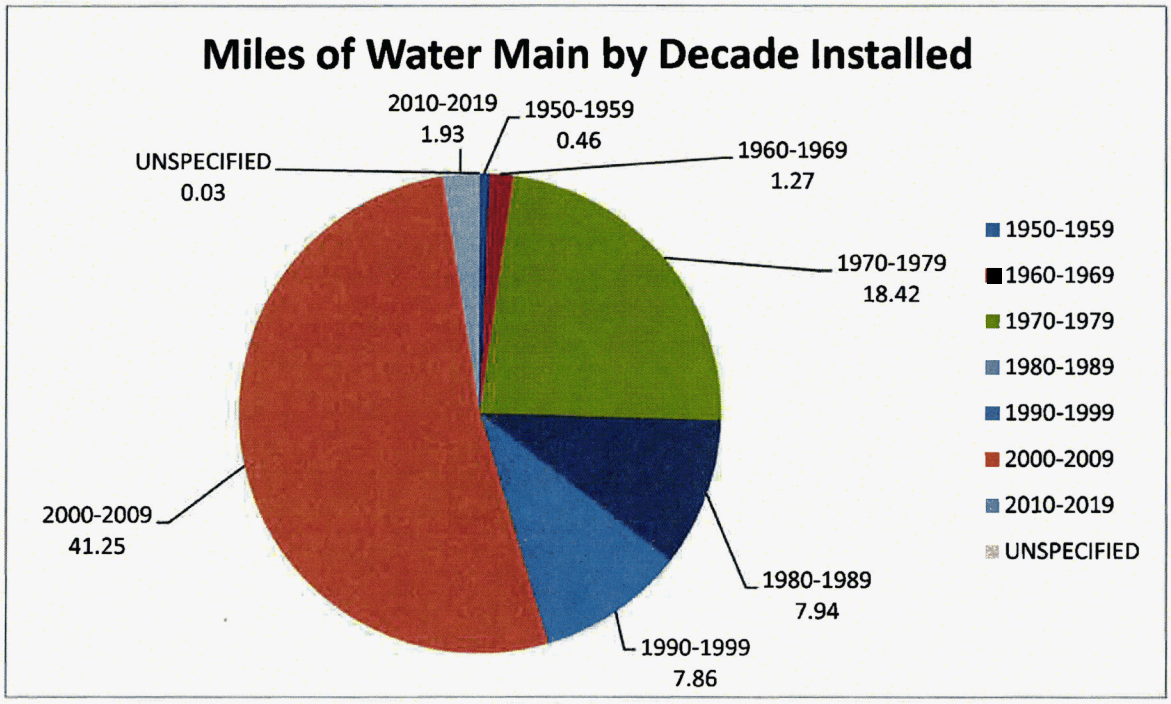
White Tank Service Area - Miles of Water Main by Material



Material Type	Miles of Main
Cement Asbestos	27.45
Ductile Iron	51.33
Polyvinyl Chloride	0.37
Unspecified	0.02

The chart and table below show the miles of water mains installed by decade and still in service. Two percent or over 9,000 LF of water mains currently in service, were installed prior to 1970 and are over 45 years old. Much of these water mains are at or reaching the end of their useful service lives and require replacement.

White Tank Service Area - Miles of Water Main by Decade Installed



Decade Installed	Miles of Water Main	Decade Installed	Miles of Water Main
1950-1959	0.46	1990-1999	7.86
1960-1969	1.27	2000-2009	41.25
1970-1979	18.42	2010-2019	1.93
1980-1989	7.94	Unspecified	0.03

Q. THE WESTERN GROUP OF WATER SYSTEMS STILL USE WATER MAINS DATING BACK TO THE EARLY 1920s, 1930s, 1940s AND 1950s. WHY ARE THESE FACILITIES A PROBLEM?

A. There are numerous studies which document the failure of infrastructure installed during this time period.[5]

Deteriorating water distribution system infrastructure results in: (1) increased leaks and breaks; (2) taste, odor and rusty water complaints; (3) reduced flow capacity because of corrosion build up on the internal unlined surface of the pipe as shown in the photo below; and (4) reduced chlorine levels because corrosion on aging water mains increases the rates of bioflim growth and chlorine residual decay. Consequently, there is an increased potential for water quality degradation and, ultimately, health risks associated with aging infrastructure.[6] As a result, this aging infrastructure needs to be replaced. The analysis included as Exhibit FKS-13 discusses, in detail, the numerous problems caused by aging infrastructure.

[5] DeBerry, David W., Kidwell, James R., and Malish, David A. (1982). *Corrosion in Potable Water Systems.* United States Environmental Protection Agency. Thomson, James and Wang, Lili (2009). *State of Technology Review Report on Condition Assessment of Ferrous Water Transmission and Distribution Systems.* United States Environmental Protection Agency.

[6] *Aging Water Infrastructure (AWI) Research (2009).* United States Environmental Protection Agency. <http://www.epa.gov/awi/distributionsys.html> October 28, 2010.

Corrosion build up inside cast iron water main

Corrosion weakens the structural integrity of the pipe, increasing the likelihood of failure. Over 20,000 LF of water mains currently in service in the Western Group are constructed of cast iron, galvanized steel, or iron materials, without any additional form of corrosion protection which was industry practice at that time. Like any other product made from iron, water mains deteriorate through pitting, corrosion, graphitization, and tuberculation build-up. One form of corrosion protection, cement lining applied to the interior of water mains, reduces internal rates of corrosion. However, cement lining of pipes did not begin until the 1940s. Consequently, cast iron water mains that were installed before 1940 suffer from both the internal and external effects of corrosion, further increasing the potential for leaks. The oldest cast iron water mains installed in 1921 in the Western Group of water systems are failing from corrosion. The EPA completed a Condition Assessment of Ferrous Water Transmission and Distribution

Systems and a copy of that assessment is included as Exhibit FKS-13. A copy of a similar assessment of Gray Cast Iron pipe is included in Exhibit FKS-14.

CA water mains were predominantly used from the 1930s to the mid 1980s and were originally expected to have a longer useful life and better flow characteristics than cast iron, galvanized steel, or steel pipe. CA water mains were commonly used in the Company's water systems beginning in the 1930s. CA does not corrode in the same manner as ferrous (i.e. cast iron, galvanized steel, or steel) water mains and, as a result, was initially considered a superior product by the water utility industry because of its low friction factors and non-metallic construction. However, chemical changes occur in the cement substrate of the CA pipe because of the interaction between water and the internal surface of the pipe, and because of the interaction between the surrounding soil and the external surface of the pipe.[7] Failure Conditions of Asbestos Cement water mains is included in Exhibit FKS-15.

These chemical changes cause the CA pipes to lose strength. Deterioration of the pipe and changes in material or pipe integrity are not immediately visible, as there is no color change or reduction in wall thickness. The result is a material that is weak and unstable, leading to leaks, breaks, and ultimately, failure of the pipe. The Company stopped using CA pipe for new water mains in 1986 when it updated its specifications to require the use of ductile iron pipe. Concerns over the failure and useful life of CA water mains have prompted many studies by the EPA, Universities and other organizations. For example, a study that analyzed pipe breaks of CA water mains in urban water systems identified the positive relationship between the rate of pipe breakage and age. This study confirmed the effects of age on pipe breaks and validates the Company's observation that water leaks are increasing as its water

[7] Kettler, A.J. and Goulter, I.C. (1985). *An Analysis of Pipe Breakage in Urban Water Distribution Network.* Canadian Journal of Civil Engineering, 12:286-293. National Research Council Canada.

systems age. Other studies show that the pipe breakage rate is also influenced by pipe diameter, with a higher rate of breaks for smaller diameters.[8] The higher rate of breaks can be attributed to thinner pipe wall and lower bending resistance of smaller diameter pipe. The Company's Western Group of water systems have many smaller diameter water mains, totaling more than 2,300,000 LF of 6-inch and smaller. Besides being a major problem within the Western Group of water systems, aging and failing water infrastructure is a national phenomenon. AWWA's Assessment of Aging and Failing Infrastructure documents this crisis in their report, Buried No Longer. A copy of AWWA's assessment is included in Exhibit FKS-16.

Q. ARE THE WATER MAINS AND SERVICE LINES IN THE WESTERN GROUP MADE OF THE SAME MATERIAL AS THE COMPANY'S EASTERN AND NORTHERN GROUPS?

A. Yes. The Company's Western Group of water systems have galvanized steel and cast iron water mains and contain a significant amount of poly service lines, which have shown increasing frequencies of failure. The Company presented evidence that CA, cast iron, and galvanized steel water mains and poly service lines were near or past the end of their useful service lives in the Company's last Western Group rate case (see Docket No. W-01445A-10-0517), last Eastern Group rate case (see Docket No. W-01445A-11-0310) and the last Northern Group rate case (see Docket No. W-01445A-12-0348).

Q. ARE THERE OTHER PROBLEMATIC WATER MAIN MATERIALS IN THE COMPANY'S WESTERN GROUP?

A. Yes. Over 20,000 LF of water mains in service in the Western Group are constructed of Concrete Lined Cylinder materials. The majority of these water mains are 24-inches or 36-inches in diameter and are among the largest

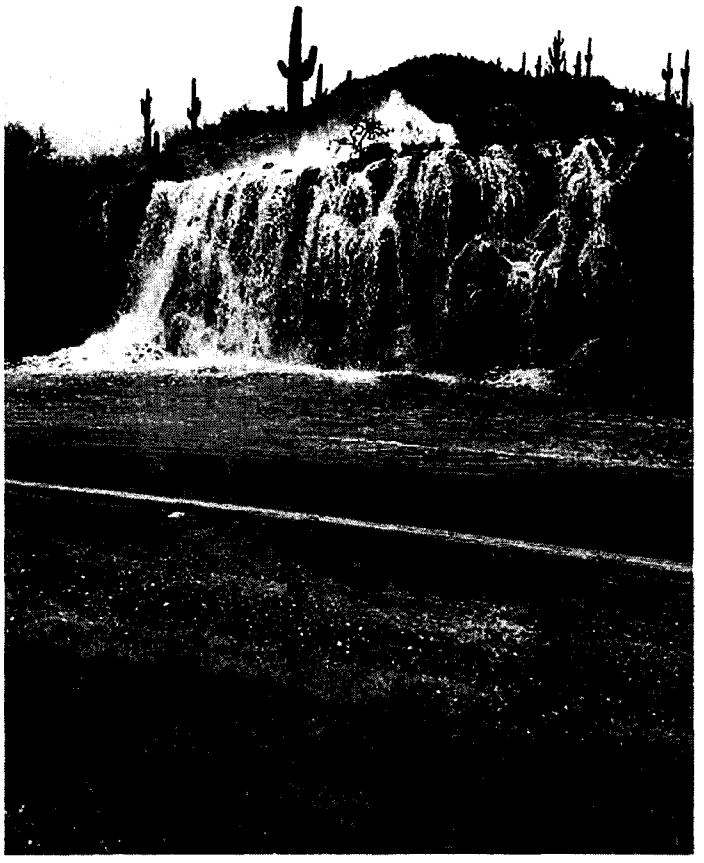
[8] Guan X. 1995, *Condition and Replacement of Regina's Water Distribution System,* M.Sc. Theses, University of Regina, Regina, SK, Canada. Mordak and Wheeler 1988. *Deterioration of Asbestos Cement Water Mains, Final Report to the Department of the Environment,* Water Research Center, Wiltshire, UK.

diameter water mains in service in the Company's Western Group. These water mains have shown signs of failure and require replacement. Breaks and failures on these water mains, as shown in the photos below, require emergency repair and replacement and may result in a disruption of service to thousands of customers.

36-inch CLC water main failure

WA 1-5332, described in my testimony under Post-Test year plant additions, is a recent example of a 36-inch CLC water main failure and emergency replacement. The photo below shows the significant amount of water loss and disruption caused by this 36-inch CLC water main failure.

Roadway flooding caused by 36-inch CLC water main failure



Planned replacement of this aging infrastructure will reduce water loss and reduce construction costs because emergency replacement is always far more costly than planned replacement.

Q. HOW IS THE COMPANY PROPOSING TO INCREASE THE RATE OF INFRASTRUCTURE REPLACEMENT TO MAINTAIN WATER LOSS BELOW 10 PERCENT?

A. The Company has prepared a detailed plan to replace approximately 318,300 linear feet of aging water mains, 4,110 aging service lines, 176 fire hydrants, and 4,110 meters, in its Western Group of water systems as discussed in the Company's Aging Infrastructure Replacement Plan for the Company's Western Group of Water Systems, Exhibit FKS-12. This plan includes specific projects

and detailed design and construction cost estimates which are included in Appendix 6.3 of Exhibit FKS-12.

Q. DID THE COMPANY PREPARE A COST ESTIMATE TO REPLACE THIS INFRASTRUCTURE?

A. Yes. The Company prepared cost estimates to replace the aging infrastructure in its Ajo, Pinal Valley and White Tank service areas. The estimated cost to replace this infrastructure for each service area are shown in the following table:

Aging Infrastructure Replacement Cost by Water System	
Area	Cost Estimate
Ajo service area	$559,000
Pinal Valley service area	$48,110,000
White Tank service area	$7,141,000

Details of these cost estimates are included in Appendix 6.5 of Exhibit FKS-12. Replacement unit costs are based on recent bids from other Company projects within the Western Group.

Q. HOW DID WE ESTIMATE THESE COSTS?

A. Company engineers estimated these costs based on previous projects and competitive bids from qualified contractors.

Q. ARE THERE OTHER METHODS TO CALCULATE COSTS TO REPLACE AGING INFRASTRUCTURE?

A. Yes. The cost of replacing infrastructure can be calculated by using the Handy Whitman Index of Public Utility Construction Costs. The Handy Whitman Index is an engineering cost index that tracks the cost of constructing various types of public utility plant in different parts of the country. This index compares the cost of constructing public utility plant from one time period to another. For example, water mains that were installed in 1921 have a cost index of 27, while the index for water mains installed in 2015 is 735.

Q. WHAT DOES THIS CHANGE IN ENGINEERING COST INDEX MEAN IN TERMS OF DOLLARS TO INSTALL TRANSMISSION AND DISTRIBUTION ("T&D") MAINS IN 2015 VERSUS INSTALLING T&D MAINS IN 1921?

A. The index is used to estimate construction costs by using today's cost index and comparing it to the cost index for the time period of the original installation. In the example above, the 2015 cost index (735), divided by the 1921 cost index (27), shows that the cost of constructing cast iron or ductile iron water mains in 2015 is more than 27 times the cost of installing the same pipe under the same conditions that existed in 1921.

Q. DOES THIS ENGINEERING COST INDEX ACCOUNT FOR THE FULL REPLACEMENT COST?

A. No. This engineering cost index does not account for cost increases caused by changes in construction conditions.

Q. PLEASE EXPLAIN FURTHER WHAT YOU MEAN BY CHANGES IN CONSTRUCTION CONDITIONS.

A. In many of the Company's water systems with older water mains, the T&D mains were installed before streets were paved, curbing and gutters installed, telephone lines installed, and other more recent underground utilities installed. Therefore, the cost of replacing T&D mains in these areas now would also need to include the cost of repairing streets and sidewalks, providing traffic control and working around other underground and above-ground installations to protect them against damage. Replacement water mains are generally larger in diameter and the replacement cost is higher than the original water main.

IX. <u>Tank Maintenance Program</u>

Q. HOW MANY WATER STORAGE TANKS DOES THE COMPANY HAVE IN ITS WESTERN GROUP?

A. The Western Group has 33 steel water storage tanks that were constructed from 1929 to 2013. A summary of the Company's Western Group water storage tanks, by PWSID number, is shown below:

ARIZONA WATER COMPANY WESTERN GROUP WATER STORAGE TANKS		
Water System	**PWS ID No.**	**Number of Storage Tanks**
Pinal Valley	11-009	19
Coolidge Airport	11-707	1
Tierra Grande	11-076	2
Stanfield	11-012	2
White Tank	07-128	7
Ajo	10-003	2

A comprehensive list of water storage tanks in the Company's Western Group, including diameter, height, year constructed, and the pertinent maintenance schedule and cost is shown in Exhibit FKS-17.

Q. WHY DO STORAGE TANKS REQUIRE PERIODIC INSPECTION AND CLEANING?

A. In accordance with American Water Works Association ("AWWA") Manual M42 for Steel Water Storage Tanks, standard AWWA practice calls for tanks to be inspected by industry professionals on a regular basis to ensure structural and sanitary integrity and to extend the useful life of the storage tank. Regular storage tank inspection also helps the Company identify problems in the storage tank which may develop into major problems if left undetected or repaired. Lack of proper maintenance and repairs leads to costly repairs and premature tank failure. These inspections should also include routine cleaning as necessary. Water storage tanks that are not routinely cleaned can cause water quality issues such as poor bacterial quality, turbidity, reduced chlorine residual and taste and odor and can lead to customer complaints. In addition to routine inspections and cleaning, AWWA standard practice calls for every tank inspection to included a

detailed inspection of the structure and foundation and a report performed by a qualified inspector documenting the inspection results.

Q. PLEASE DESCRIBE THE COMPANY'S TANK MAINTENANCE PROGRAM.

A. The Company inspects and cleans water storage tanks on a regular schedule, typically every three to five years. The Company recoats interiors every 14 years and recoats the exteriors every seven years. Without this program, water storage tanks would deteriorate more rapidly, shortening the useful life of each tank and increasing costs.

Q. HOW OFTEN DOES THE COMPANY INSPECT ITS WATER STORAGE TANKS?

A. In addition to the three to five years inspection schedule, inspections occur more often as the coating reaches the end of its useful life, and depends on tank age, condition from previous inspection, and amount of material accumulation in the storage tank.

Q. WHO PERFORMS INSPECTIONS OF COMPANY TANKS?

A. Company engineers and a NACE-certified inspector perform the tank inspections. NACE is the National Association of Corrosion Engineers. NACE is the largest corrosion professional institution in the world and is the national recognized leader in training, testing, and certifying inspectors in the protective coating industry.

Q. WHAT TASKS ARE PERFORMED DURING A TANK INSPECTION?

A. A NACE-certified inspector carefully investigates the tank's interior, exterior, foundation, and accessories, such as roof vents and ladders.

Q. HOW DOES THE COMPANY PERFORM WATER STORAGE TANK INSPECTIONS?

A. There are generally three options for inspection – dry, commercial divers, and remote operated vehicle ("ROV"). Dry inspection is where all water is removed from the water storage tank and qualified inspectors enter the tank to conduct the

internal inspection in accordance with Company and AWWA standards. This method requires draining the tank, includes the expense of re-filling the tank, extended down time, lockout/tag-out for confined space, and disinfection of the tank.

Commercial diver inspections require disinfection of the diving equipment, lockout/tag-out of the tank, and raise serious safety concerns always present when a person enters a tank full of water.

ROV inspections does not require draining and filling the tank, nor do they require the lockout/tag-out procedures associated with commercial divers. ROV complies with AWWA inspection requirements and standards and is a cost effective solution often used by the Company to inspect tank coating and interior conditions. Each option for tank inspection is used by the Company to perform storage tank inspections where applicable and as appropriate.

Q. HOW DOES THE COMPANY NORMALLY CLEAN ITS WATER STORAGE TANKS?

A. If inspection reveals minor cleaning of the water storage tank is required, the Company will clean the tank while it is in service and full of water by using large vacuum-type equipment. If more extensive cleaning is required, the Company drains the water storage tank, then cleans and physically inspects it using specialized ventilation equipment and inspection scaffolding inside the tank.

Q. WHAT IS THE INDUSTRY-STANDARD TANK COATING INTERVAL?

A. The Company has adopted a 14-year and 7-year coating interval for interior and exterior coating, respectively. The generally accepted interval for tank coating is 10-15 years depending on tank material and exposure to environmental conditions such as water quality, weather, and soil conditions. The Company's adopted coating interval is in accordance with industry standards.

Q. WHY DOES THE COMPANY USE 14-YEAR AND 7-YEAR COATING INTERVALS?

A. Typically, the Company finds that interior coating shows deterioration after 14 years. It has been the Company's experience that postponing interior recoating beyond 14 years will result in premature metal damage, which increases repair and replacement costs. Similarly, after 7 years exterior coating show signs of chalking and cracking due to exposure to ultraviolet rays from sunlight. Recoating is required to protect the exterior metal surface to maintain a suitable exterior appearance, and to prevent surface corrosion. The Company's 14-year and 7-year schedules work well, keep the tanks protected, and maintain a suitable exterior appearance.

Q. DOES THE COMPANY USE METHODS IN ADDITION TO PROTECTIVE COATINGS TO REDUCE STORAGE TANK CORROSION?

A. Yes, the Company uses cathodic protection systems on new storage tanks and where Company engineers have observed increases in corrosion and shortened coating life.

Q. WHAT IS A CATHODIC PROTECTION SYSTEM?

A. In the water industry, there are two types of cathodic protection systems used on steel water storage tanks; sacrificial anode and impressed current.

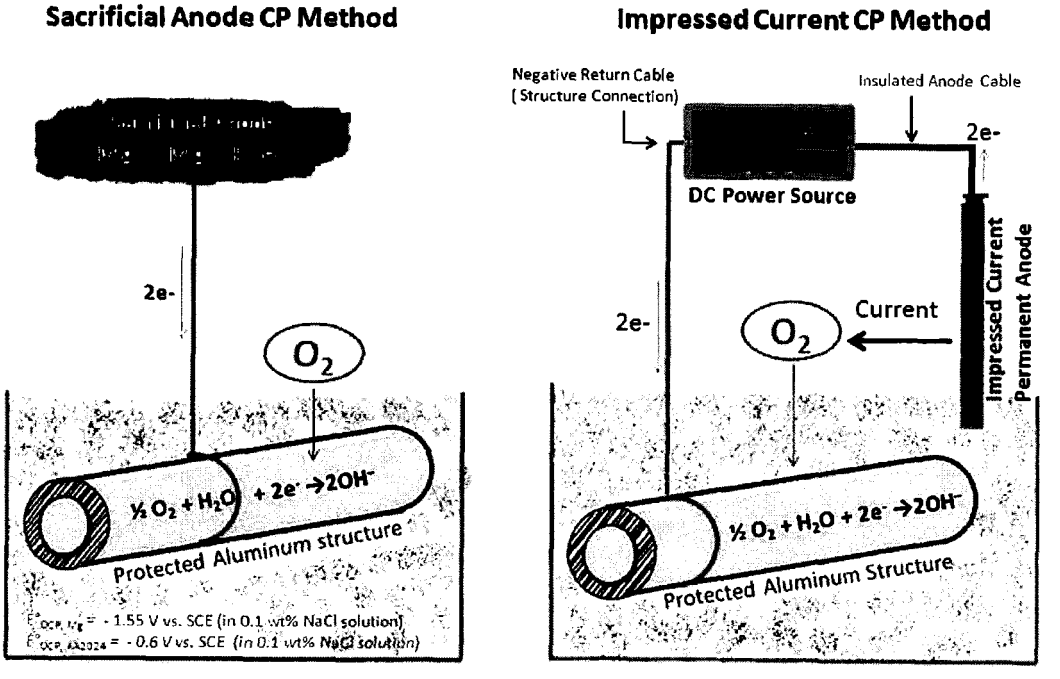
Sacrificial anodes are attached to a coated steel storage tank and are pieces of metal more electrically active than steel. The most common metal anodes are made of zinc, magnesium and aluminum. Because these anodes are more active, the corrosive current will exit from them rather than the steel. This means the steel is protected from corrosion and the attached anode is "sacrificed" or corroded. For effective corrosion protection using anodes, depleted anodes must be periodically inspected and replaced. This type of cathodic protection is used on smaller storage tanks, typically under 500,000 gallons.

Impressed current cathodic protection systems use a rectifier to convert alternating current (AC current) to direct current (DC current). Basically,

household current (AC) is converted to current typically used in a vehicle (DC). The DC current is sent through an insulated wire from the DC source to the anodes, which are special metal bars buried in the soil near the storage tank. The current then flows through the soil to the tank cathodic protection system and returns to the rectifier through an insulated wire attached to the storage tank. The storage tank is protected because the current going to the storage tank overcomes the corrosion-causing current normally flowing away from it.

A schematic of each type of cathodic protection system is shown below.[9]

Typical Cathodic Protection Systems



Cathodic Protection (CP) Methods

Q. WHAT IS THE COMPANY'S SCHEDULE FOR INSPECTING CATHODIC PROTECTION SYSTEMS ON WATER STORAGE TANKS?

A. Cathodic protection systems are inspected annually by Company engineers and NACE Certified Cathodic Protection Inspectors and Technicians. Any necessary

[9] http://www.mdpi.com/2075-4701/2/3/353/htm

servicing and repairs are performed during the inspection process. Not all storage tanks have or require cathodic protection.

Q. WHAT ARE THE ESTIMATED COSTS TO PERFORM THIS STORAGE TANK MAINTENANCE?

A. The estimated normalized annual maintenance expense for the next 14-year cycle, beginning with the adjusted recorded 2014 test year, is $231,105, $55,199 and $18,953, in the Pinal Valley, White Tank and Ajo service areas, respectively. Mr. Reiker discusses the adjustment to annual tank maintenance expense in Section VII of his direct testimony.

X. <u>Nitrate Cost Recovery Mechanism ("NCRM")</u>

Q. IS THE COMPANY EXPERIENCING INCREASED LEVELS OF NITRATES IN ITS GROUNDWATER SUPPLIES?

A. Yes. Nitrate levels are increasing in the Company's Pinal Valley Service Area wells and are approaching the maximum drinking-water standard or maximum contaminant level ("MCL") in four of the Company's wells in the Pinal Valley service area, specifically Well Nos. 7, 27, 32 and 33.

Q. HAS THE EPA PERFORMED AN ASSESSMENT OF NITRATES AND NITRITES ON HUMANS?

A. Yes. The EPA completed a Toxicity and Exposure Assessment for Children's Health in May 22, 2007. That report shows the detrimental effects of nitrates on children, pregnant women and even adults. A copy of the EPA Toxicity and Exposure Assessment for Children's Health is included in Exhibit FKS-18.

Q. HAVE THE EPA AND ADEQ ESTABLISHED AN MCL FOR NITRATES IN DRINKING WATER?

A. Yes. In 1974, Congress passed the Safe Drinking Water Act and in 1992, the EPA established regulations for nitrates in drinking water. EPA has set a nitrate MCL of 10 mg/L (10 ppm). ADEQ has adopted this MCL by reference to EPA's Safe Drinking Water Act regulations.

Q. WHY DID THE EPA ESTABLISH A DRINKING WATER MCL FOR NITRATES?

A. The EPA established an MCL for nitrates in drinking water due to the severe health effects on humans and the common occurrence of nitrates in groundwater used for drinking water. Nitrates in drinking water are an acute violation of the Safe Drinking Water Act and require a Tier 1 public notice for any MCL violation or exceedance.

Q. WHAT IS AN ACUTE VIOLATION?

A. Acute violations are very serious, life threatening occurrences and must be reported to the public within 24 hours. Additionally, a water system must use media outlets such as television, radio, newspapers, and internet, post notice in public places, or personally deliver notice to those who may be affected. Acute health effects result from ingestion of a contaminant over a short period of time.

Q. IS AN ACUTE VIOLATION LIFE THREATENING?

A. Yes. An acute violation means that if humans drink the water, they could die. MCL exceedances of nitrates in drinking water are that serious.

Q. WHO IS MOST AT RISK OF DEATH FROM NITRATES IN DRINKING WATER?

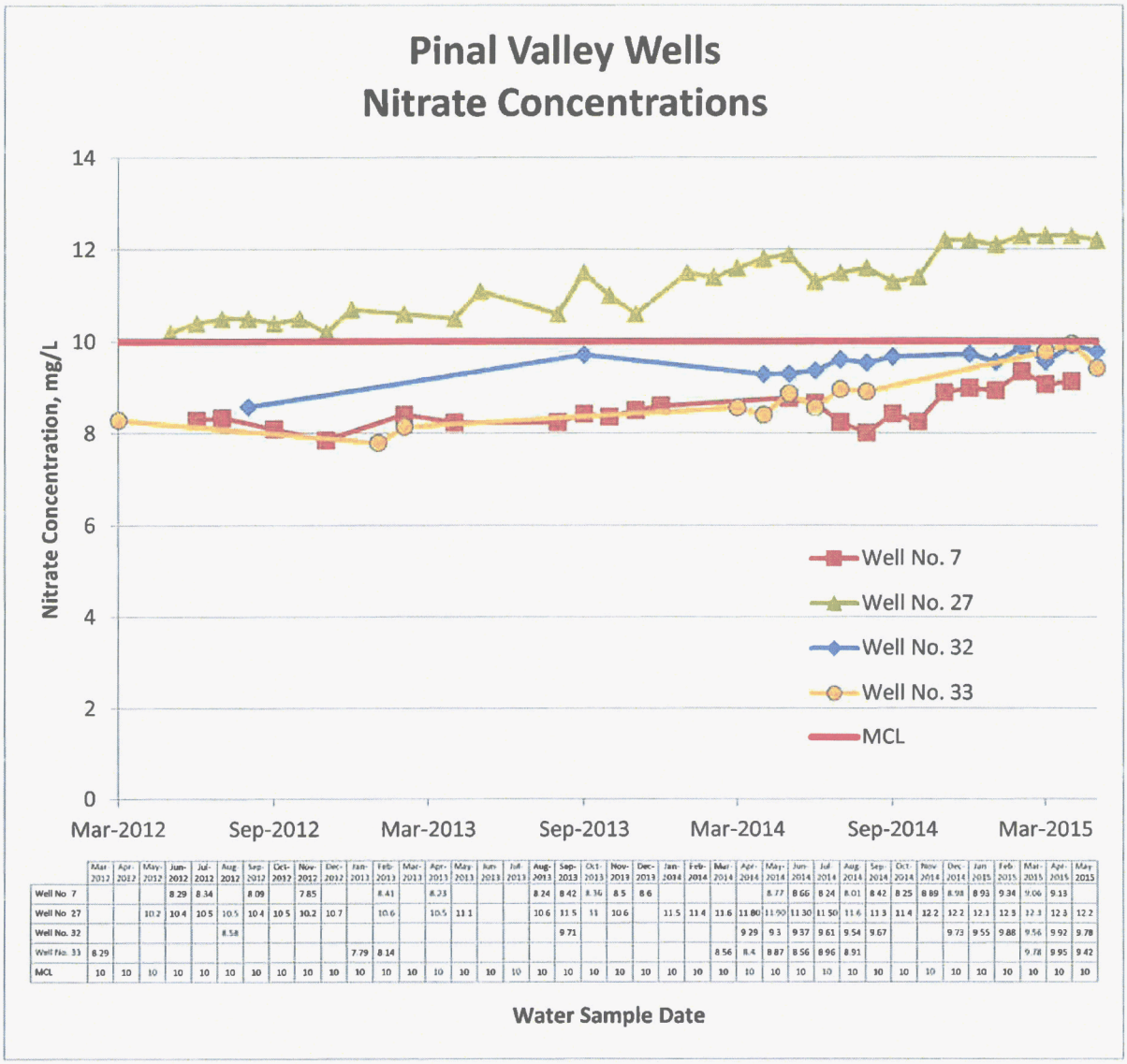
A. Infants below six months who drink water containing nitrate in excess of the maximum contaminant level (MCL) may become seriously ill and, if untreated, may die. Nitrate levels above the MCL have been proven to cause a fatal blood disorder in infants under six months of age called methemoglobinemia, or more commonly known as "blue-baby" syndrome. Blue baby syndrome disrupts and greatly restricts oxygen-carrying capacity of blood. Other people at risk include pregnant women, individuals with reduced gastric acidity, and individuals with a hereditary lack of methemoglobin reductase.

Q. CAN A CUSTOMER BOIL DRINKING WATER TO REMOVE NITRATES?

A. No. Boiling water makes the nitrate contamination even more deadly because it significantly concentrates the nitrates in the water through evaporation.

Q. WHAT ARE THE NITRATE LEVELS IN THE COMPANY'S WELLS YOU NOTED?

A. The nitrate levels in three wells are approaching and one well has exceeded the 10 ppm MCL and is blended. Company constructed a tank and booster pump station in 2010 to blend Well No. 27 water with low nitrate water from Coolidge prior to EPDS. Data in graph represents Well No. 27 results, not EPDS. Well nos. 7, 27, 32 and 33 will require nitrate removal equipment in the near future. A graph and table showing the nitrate results and trends from these wells is shown below.



	Mar-2012	Apr-2012	May-2012	Jun-2012	Jul-2012	Aug-2012	Sep-2012	Oct-2012	Nov-2012	Dec-2012	Jan-2013	Feb-2013	Mar-2013	Apr-2013	May-2013	Jun-2013	Jul-2013	Aug-2013	Sep-2013	Oct-2013	Nov-2013	Dec-2013	Jan-2014	Feb-2014	Mar-2014	Apr-2014	May-2014	Jun-2014	Jul-2014	Aug-2014	Sep-2014	Oct-2014	Nov-2014	Dec-2014	Jan-2015	Feb-2015	Mar-2015	Apr-2015	May-2015
Well No 7				8.29	8.34		8.09		7.85			8.41		8.23				8.24	8.42	8.36	8.5	8.6					8.77	8.66	8.24	8.01	8.42	8.25	8.89	8.98	8.93	9.34	9.06	9.13	
Well No 27			10.2	10.4	10.5	10.5	10.4	10.5	10.2	10.7		10.6		10.5	11.1			10.6	11.5	11	10.6		11.5	11.4	11.6	11.80	11.90	11.30	11.50	11.6	11.3	11.4	12.2	12.2	12.3	12.3	12.3	12.3	12.2
Well No. 32						8.58													9.71							9.29	9.3	9.37	9.61	9.54	9.67			9.73	9.55	9.88	9.56	9.92	9.78
Well No. 33	8.29										7.79	8.14													8.56	8.4	8.87	8.56	8.96	8.91						9.78	9.95	9.42
MCL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

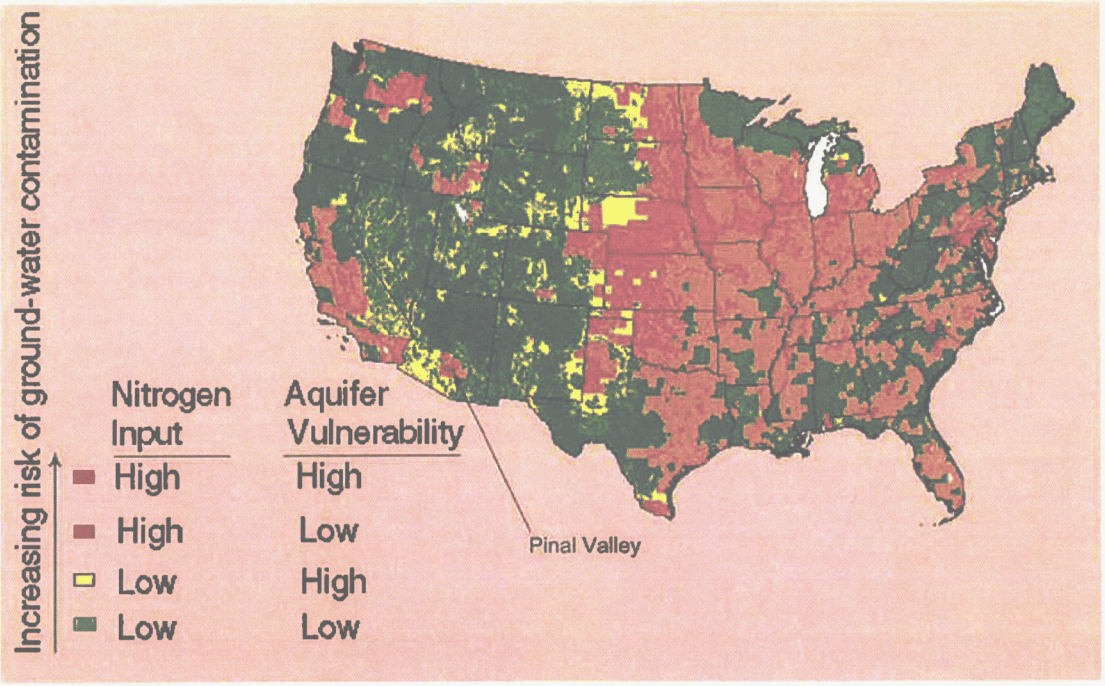
Q. WHAT CAUSES INCREASING NITRATE LEVELS IN GROUNDWATER SUPPLIES?

A. According to the EPA, the major sources of nitrates in drinking water are runoff from fertilizer use for agriculture, leaking from septic tanks, sewage, and erosion of natural nitrate deposits. When nitrogen fertilizers are used to enrich soils, rain, irrigation, and other surface waters carry the nitrates through the soil into ground water. Human and animal wastes can also contribute to nitrate contamination in groundwater.

Q. WHAT CAUSED THE INCREASED NITRATE LEVELS IN THE COMPANY'S GROUNDWATER SUPPLIES IN PINAL VALLEY?

A. The increased nitrate levels are caused by agriculture and is a widespread problem in the Pinal Valley area, a national problem and a legacy that must be dealt with. The USGS map below shows a national risk assessment of nitrate contamination in groundwater.

National Risk Assessment of Nitrate Contamination in Groundwater



The map shows four levels of nitrate contamination risk (low to high) and the Pinal Valley area is located in the red which is the highest risk. The report is included in Exhibit FKS-19.

Q. HOW MUCH OF THE COMPANY'S DRINKING WATER COMES FROM GROUNDWATER SUPPLIES IN PINAL VALLEY?

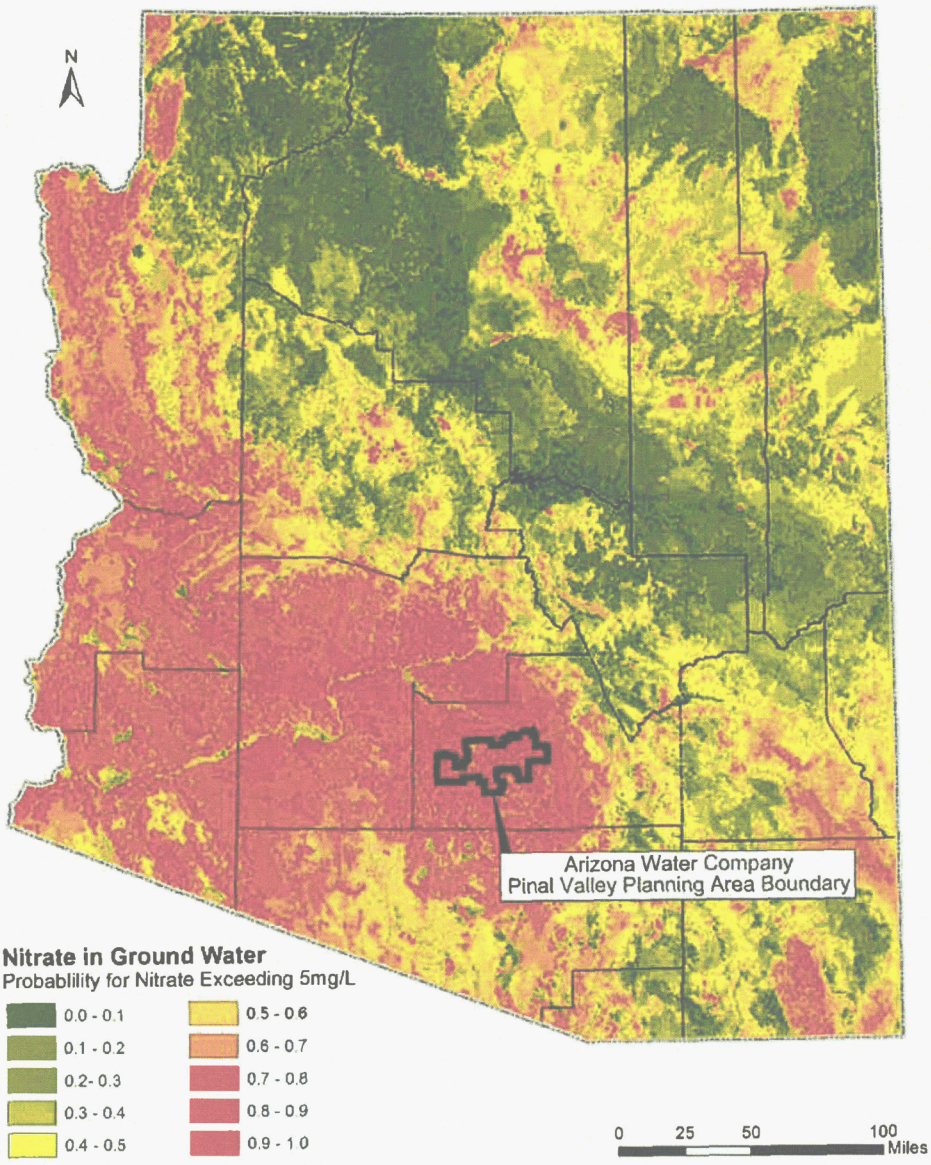
A. Drinking water supplies the Company provides to its customers in the Pinal Valley Service Area come from local groundwater supplies. More specifically, the Company pumped 16,332 acre-feet in 2014.

Q. IS NITRATE GROUNDWATER CONTAMINATION WIDESPREAD IN ARIZONA?

A. Yes, nitrate is the most common pollutant in Arizona's groundwater and is undetectable without testing because it is colorless, odorless and tasteless. Nitrate contamination levels in Arizona groundwater are increasing.[10] The map of Arizona shown below was published in July 2011 by the Arizona Cooperative Extension of the University of Arizona, College of Agriculture and Life Sciences.

[10] http://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1536.pdf].

Predicted Nitrate Contamination in Arizona Groundwater



The map shown above predicts concentrations of nitrate contamination in groundwater. The Arizona Cooperative Extension publication shows over nine percent of the state, or 12,200 square miles, has shown an 80 percent chance (probability) of nitrate groundwater contamination. The red color on the map has the highest probability. For reference purposes, I overlaid the Company's Pinal Valley Planning Area Boundary. As shown on the map, most of the Company's

Pinal Valley Planning Area is in the red area of the map and has the highest probability of nitrate contamination. The entire publication is included in Exhibit FKS-20.

Q. HAS NITRATE GROUNDWATER CONTAMINATION IN THE PINAL VALLEY AREA BEEN STUDIED AND QUANTIFIED?

A. Yes. Studies have been completed by the United States Geological Survey, Bureau of Reclamation, Arizona Department of Water Resources, Arizona Department of Environmental Quality, University of Arizona and other various smaller agencies. According to the 1995-1998 USGS report, the Central Arizona groundwater basin is predicted to equal or exceed the EPA drinking-water standard.[11] A copy of the United States Geological Survey report, summary of findings which evaluated groundwater conditions and the increasing specific nitrate contamination in groundwater between the southern Arizona border and Phoenix is included in Exhibit FKS-21. In 2010, Arizona Department of Environmental Quality completed a study of surface and groundwater conditions in Arizona. The ADEQ report studied the Pinal Active Management Area Groundwater Basin for nitrate contamination. The report concluded that despite the average well depth in the Pinal AMA being 1,040 feet deep, nitrates were detected in 89 groundwater samples and 15 of those samples were over the nitrate MCL of 10 ppm. The highest detected was nearly 4 times the national drinking-water standard (MCL) at 36.4 ppm. A copy of the cover sheet of the report and the Appendix I - Groundwater Assessment is included in Exhibit FKS-22.

Q. CAN THE COMPANY BLEND THESE HIGH NITRATE WELLS WITH WELLS HAVING A LOWER NITRATE LEVEL?

[11] USGS release 9/27/12: http://www.usgs.gov/newsroom/article.asp?ID=3411#.VdIJlK3blkI

A. Blending water from other Company wells is not possible because there are no lower nitrate level wells nearby. Where blending is possible and has been implemented, the Company runs the risk of losing a source of supply if the well having a low nitrate level needs to be shut down or the nitrate level increases to levels where blending is no longer possible. Due to increasing nitrate levels in these four wells as shown on the graph and table above, the Company must construct four new nitrate removal facilities.

Q. CAN THE COMPANY DRILL NEW WELLS IN ANOTHER NEARBY AREA?

A. No. As shown in the maps above, the nitrate contamination of groundwater in the Pinal Valley area is widespread and we can't simply move to an uncontaminated area. In addition, there is tremendous risk to drill a well as a new well could have higher levels of nitrate contamination or could require other forms of treatment, possibly more costly, to comply with Safe Drinking Water Standards.

Q. HOW ARE NITRATES REMOVED FROM DRINKING WATER SUPPLIES?

A. EPA has determined that the best available treatment technologies are ion exchange, reverse osmosis, and electrodialysis all of which are approved as effective at removing nitrates from drinking water.

Q. CAN YOU PROVIDE A BRIEF SUMMARY OF THE EPA LISTED BEST AVAILABLE TECHNOLOGIES FOR REMOVING NITRATES IN GROUNDWATER FOR DRINKING WATER SUPPLIES?

A. Yes. Ion Exchange is the most commonly used nitrate removal method for drinking water. Ion exchange for nitrate removal is similar to a home water softener, except nitrate ions are removed rather than hardness ions by the use of resins specifically designed for nitrate removal. Nitrate is removed by flowing water through a bed of anion exchange resin and displacing chloride ions from the resin. Once the resin is saturated with nitrates, nitrate is then removed from the resin through a regeneration process using a highly concentrated salt

solution that displaces the nitrate from the resin by chloride. The concentrated waste brine solution is high in nitrate and requires disposal at a permitted landfill or in evaporation ponds.

In a reverse osmosis nitrate removal process, nitrate is removed from drinking water by forcing water through a semi-permeable membrane under high pressure, typically hundreds of pounds per square inch. The water passes through the membrane while the nitrate and other contaminants are too large to pass through the membrane. Pretreatment of the influent is required to prevent membrane fouling and scaling. Reverse osmosis requires large pumping equipment. To clean the membranes, the flow is reversed using treated drinking water. Water which bypasses the membrane (waste) is a highly concentrated brine solution and requires disposal at a permitted landfill or in evaporation ponds.

Electrodialysis for nitrate removal in drinking water supplies works by passing an electric current through a series of anion and cation exchange membranes that trap nitrate and other ions in a concentrated waste stream. Pretreatment of the influent is required to prevent membrane fouling and scaling and chemicals are required to enhance the cleaning process. The polarity of the system can be reversed with electrodialysis reversal to reduce membrane fouling. Reversing the polarity reverses the flow direction and moves ions in the opposite direction through the membranes which minimizes build up. Water which bypasses the membrane (waste) is a highly concentrated brine solution and requires disposal at a permitted landfill or in evaporation ponds.

Nitrate removal processes are costly to construct, operate and maintain.

Q. HAVE COMPANY ENGINEERS ESTIMATED THE COST TO CONSTRUCT EACH OF THESE TYPES OF NITRATE REMOVAL TECHNOLOGIES?

A. Yes. Company engineers performed a detail cost estimate for each EPA recommended nitrate removal option including construction, operational and

maintenance costs at the Company's Well No. 33. The table below summarizes the construction cost of each EPA best available technology at Well No. 33.

Nitrate Removal Technology	Pinal Valley Well No. 33 NRF Estimated Construction Cost
Ion Exchange	$6,529,000
Reverse Osmosis	$9,902,000
Electrodialysis	$11,197,000

The Company's analysis shows that the least cost option for removing nitrates from groundwater to comply with the Safe Drinking Water Act using the best available technology defined by the EPA is Ion Exchange. A detailed cost estimate for each of the nitrate removal technologies listed above are shown in Exhibit FKS-23.

Q. DOES THE COMPANY HAVE EXPERIENCE CONSTRUCTING, OPERATING, AND MAINTAINING A NITRATE REMOVAL FACILITY?

A. Yes. The Company currently owns, operates, and maintains two nitrate removal facilities and one combination arsenic and nitrate removal facility. One nitrate removal facility is located in the Company's White Tank water system and the other is located in Pinal Valley. The Company's combination arsenic and nitrate removal system is also located in Pinal Valley in the Company's Stanfield water system.

Q. WHAT IS REQUIRED TO CONSTRUCT A NITRATE REMOVAL FACILITY AT THE COMPANY'S WELL NO. 33?

A. Company's Well No. 33 has a production capacity of 2.2 MGD. To construct a nitrate removal facility of this size, additional land is required because the existing well site is too small. In addition to the nitrate removal vessels, salt, brine and brine waste tanks are required. A storage tank and booster pump station is required so that the resin used in the treatment process is not subjected to water system operating pressures which can damage or destroy the expensive

specialized resin. The Company's other nitrate removal facilities required similar equipment. Company engineers estimate the cost to construct a nitrate removal facility at Well No. 33 in Pinal Valley is $6,529,000.

As I described earlier in this section of my testimony, the company will likely need to construct four of these nitrate removal facilities at a total estimated construction cost of $18,900,000 to continue supplying a safe drinking water supply in the Pinal Valley service area. Project descriptions, preliminary site plans and construction cost estimates for each of the four nitrate removal facilities are shown in Exhibit FKS-24.

Q. WHAT IS THE COMPANY'S ESTIMATED COST TO OPERATE AND MAINTAIN A NITRATE REMOVAL FACILITY?

A. Company engineers estimate the cost to operate and maintain a nitrate removal facility, using Ion Exchange technology is $1,400 per acre foot. The Company bases this estimate on actual operation and maintenance costs of the Company's two existing ion exchange nitrate removal facilities. For the Company's Well No. 33, this would be $1,750,000 annually. A detailed summary of the operational and maintenance costs are shown in Exhibit FKS-25.

Q. HOW DOES THE COST TO OPERATE AND MAINTAIN A NITRATE REMOVAL FACILITY COMPARE TO THE COST TO OPERATE AND MAINTAIN A SIMILAR SIZED ARSENIC REMOVAL FACILITY?

A. In comparison, the Company's arsenic removal facility located at Well No. 29 in the Pinal Valley service area, which has a similar production capacity of 2.2 MGD, costs approximately $45,000 annually to operate and maintain. It costs 20 times more to operate and maintain a nitrate removal facility than it does to operate and maintain an arsenic removal facility.

Q. WHY IS THE TREATMENT COST FOR REMOVING NITRATE MORE EXPENSIVE THEN ARSENIC?

A. The primary reason is the amount of contaminant which must be removed from the drinking water. As a comparison, arsenic is measured in parts per billion or ppb and nitrates are measured in parts per million or ppm. One ppm is equal to 1,000 ppb. For a well with 13 ppm nitrates, that would be equal to 13,000 ppb of nitrates.

Q. YOU ARE REMOVING 1,000 TIMES MORE CONTAMINATION FOR NITRATE REMOVAL THAN ARSENIC REMOVAL?

A. Yes, that is correct.

Q. WHY IS A NITRATE COST RECOVERY MECHANISM (NCRM) NECESSARY?

A. Nitrate removal facilities require high capital investment and significant operating expense. Constructing, operating and maintaining four nitrate removal facilities without the ability to recover the associated costs until the Company files a new rate case will divert capital needed by the Company's to fund other critical and necessary utility plant infrastructure to provide safe and reliable water supplies.

Q. HAS THE COMPANY REQUESTED A COST RECOVERY MECHANISM REQUIRED FOR NITRATE REMOVAL?

A. Yes, for the reasons outlined above, the Company requests an NCRM for the Pinal Valley and White Tank service areas.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY IN THIS MATTER?

A. Yes.

FKS-1

WA 1-4806

Western Group Rate Case

Exhibit FKS-1

4806 Coolidge Well No. 13 ARF

ARIZONA WATER COMPANY
WORK AUTHORIZATION

W.A. NUMBER: 1-4806
P.E. NUMBER:
BUDGET ITEM NO.: B-1
SHEET NO.: 1 of 2

SYSTEM:	PINAL VALLEY	RETENTION REQUIRED:	☐ YES ☑ NO
DIVISION:	CASA GRANDE	WORK TO START BY:	UPON AUTHORIZATION
RESPONSIBLE PERSON:	JAMES WILSON	WORK TO BE FINISHED BY:	WITHIN 300 DAYS
TAX CODE:			

DESCRIPTION OF WORK:

Design and permit a 800 gpm Arsenic Removal Facility (ARF) at Coolidge Well No.13 in the Pinal Valley water system.

FACTORS JUSTIFYING WORK:

Coolidge Well No. 13 was taken out of service in 2011. Company operators routinely took water quality samples for Arsenic from 2009 through 2011. During this time EPA's Arsenic MCL of 0.010 mg/L was exceeded in the majority of the samples. The collected data shows Arsenic concentrations ranged from between 0.0079 to 0.023 mg/L, with an average of 0.0146 mg/L. The well is needed to meet increasing demands within the Heartland development and Coolidge area. Company engineers have determined that design of an Arsenic Removal Facility (ARF) employing either adsortive media or coagulation/filtration removal technologies is required for the well in order to facilitate expedited construction and implementation of the ARF.

COST ESTIMATE		AUTHORIZATION	DATE
COST OF WORK:		PREPARED BY:	
MATERIAL	0	James Wilson	
LABOR	4,400	REVIEWED FOR ESMT/ROW VERIFICATION:	
CONTRACT PORTION	125,000	Charles Briggs	
OVERHEAD	15,500	REVIEWED BY:	
TOTAL AUTHORIZED EXPENDITURES CHARGEABLE TO THIS W.A.	$ 144,900	Andy Haas	
FUNDS RECEIVED:		APPROVED BY ENGINEERING:	
CONTRIBUTIONS RECEIVED	0	Fredrick Schneider	
REFUNDABLE ADVANCES RECEIVED	0	APPROVED BY FINANCE:	
TOTAL CONTRIBUTIONS/ADVANCES	0	Joseph Harris	
NET COMPANY CASH REQUIRED	$ 144,900	AUTHORIZED BY PRESIDENT:	
		William Garfield	

COMMENTS:

RELEASE TO DESIGN ONLY

CONSTRUCTION RELEASE:

2015 BUDGET

AFH

ARIZONA WATER COMPANY

WORK AUTHORIZATION - DETAIL SHEET

W.A. NUMBER: 1-4806
P.E. NUMBER:
BUDGET ITEM NO.: B-1
SHEET NO.: 2 of 2

RETIREMENT PROPERTY UNITS	PLANT PROPERTY ACCOUNT	UNIT DESCRIPTION	QUANTITY	YEAR INSTALLED AND W.A. NUMBER

PROJECT DESCRIPTION

Design and permit a 800 gpm Arsenic Removal Facility (ARF) at Coolidge Well No. 13 in the Pinal Valley water system.

	DESCRIPTION	PLANT PROP ACCT	QUANTITY	UNIT COST	TOTAL
CONTRACT WORK	Cost Incurred to Date	332	1	$ 50,000.00	$ 50,000
	Engineering Design	332	1	$ 75,000.00	$ 75,000
	SERVICE CONNECTIONS COMPLETE: DOUBLE-LONG	345			
	SERVICE CONNECTIONS COMPLETE: DOUBLE-SHORT	345			
	SERVICE CONNECTIONS COMPLETE: SINGLE-LONG	345			
	SERVICE CONNECTIONS COMPLETE: SINGLE-SHORT	345			
TOTAL CONTRACT WORK					$ 125,000
MATERIALS					
	SERVICE CONNECTIONS: DOUBLE-LONG	345			
	SERVICE CONNECTIONS: DOUBLE-SHORT	345			
	SERVICE CONNECTIONS: SINGLE-LONG	345			
	SERVICE CONNECTIONS: SINGLE-SHORT	345			
	METERS	346			
TOTAL MATERIALS					$ -
LABOR	Engineering and Project Management	332	80	$ 55.00	$ 4,400
	TESTING FEE				
	PERMIT FEE				
	SURVEY FEE				
	FIELD INSPECTION				
	INSTALL SERVICE CONNECTIONS: DOUBLE-LONG	345			
	INSTALL SERVICE CONNECTIONS: DOUBLE-SHORT	345			
	INSTALL SERVICE CONNECTIONS: SINGLE-LONG	345			
	INSTALL SERVICE CONNECTIONS: SINGLE-SHORT	345			
TOTAL LABOR					$ 4,400
SUBTOTAL - CONTRACT WORK, MATERIALS, AND LABOR					$ 129,400
OVERHEAD					15,500
TOTAL	REFUNDABLE PORTION ☐	NON-REFUNDABLE PORTION ☐		**COST ESTIMATE**	$ 144,900

AFH

ARIZONA WATER COMPANY

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY

Alternatives Evaluation Technical Memorandum

DRAFT
November 2011

4600 EAST WASHINGTON STREET • SUITE 500 • PHOENIX, ARIZONA 85034 • (602) 263-9500 • FAX (602) 265-1422

ARIZONA WATER COMPANY

COOLIDGE WELL NO. 13 ARSENIC REMOVAL FACILITY

ALTERNATIVES EVALUATION TECHNICAL MEMORANDUM

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION/BACKGROUND	1-1
2.0	BASIS OF EVALUATION	2-2
2.1	Design Criteria and Assumptions	2-3
2.2	Site Constraints	2-7
3.0	ALTERNATIVE 1 – PARTIAL TREATMENT	3-9
3.1	Alternative 1 Coagulation/Filtration (1 C/F)	3-9
3.2	Alternative 1 Ion Exchange (1 IX)	3-9
3.3	Alternative 1 Sorptive Media (1SM)	3-9
3.3.1	Lead-Lag Operation	3-9
3.3.2	Parallel Operation	3-9
3.4	Conclusions for Alternative 1	3-10
4.0	ALTERNATIVE 2 – FULL TREATMENT	4-19
4.1	Alternative 2 Coagulation/Filtration (2 C/F)	4-19
4.2	Alternative 2 Ion Exchange (2 IX)	4-19
4.3	Alternative 2 Sorptive Media (2 SM)	4-19
4.3.1	Lead-Lag Operation	4-19
4.3.2	Parallel Operation	4-19
4.4	Conclusions for Alternative 2	4-20
5.0	COST ANALYSIS	5-25
5.1	Comparison of Costs	5-26
6.0	QUALITATIVE EVALUATION OF ARSENIC TREATMENT ALTERNATIVES	6-36
6.1	Current State of Filter Medias	6-38
6.2	Current State of Sorptive Medias	6-39
6.3	Ranking of C/F and SM Medias	6-41
7.0	EVALUATION SUMMARY	7-44
7.1	Site Layout Conclusions	7-44
7.2	Cost Conclusions	7-45
7.3	Recommendation	7-45

APPENDICES

APPENDIX A WATER QUALITY (WELL NO. 11 AND NO. 13)
APPENDIX B CONSTRUCTION COST DETAILS
APPENDIX C O&M COST DETAILS

LIST OF TABLES

Table 1	Arsenic Treatment Technology and Mitigation Strategy Alternatives	1-2
Table 2	Design Criteria and Assumptions Used for Sizing Treatment Footprints	2-4
Table 3	Summary of Bypass Flows and Treatment Equipment Footprints	2-5
Table 4	Summary of Ancillary Equipment Sizes and Footprints	2-6
Table 5	Capital and O&M Cost Details for Alternative No. 1 (Partial Treatment) for Well No. 13	5-27
Table 6	Capital and O&M Cost Details for Alternative No. 2 (Full Treatment) for Well No. 13	5-28
Table 7	Capital and Life-Cycle Cost Summary for Alternative No. 1 and No. 2 for Well No. 13	5-29
Table 8	Capital and O&M Cost Details for Alternative No. 1 (Partial Treatment) for Well No. 11	5-33
Table 9	Capital and O&M Cost Details for Alternative No. 2 (Full Treatment) for Well No. 11	5-34
Table 10	Capital and Life-Cycle Cost Summary for Alternative No. 1 and No. 2 for Well No. 11	5-35
Table 11	Comparison of Arsenic Treatment Alternatives	6-37
Table 12	Current Status of Medias Used for Coagulation/Filtration [(1)]	6-39
Table 13	Current Status of Arsenic Sorptive Medias	6-40
Table 14	Qualitative Ranking of C/F and SM Medias	6-43

LIST OF FIGURES

Figure 1	Well No. 13 Site Constraints	2-8
Figure 2	C/F Process Flow Schematic	3-11
Figure 3	Alternative 1 C/F Site Layout	3-12
Figure 4	IX Process Flow Schematic	3-13
Figure 5	Alternative 1 IX Site Layout	3-14
Figure 6	SM Lead-Lag Process Flow Schematic	3-15
Figure 7	Alternative 1 SM Lead-Lag Site Layout	3-16
Figure 8	SM Parallel Process Flow Schematic	3-17
Figure 9	Alternative 1 SM Parallel Site Layout	3-18
Figure 10	Alternative 2 C/F Site Layout	4-21
Figure 11	Alternative 2 IX Site Layout	4-22
Figure 12	Alternative 2 SM Lead-Lag Site Layout	4-23
Figure 13	Alternative 2 SM Parallel Site Layout	4-24
Figure 14	Life-Cycle Costs for Alternative No. 1 (Partial Treatment)	5-30
Figure 15	Life-Cycle Costs for Alternative No. 2 (Full Treatment)	5-31
Figure 16	Life-Cycle Costs for C/F and SM at Various Well Utilization Rates	5-32

1.0 INTRODUCTION/BACKGROUND

Arizona Water Company (AWC) owns a production well site located within a residential area on Vah Ki Inn Road in Coolidge, Arizona. The well historically has a production capacity of 1,250 gallons per minute (gpm), which is pumped directly into the distribution system. The current arsenic concentration in Well No. 13 approximately 0.013 mg/L, but is anticipated to increase to an ultimate concentration of approximately 0.018 mg/L based on observed water quality trends of surrounding wells. The range of duty cycle for the well is initially anticipated to be from 25 to 50 percent, and increase to a range of duty cycle from 75 to 100 percent as the water system demands increase. Future demands will also be met with additional flow of 1,250 gpm from a second nearby well currently drilled, but not yet equipped.

AWC has contracted with Carollo Engineers (Carollo) to conduct an evaluation of various arsenic treatment technologies or mitigation strategies for Well No. 13. The objective of this study is to determine the most cost effective strategy for implementation that meets AWC's and regulatory requirements.

Two treatment alternatives will be evaluated during this study:

- Partial stream arsenic treatment at Well No. 13.
- Full stream arsenic treatment at Well No. 13.

Three arsenic treatment technology options will be considered for this study:

- Coagulation/filtration (C/F) including horizontal and vertical pressure vessel arrangements.
- Ion exchange (IX).
- Sorptive media (SM), including parallel flow vs. lead-lag flow treatment vessel arrangements.

These technologies were selected for evaluation in this study, as they are the primary groundwater arsenic removal technologies currently in use. Other arsenic treatment technologies are also available; however, they are generally some variation of the primary categories. Additionally, due to potential contamination and liability issues, AWC will not use arsenic treatment systems that require off-site media regeneration.

Coagulation/filtration treatment involves a pressurized granular media filtration process following iron addition. Ion exchange treatment includes arsenic adsorption onto resin-type media, which requires regeneration using concentrated sodium chloride solution (i.e., brine). This is a very complex process that involves pumps, storage of waste brine, and periodic discharge of the brine to onsite or offsite facilities. Adsorption is a simpler process and includes treatment using a special disposable or regenerable media, which possess effective arsenic removal capabilities.

Table 1 provides a summary of the various treatment technology and mitigation strategies evaluated as part of this study.

Table 1 Arsenic Treatment Technology and Mitigation Strategy Alternatives
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

		Coagulation/ Filtration (CF)	Ion Exchange (IX)	Sorptive Media (SM)
Alt. 1	Partial treatment	Alt. 1 C/F	Alt. 1 IX	Alt. 1 SM
Alt. 2	Full treatment	Alt. 2 C/F	Alt. 2 IX	Alt. 2 SM

After the initial workshop, AWC requested that Well No. 11 be considered for treatment at the Coolidge Well No. 13 site. Costs were developed based on a single sample collected during well development of Well No. 11. The pH and arsenic are higher in Well No. 11 compared to Well No. 13 so pH adjustment will likely be needed. Costs are presented at the end of Section 5.

2.0 BASIS OF EVALUATION

This evaluation will review the advantages and disadvantages of the various treatment technologies evaluated, as well as site constraints and issues. The evaluation will also include a cost analysis for each alternative. In order to properly select the best arsenic mitigation alternative, the evaluation process for this study will include the following components:

- Site space restrictions and new equipment spacing and layouts.
- Limitations on building heights.
- Potential of blending groundwater for partial stream treatment to reduce treatment equipment footprints and costs.
- Disposal costs for residual streams from the treatment processes for each of the treatment alternatives evaluated.

- Evaluation of extra pipeline costs for centralized treatment system, versus dedicated treatment systems for each site.
- Well production, AWC system production requirements, and well water quality parameters and their impacts on the different treatment technologies.
- Capital construction costs for each alternative.
- O&M costs for each alternative.
- 20-year life cycle costs for each analysis.
- Relative pros and cons of each alternative including:
  - Treatment technology effectiveness and reliability.
  - Each of operations, and the ability of the treatment systems to be shut down for weeks or months and then be restarted.
  - Disposal of residuals, regulatory permitting, and potential issues and costs associated with generation and disposal of Resource Conservation and Recovery Act (RCRA) wastes.
  - Constructability.
  - Footprint.
  - Impact on neighbors.
  - Issues associated with the relative remoteness of Coolidge Well #13 site as it relates to chemical shipments and chemical storage.

2.1 Design Criteria and Assumptions

Table 2 summarizes the design criteria and assumptions used to calculate the approximate sizes and footprints of new equipment. Table 3 summarizes the bypass flow calculations, and main treatment equipment footprints. Table 4 summarizes the ancillary equipment footprints (e.g., dewatering system, brine supply, ferric system).

Table 2 Design Criteria and Assumptions Used for Sizing Treatment Footprints
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

Item	Units	Value	Notes
Treatment Equipment (Pressure Vessels & Backwash Tanks)			
Flow Rates			
Coolidge #13	gpm	1250	
(other wells)	gpm	0	(not used)
Well Utilization Rates			
Coolidge #13	%	25 -100	
Raw Water Arsenic			
Coolidge #13	µg/L	18	
(other wells)	µg/L	0	(not used)
Level of Treatment per Process			Arsenic concentration coming off filters/contactors. Value will affect blending ratio.
C/F	µg/L	6	AWC Oasis Site has 8 µg/L arsenic in filter effluent.
IX	µg/L	4	
SM (parallel)	µg/L	4	
SM (lead-lag)	µg/L	1	
Treatment goal for arsenic			Arsenic concentration going to distribution system. Value set by AWC.
C/F	µg/L	7	
IX	µg/L	7	
SM (parallel)	µg/L	7	ST and Siemens bed volume estimate (Well No. 13) was 76,000 and 30,000 respectively.
SM (lead-lag)	µg/L	8	ST bed volume estimate (Well No. 13) was 95,000.
Media Bed Depth			
C/F	ft	3.33	
IX	ft	3.33	
SM	ft	3.33	
Setback distances			
Between vessels or tanks	ft	3	C/F, IX, SM parallel
Between trains of vessels	ft	6	SM...between lead-lag and between train no.1 / no.2
Edge of Equipment to Edge of Pad	ft	2	BW, brine tanks, bag filters
Dished head height	ft	2	semi-elliptical dish assumed
Property line to equipment	ft	5	for equipment on north property line. Based on existing setback for chlorine storage shed
Property line to equipment	ft	10	for all other equipment
Backwash rates	gpm/ft^2	12	SM
		20	C/F
	gpm	---	Should not exceed total pumping capacity of well(s)
Backwash duration	min	10	
Backwash Storage Tank			
No. of backwash volumes	no.	1.5	SM
		3.5	C/F...all three cells washed sequentially when operator is on-site
Height	ft	11.5	Storage volume only. Does not include freeboard or roof pitch
Ancillary Equipment (Chemical Tanks, Dewatering Equipment and Brine Tanks)			
Setbacks			
Tank to pad	ft	1.75	
Pad to curb	ft	3	
Curb Width	ft	0.5	
Curb Height	ft	0.75	
Tank Size			
Ferric System			Approximately 30 days of storage at average dose and maximum well flow Minimum 250 gallon considering minimum delivery size provided by suppliers Size based on standard sizes for double-lined tanks from Polyprocessing (HDPE)
Ferric chloride dose	mg/L	3	
Containment volume	%	25	% of total bulk storage volume
Dewatering			Reflects standard size for SludgeMate dewatering equipment including setbacks
Brine Supply			30 days of storage
Brine Waste	gal/gpm	40	gallons storage per gpm of treatment capacity
Brine Reuse	%	10	of waste storage

Table 3 Summary of Bypass Flows and Treatment Equipment Footprints
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

Alternative No.	Treatment Technology	Coolidge #13											
		Flowrates (gpm)			Treatment Vessel			Vessel Pad			Backwash Tank		Backwash Tank Pad
		Treated	Bypassed	Total	No.	Dia. (ft)	Length (ft)	Length (ft)	Width (ft)	Pad (ft^2)	Dia. (ft)	Vol. (gal)	Length or Width (ft)
1	C/F (vertical)	1,146	104	1,250	2	11.0	---	30	16	480	31	66,523	37
	C/F (horizontal)	1,146	104	1,250	1	9.0	25	25	14	354	26	44,730	31
	SM (parallel)	982	268	1,250	2	10	---	28	15	420	14	14,137	18
	SM (lead-lag)	735	515	1,250	4	8.7	---	28	28	807	13	10,700	17
	IX	982	268	1,250	3	10	---	41	15	615	(see "Ancillary Equipment" table)		
2	C/F (vertical)	1,250	0	1,250	2	11.5	---	31	17	512	33	72,708	37
	C/F (horizontal)	1,250	0	1,250	1	9.8	25	25	15	374	27	48,706	31
	SM (parallel)	1,250	0	1,250	2	11.3	---	31	16	499	16	18,052	20
	SM (lead-lag)	1,250	0	1,250	4	11.3	---	34	34	1129	16	18,052	20
	IX	1,250	0	1,250	3	11.3	---	45	16	732	(see "Ancillary Equipment" table)		

Notes:

1. "Total" represents total flow to distribution system.
2. Backwashing for C/F or SM will use distribution system water, thus eliminating the need to design using smaller filters to accommodate backwash flowrates.
3. Footprints represent large unit processes. Refer to "Ancillary Equipment" table for additional tanks. Small process pumps and equipment (e.g., backwash return) are not considered. These will be small enough to fit adjacent to tanks.
4. For IX, the vessel quantity and sizing is the same as SM (parallel) except for the addition on an additional vessel to serve as standby after media regeneration.

Table 4 **Summary of Ancillary Equipment Sizes and Footprints**
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

Alternative No.	Treatment Technology	Ancillary Unit Process	Tank				Pad			Containment Volumes	
			No.	Size	Units	Diameter (ft)	Length (ft)	Width (ft)	Area (ft^2)	Min. Required (gal)	Calculated (gal)
1	C/F (w/ bypass)	Ferric	1	540	gal	7	14	11	142	135	154
		Sludge Dewatering	2	25	CY	—	24	16	372	—	—
2	C/F (no bypass)	Ferric	1	540	gal	7	14	11	142	135	154
		Sludge Dewatering	2	25	CY	—	24	16	372	—	—
3	IX (w/ bypass)	Bag Filters (Prefilter)	9	982	gpm	1	19	3	57	—	—
		Brine Supply	2	30	ton	10	27	14	378	—	—
		Brine Waste	3	9,100	gal	12	46	16	736	—	—
		Brine Recycle	1	5,893	gal	9	13	13	173	—	—
4	IX (no bypass)	Bag Filters (Prefilter)	12	1,250	gpm	1	25	3	75	—	—
		Brine Supply	2	40	ton	10	27	14	378	—	—
		Brine Waste	3	12,150	gal	12	46	16	736	—	—
		Brine Recycle	1	5,893	gal	9	13	13	173	—	—
5	SM Parallel (w/ bypass)	Bag Filters (Prefilter)	9	982	gpm	1	19	3	57	—	—
		Bag Filters (Recycle)	1	98	gpm	1	3	3	9	—	—
6	SM Lead-Lag (w/ bypass)	Bag Filters (Prefilter)	7	735	gpm	1	15	3	45	—	—
		Bag Filters (Recycle)	1	98	gpm	1	3	3	9	—	—
7	SM Parallel (no bypass)	Bag Filters (Prefilter)	12	1,250	gpm	1	25	3	75	—	—
		Bag Filters (Recycle)	1	125	gpm	1	3	3	9	—	—
8	SM Lead-Lag (no bypass)	Bag Filters (Prefilter)	12	1,250	gpm	1	25	3	75	—	—
		Bag Filters (Recycle)	1	125	gpm	1	3	3	9	—	—

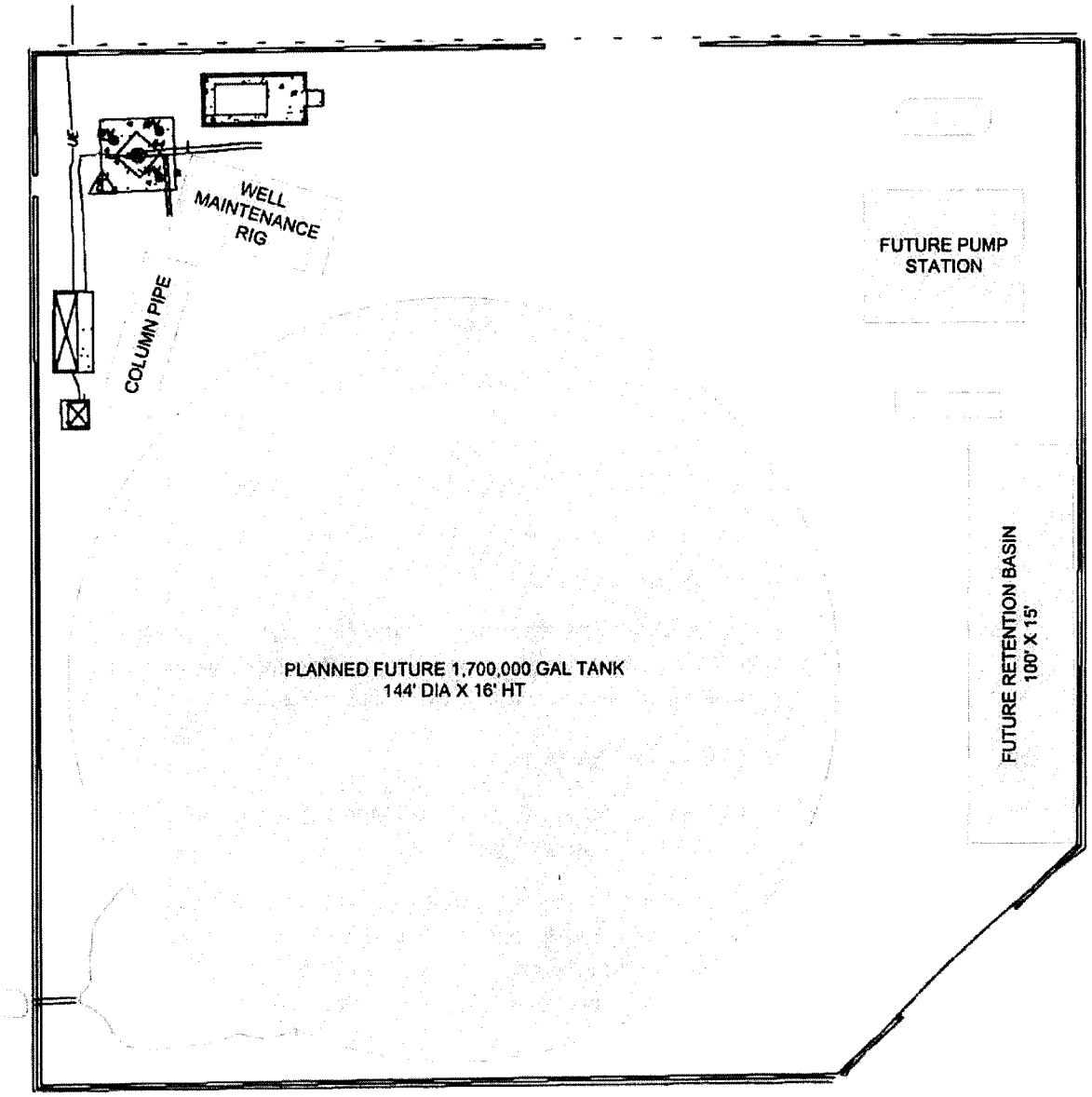
2.2 Site Constraints

This evaluation includes conceptual site layouts for each alternative in order to visualize the footprints of treatment and ancillary equipment on the site, which must take into account the significant area constraints at the Well No. 13 site. Site constraints associated with the Well No. 13 site are depicted in Figure 1 and described as follows:

- Well No. 13 in northwest corner of the site.
- Existing chlorination building and electrical control panel are located in the northwest corner of the site.
- Allow areas for rig to access Well 13, and for column pipe to be laid.
- Future retention basin on east side of the site, can be relocated to the southwest corner of the site.
- Future 1.7-MG storage tank is planned in the center of the site.
- Future booster pump station and hydropneumatic tank in northeast corner of the site.
- Future primary access to site will be via the southeast corner of the site, therefore the area must remain unobstructed.

The site layouts presented as part of the evaluation for each alternative includes the footprints of AWC's future planned equipment. These planned components are shown in light blue in the figures for the alternative site layouts. The grey components represent the footprints of the arsenic treatment equipment required for the first phase of construction to treat a flow of 1,250 gpm from Well No. 13. The light green components represent the footprints of the additional arsenic treatment equipment required for buildout flow of 2,500 gpm from both Well Nos. 11 and 13.

All sites layouts presented herein use an raw water arsenic concentration of 0.023 mg/L. This is a conservative approach used to take into account any increases in groundwater arsenic concentration coming from Well No. 13 or if nearby Well No. 11 is ever brought to the site for treatment. Well No. 11 has higher arsenic levels compared to Well No. 13.



0 ft. 18 ft. 30 ft. 60 ft.

N

LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 1 – Well No. 13 Site Constraints

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo

3.0 ALTERNATIVE 1 – PARTIAL TREATMENT

Alternative 1 involves a partial treatment stream (coagulation/filtration, ion exchange, or sorptive media) allowing for blending in order to meet finished water arsenic goals.

3.1 Alternative 1 Coagulation/Filtration (1 C/F)

A process flow schematic for coagulation/filtration treatment is presented in Figure 2. The bypass line shown is applicable for Alternative 1 where partial treatment will occur.

Figure 3 provides a conceptual site plan for the treatment and ancillary equipment required for coagulation/filtration at the Well No. 13 site. This site plan assumes horizontal pressure vessels. An equipment space is also shown for "Solids Handling." This space is based on a SludgeMate type bin that further thickens the used backwash water residuals in order to reduce the disposal volumes.

3.2 Alternative 1 Ion Exchange (1 IX)

Figure 4 is a process flow schematic for ion exchange, in which the bypass line shown will be applicable for Alternative 1. Figure 5 provides a conceptual site plan for the treatment and ancillary equipment required for ion exchange at the Well No. 13 site.

3.3 Alternative 1 Sorptive Media (1SM)

Arsenic treatment via sorptive media can be accomplished in two configurations: lead-lag and parallel. This evaluation explored both configurations.

A conservative layout was considered by assuming that a second backwash waste tank is required when the treatment capacity is expanded in the future. It is possible that due to such infrequent backwashing of the SM process (e.g., once a month) that only one tank would be needed. There would be adequate time between backwashing vessels to recycle the decanted backwash water.

3.3.1 Lead-Lag Operation

Figure 6 provides a process flow schematic for arsenic treatment using sorptive media in the lead-lag configuration. For partial treatment of Well No. 13, the bypass line would be utilized.

Figure 7 provides a conceptual site plan for treatment and ancillary equipment needed for sorptive media the Well No. 13 site in a lead-lag configuration.

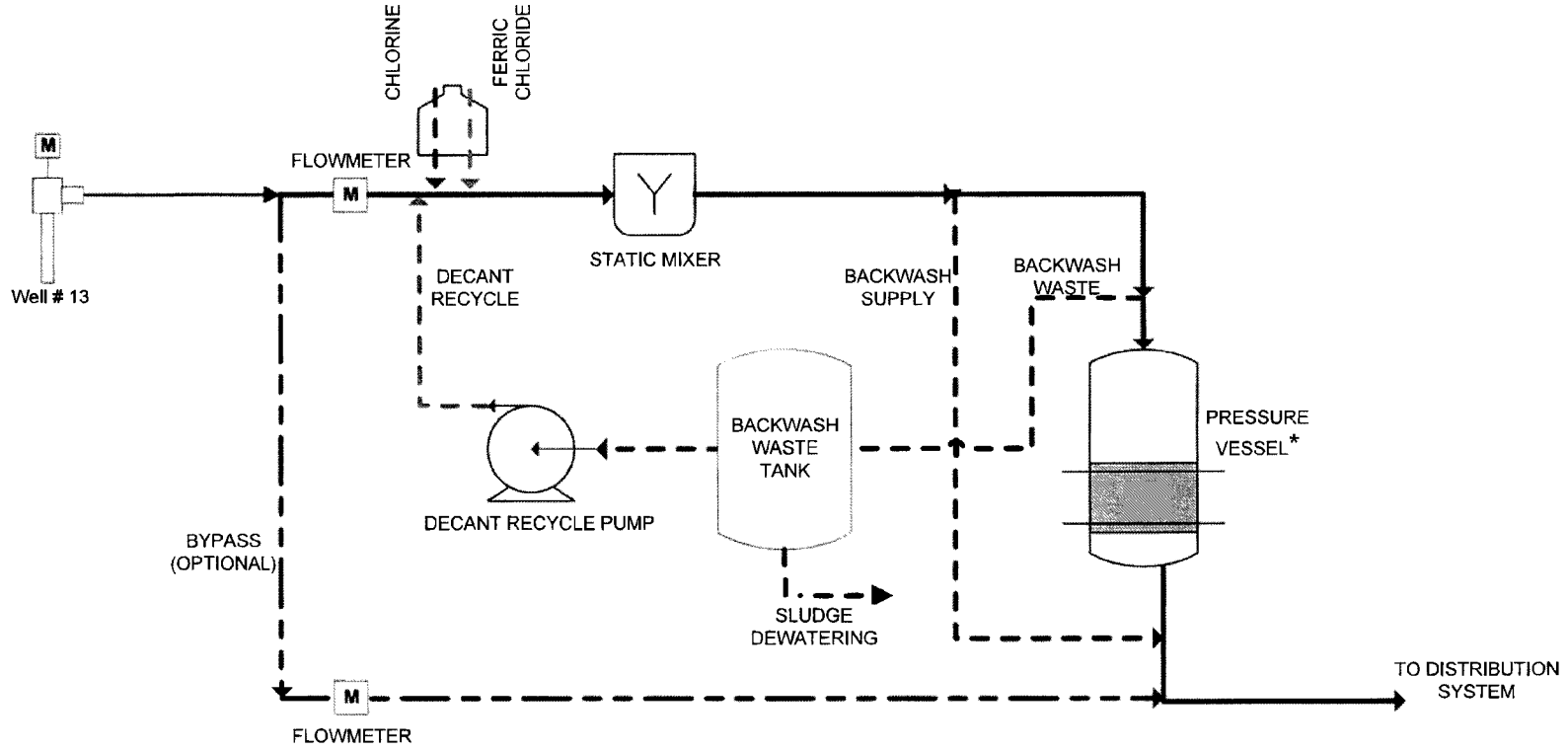
3.3.2 Parallel Operation

Figure 8 presents the process flow schematic for arsenic treatment using sorptive media in the parallel configuration.

Figure 9 shows the conceptual site plan for the treatment and ancillary equipment needed for sorptive media at the Well No. 13 site, but in a parallel configuration

3.4 Conclusions for Alternative 1

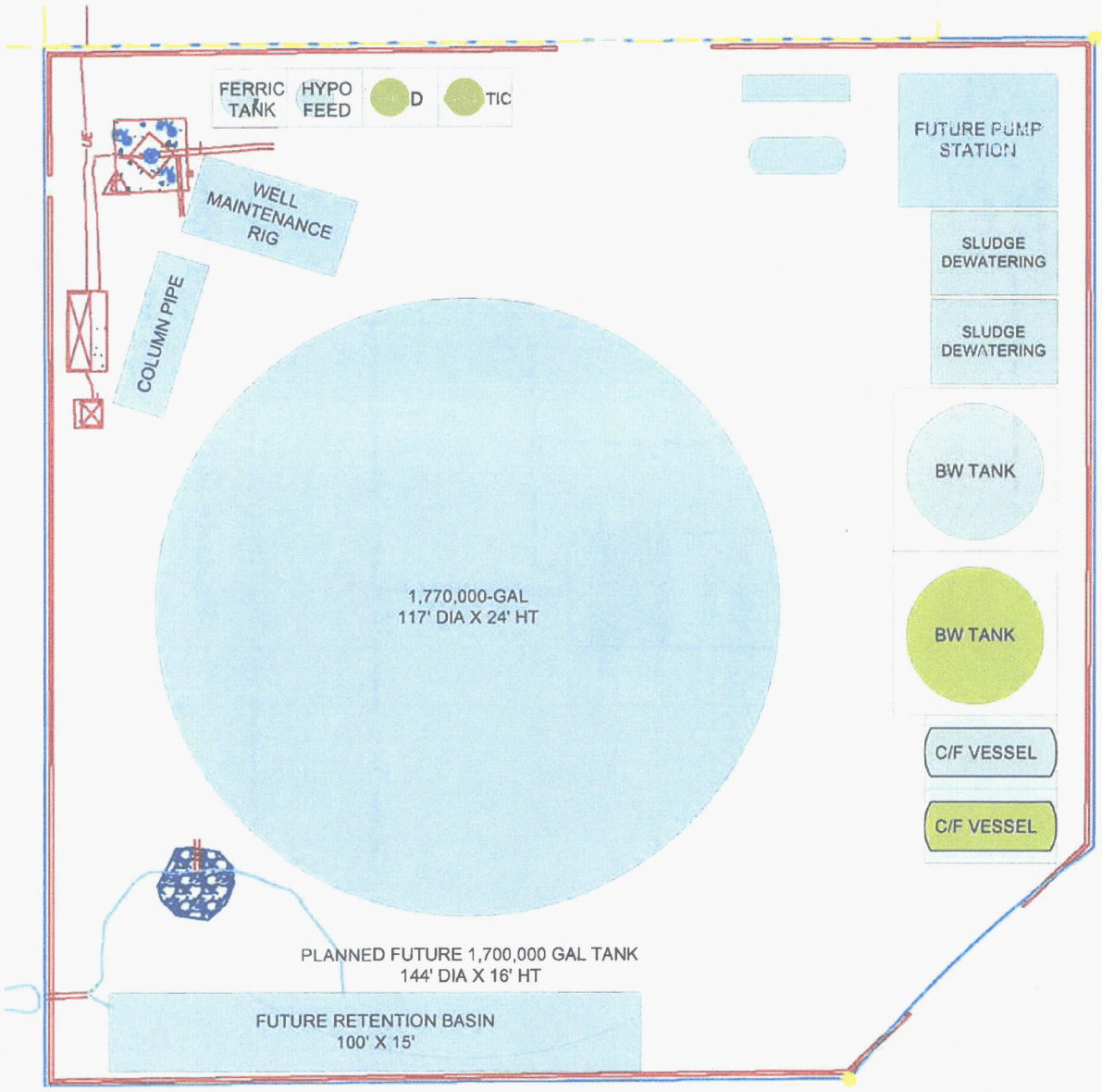
This alternative considers partial treatment of the well. A portion of raw well water is bypassed and then blended with the treatment effluent. The final blend before going into the distribution system is less than 0.010 mg/L. In order of increasing footprint, treatment technologies ranked as follows: SM (parallel), SM (lead-lag), C/F and IX. All treatment technologies were able to fit on the site considering that most of the area is undeveloped. Treatment equipment for all technologies was located on the east side of the site. This provides maintenance access between the treatment equipment and future storage tank.



* ONLY ONE VESSEL SHOWN FOR CLARITY. PFD IS APPLICABLE WHETHER VESSELS IS VERTICAL OR HORIZONTAL IN ORIENTATION.

Figure 2 – C/F Process Flow Schematic

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY



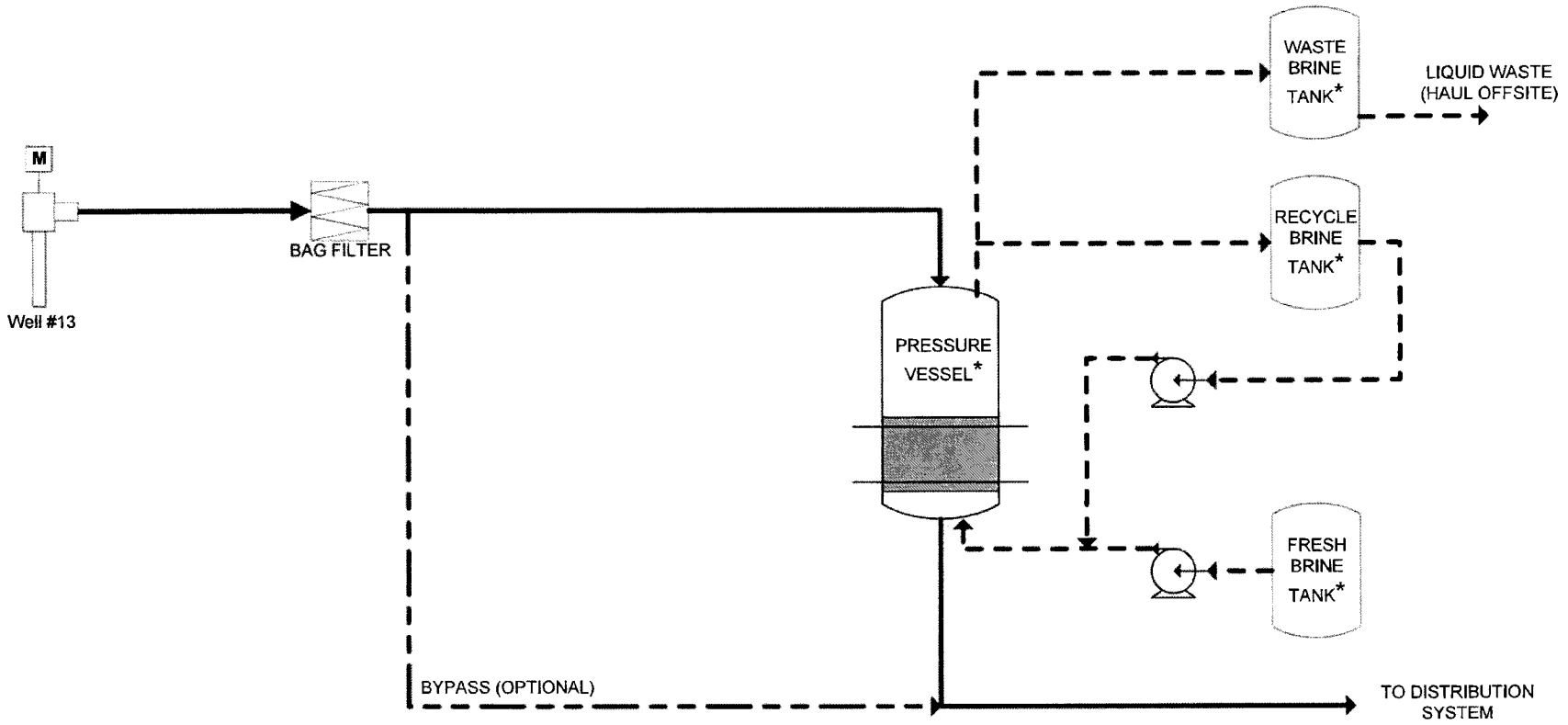
LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 3 – Alternative 1 C/F Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

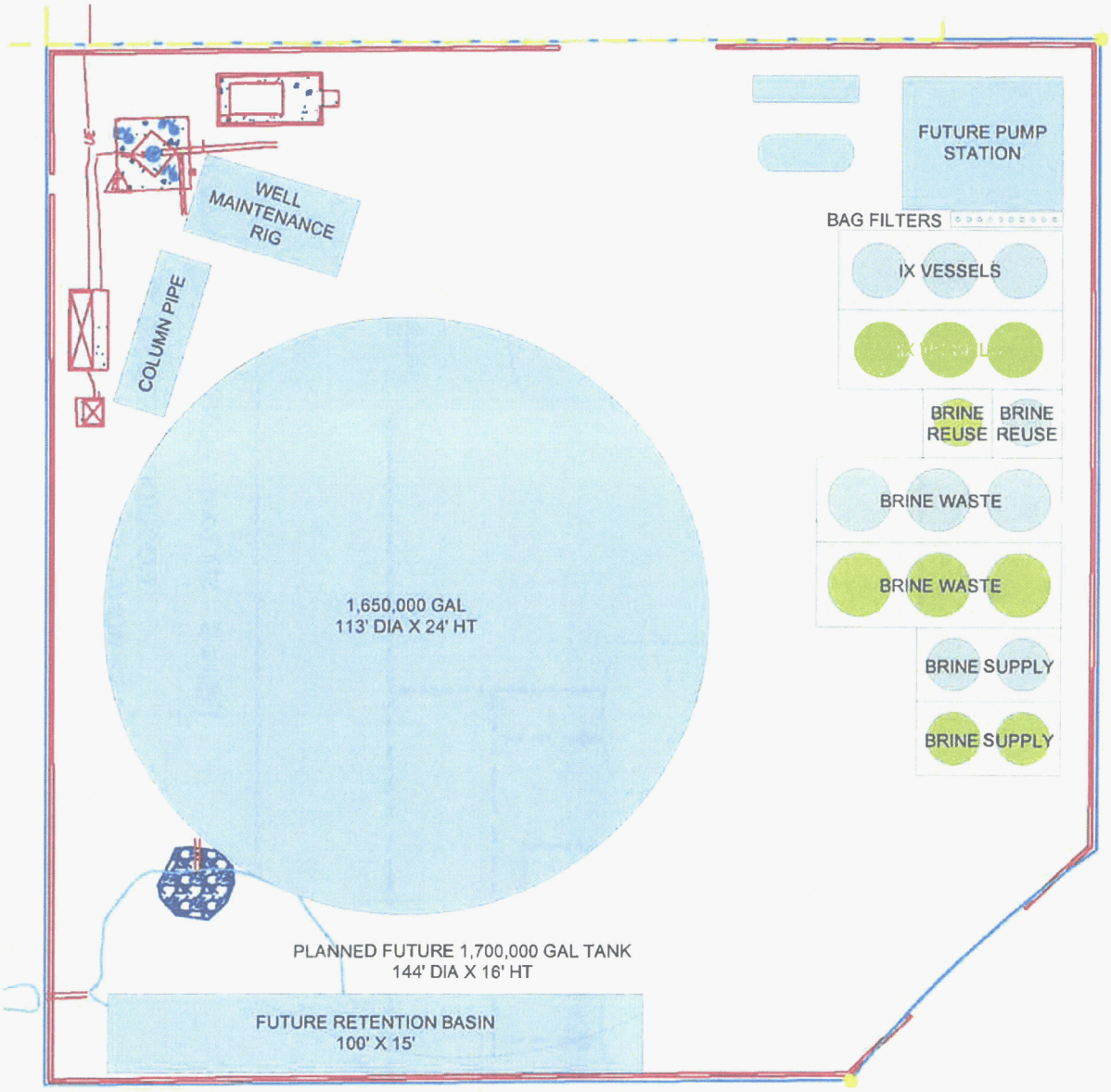
carollo

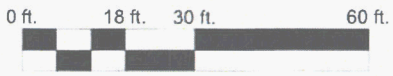


* ONLY ONE TANK/VESSEL SHOWN FOR CLARITY

Figure 4 – IX Process Flow Schematic

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY





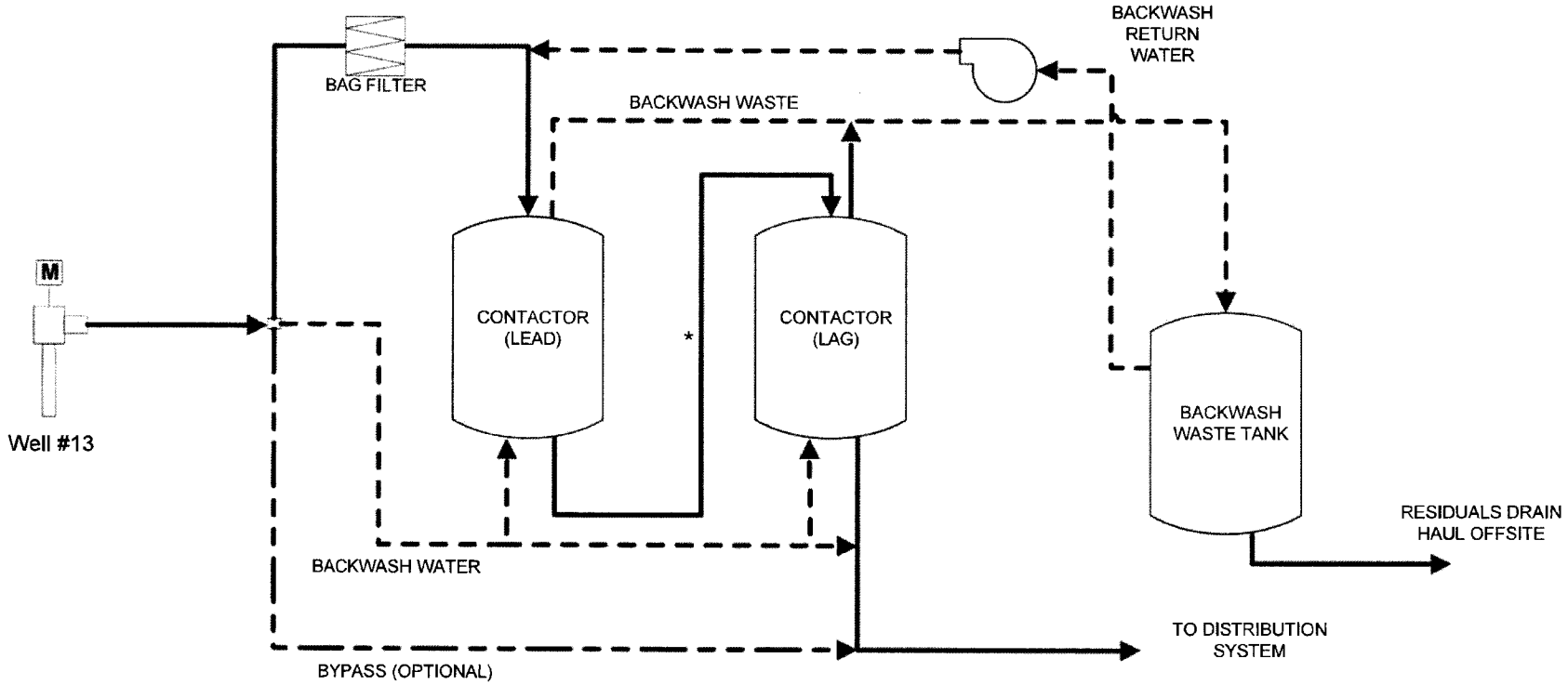
LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 5 – Alternative 1 IX Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

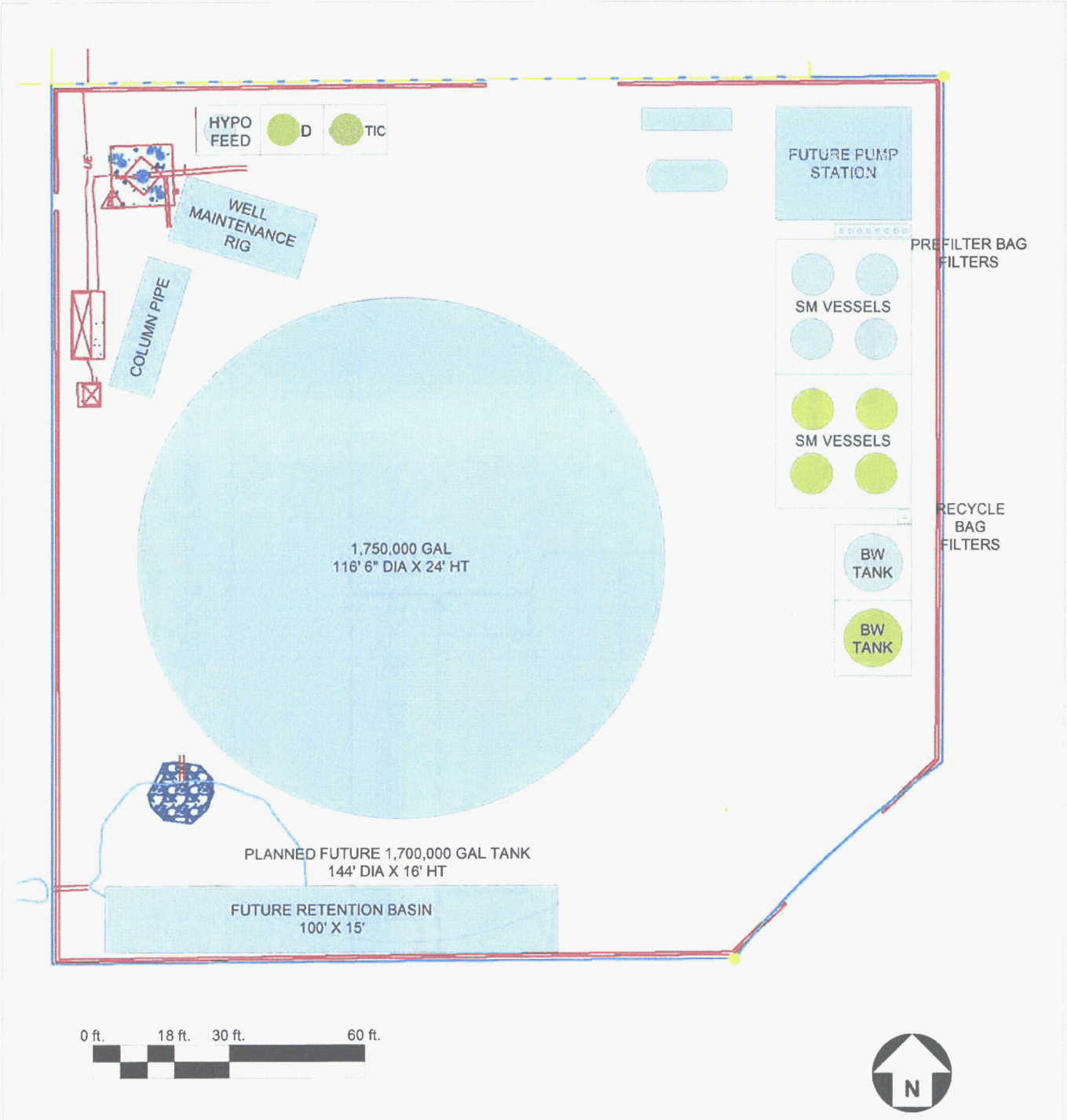
carollo



* FOR CLARITY, PIPING DOES NOT SHOW HOW LEAD CONTACTOR BECOMES LAG CONTACTOR.

Figure 6 – SM Lead-Lag Process Flow Schematic

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY



LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 7 – Alternative 1 SM Lead-Lag Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo

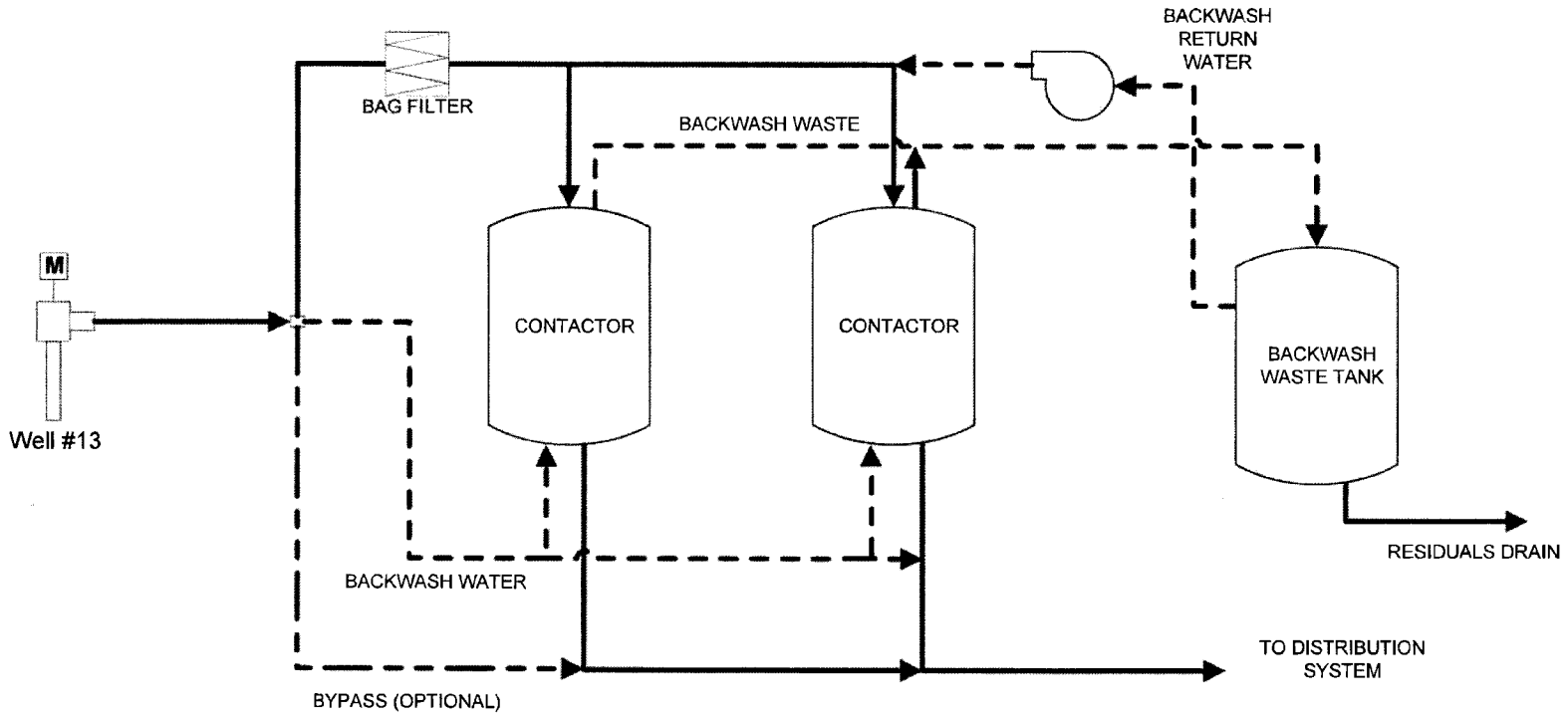
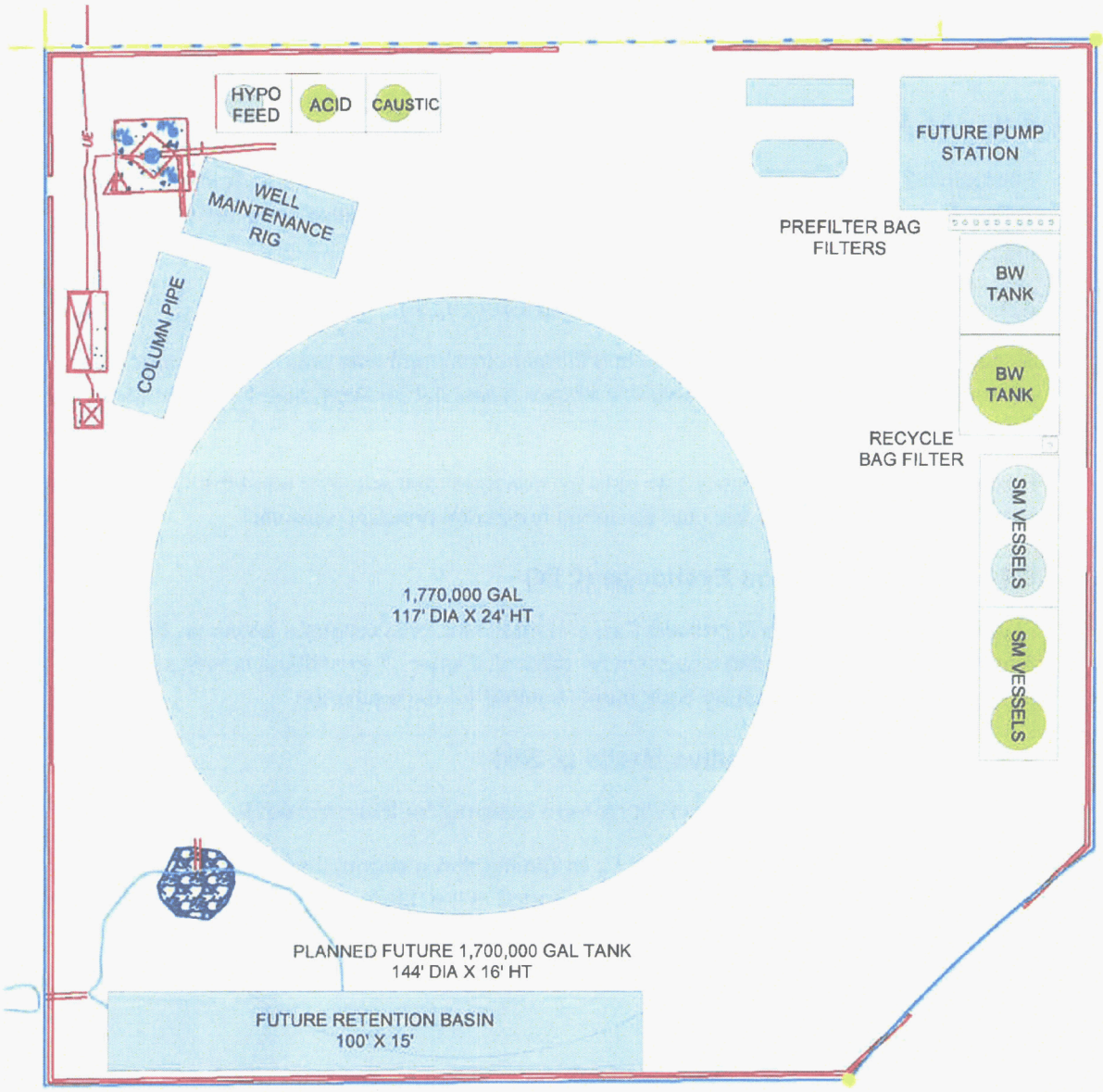


Figure 8 – SM Parallel Process Flow Schematic

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY



LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 9 – Alternative 1 SM - Parallel Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo

4.0 ALTERNATIVE 2 – FULL TREATMENT

Alternative 2 assumes full treatment (coagulation/filtration, ion exchange or sorptive media) of flow from Well No. 13. In contrast to Alternative 1, this alternative does not allow for blending of treated and raw water in order to meet finished water arsenic goals.

4.1 Alternative 2 Coagulation/Filtration (2 C/F)

A process flow schematic for coagulation/filtration treatment was provided in Figure 2. In contrast to Alternative 1, the bypass line shown would not be applicable for Alternative 2 as full treatment would occur.

Figure 10 provides a conceptual site plan for treatment and ancillary equipment required for coagulation/filtration. This site plan assumes horizontal pressure vessels.

4.2 Alternative 2 Ion Exchange (2 IX)

Figure 4 provided a general process flow schematic for ion exchange; however, for Alternative 2, the bypass line would not be utilized. Figure 11 provides a conceptual site plan for treatment and ancillary equipment required for ion exchange.

4.3 Alternative 2 Sorptive Media (2 SM)

Both lead-lag and parallel configurations were explored for this alternative.

A conservative layout was considered by assuming that a second backwash waste tank is required when the treatment capacity is expanded in the future. It is possible that due to such infrequent backwashing of the SM process (e.g., once a month) that only one tank would be needed. There would be adequate time between backwashing vessels to recycle the decanted backwash water.

4.3.1 Lead-Lag Operation

Figure 6 provided a general process flow schematic for arsenic treatment using sorptive media in the lead-lag configuration. For full treatment of Well No. 13, the bypass line shown would not be applicable for Alternative 2.

Figure 12 provides a conceptual site plan for treatment and ancillary equipment needed for sorptive media in a lead-lag configuration.

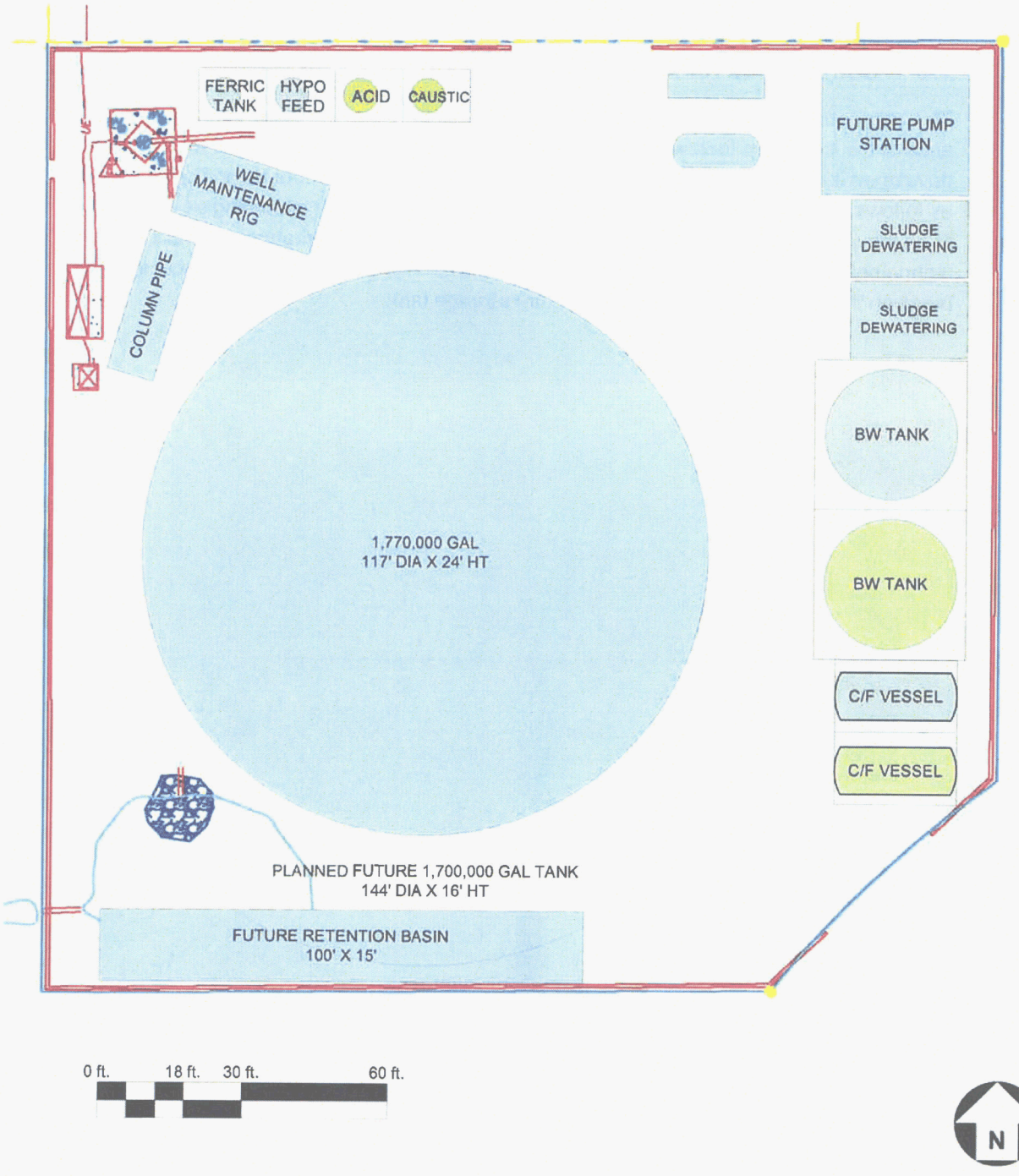
4.3.2 Parallel Operation

Figure 8 presented the general process flow schematic for arsenic treatment using sorptive media in the parallel configuration. Alternative 2 is represented without the bypass line.

Figure 13 also shows the conceptual site plan for the treatment and ancillary equipment needed for sorptive media, but in a parallel configuration

4.4 Conclusions for Alternative 2

This alternative considers full flow treatment of the well. Thus, the footprints associated with each of the treatment technologies for Alternative 2 will be larger compared to footprints developed for Alternative 1. In order of increasing footprint, treatment technologies ranked as follows: SM (parallel), SM (lead-lag), C/F and IX. All treatment technologies were able to fit on the site considering that most of the area is undeveloped. Treatment equipment for all technologies was located on the east side of the site. This provides maintenance access between the treatment equipment and future storage tank.



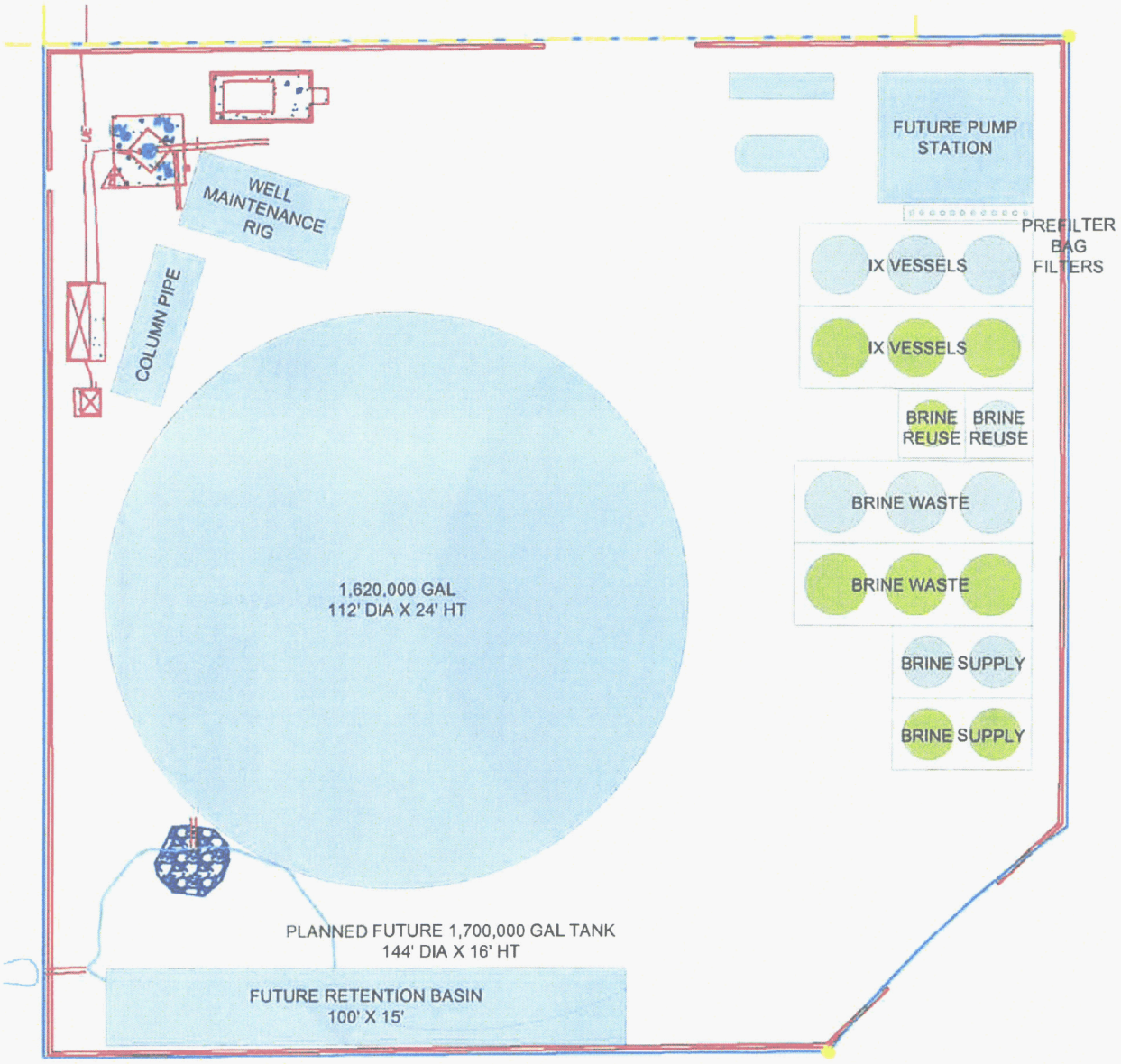
LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 10 – Alternative 2 C/F Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo



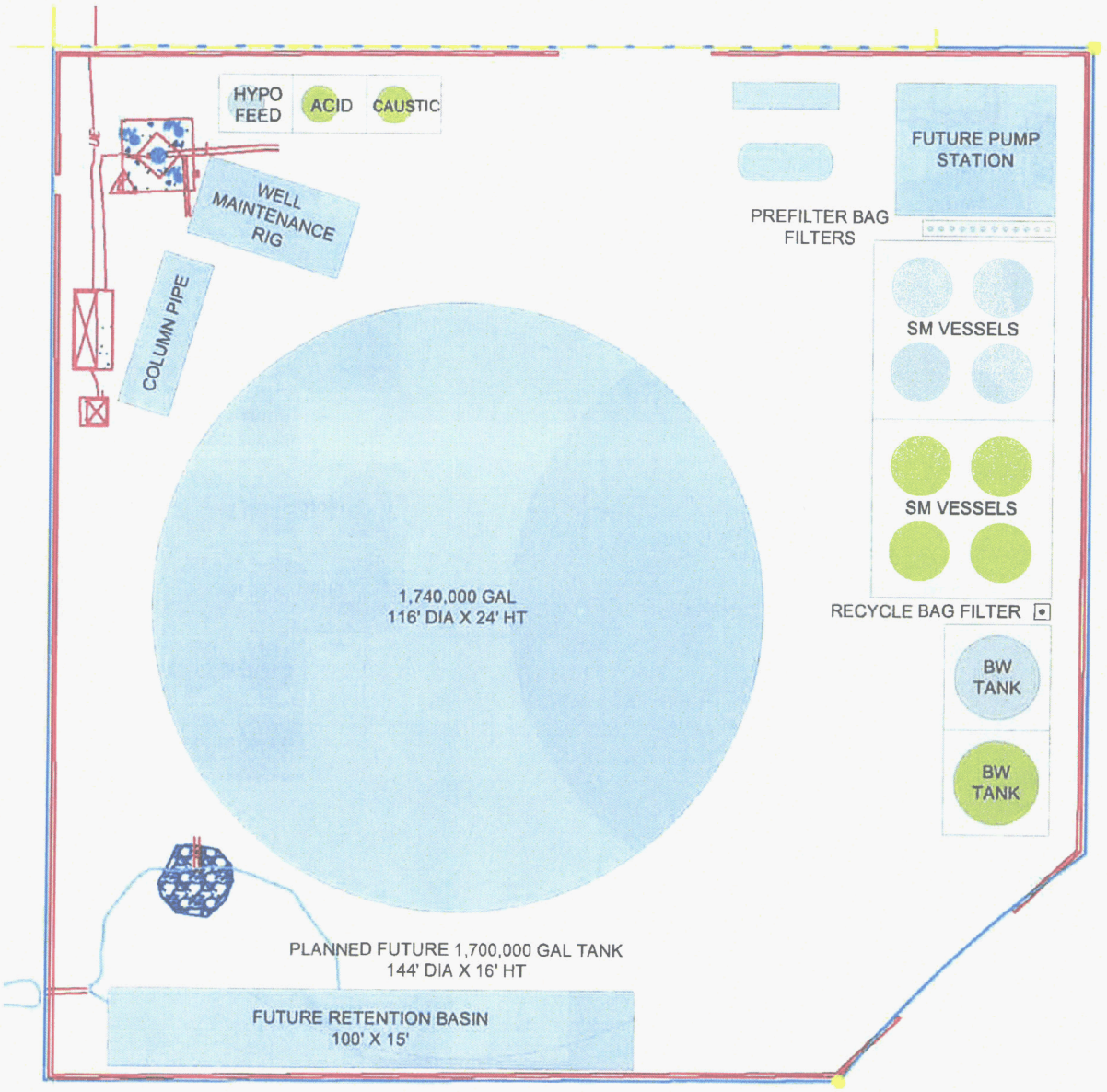
LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 11 – Alternative 2 IX Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo



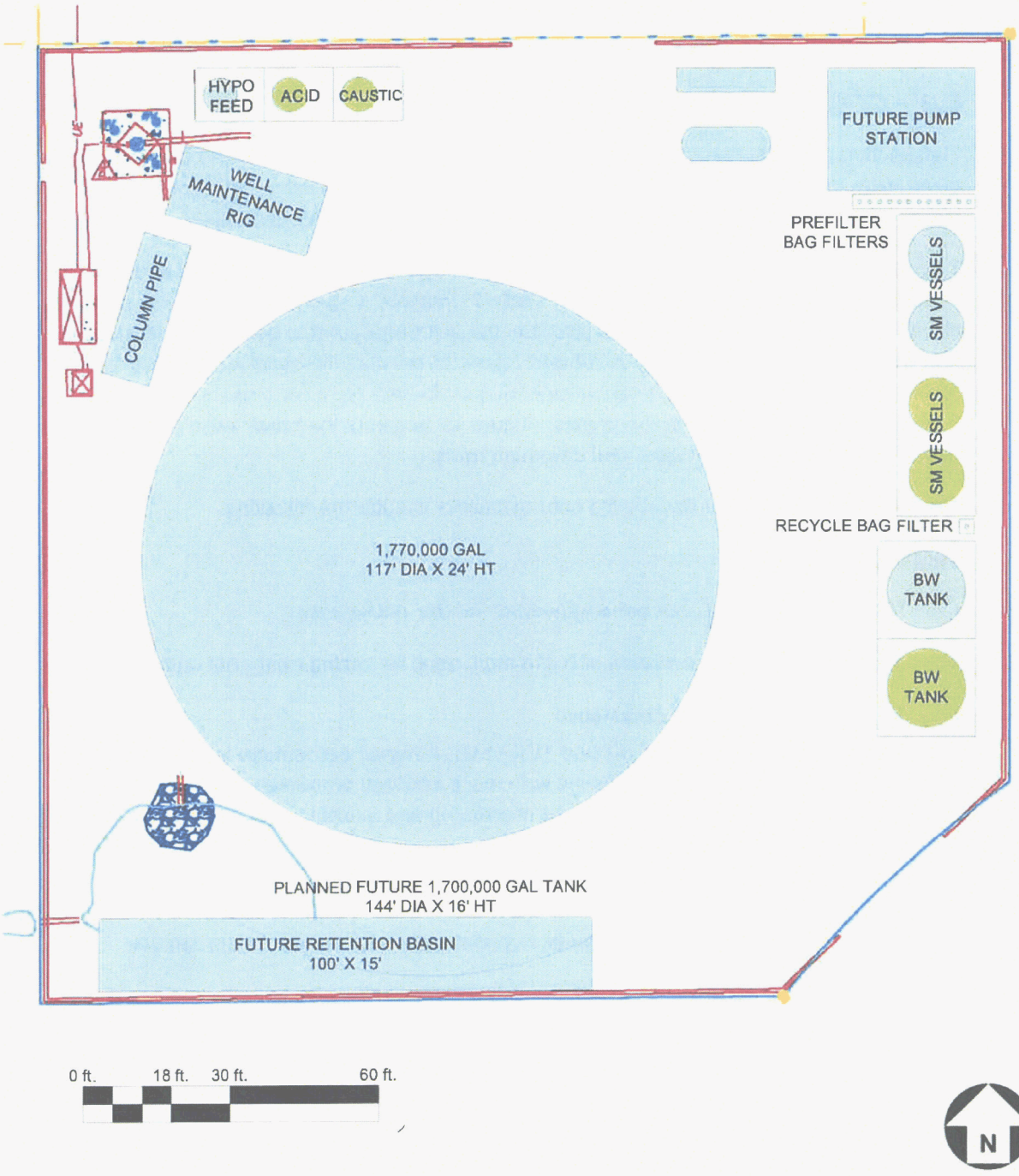
LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 12 – Alternative 2 SM – Lead-Lag Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo



LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Figure 13 – Alternative 2 SM - Parallel Site Layout

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo

5.0 COST ANALYSIS

This section presents construction costs, operating and maintenance (O&M) costs, and life-cycle costs for each alternative. Construction costs were developed using a combination of sources including Carollo cost databases, RS Means, and supplier quotations.

Table 5 and 6 present the cost breakdowns for Alternative 1 (partial treatment) and Alternative 2 (full treatment) respectively. Table 7 presents a summary of life-cycle costs for all alternatives. Appendices B and C provides the unit costs used to develop construction and O&M costs respectively. Figure 14 and Figure 15 present life-cycle cost curves for Alternative 1 and Alternative 2 to determine the break-even point (or crossover point) between different treatment technologies. Figure 16 presents the break-even point between C/F and SM at different well utilization rates.

Key assumptions used for developing cost estimates include the following:

Construction Costs

- "Custom layout" (i.e., not pre-engineered, vendor packages)
- Arsenic influent concentration of 0.018 mg/L used for sizing treatment equipment.
- Percentage markups of direct cost:
  - E&IC: 20% (C/F and IX) and 10% (SM). A higher percentage is assumed for those treatment technologies with more ancillary processes that must be connected and coordinated for monitoring and control.
  - Civil Site Work: 10%
  - Contingency: 20%
- General Conditions Includes: bonds, superintendent & foreman salary, on-site trailer/facilities & profit: 10%.
- Sales Tax: 4% (of half of all direct costs).
- The costs are in today's dollars (November 2011) and are not escalated for future construction or operation.

O&M Costs

- 20-year life-cycle with 4-percent interest rate.
- AWC staff operating the systems (i.e., no leasing agreement with system supplier).

To normalize the cost comparison, all treatment technologies were sized based on a "custom" design. All of the treatment technologies are offered in vendor-designed, package

plants of a variety of sizes. Vendors may adjust and fine tune treatment footprints as appropriate for their given system.

5.1 Comparison of Costs

Key findings from the cost comparison among the different alternatives and treatment technologies are as follows:

- As would be expected, partial treatment (Alternative 1) has lower construction (capital), life cycle, and O&M costs. Subsequent findings below are bas ed on results from Alternative 1 only.
- In order of lowest to highest construction costs: SM (parallel), SM (lead-lag), C/F (horizontal vessel), C/F (vertical vessel) and IX.
- Lowest construction cost is SM (parallel) at $1.3 million.
- Lowest life-cycle cost alternative at 50% well utilization rate is SM (lead-lag) at $3.3 million.
- At a 50% well utilization rate, SM (lead-lag) has a lower life-cycle cost after year 7 compared to SM (parallel) and C/F.
- For well utilization rates greater than 70%, CF has a slightly lower life-cycle cost (only 3% at year 20).

Table 5 Capital and O&M Cost Summary for Alternative No. 1 (Partial Treatment) for Well No. 13
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Capital Cost					
Site Work	$216,000	$205,000	$137,000	$182,000	$311,000
Yard Piping	$349,000	$349,000	$325,000	$289,000	$325,000
Treatment Equipment	$282,000	$340,000	$323,000	$517,000	$413,000
E&IC	$300,000	$290,000	$100,000	$120,000	$350,000
Ancillary Systems	$84,000	$84,000	$18,000	$14,000	$179,000
Waste Storage / Treatment	$271,000	$189,000	$75,000	$62,000	$182,000
Direct Costs	**$1,500,000**	**$1,460,000**	**$980,000**	**$1,180,000**	**$1,760,000**
Contingency	$300,000	$290,000	$200,000	$240,000	$350,000
General Conditions	$180,000	$180,000	$120,000	$140,000	$210,000
Sales Tax	$40,000	$40,000	$30,000	$30,000	$50,000
Indirect Costs	**$520,000**	**$510,000**	**$350,000**	**$410,000**	**$610,000**
TOTAL CONSTRUCTION COSTS	**$2,020,000**	**$1,970,000**	**$1,330,000**	**$1,590,000**	**$2,370,000**
Annual O&M Cost					
Labor	$38,800	$38,800	$22,800	$22,800	$46,800
Electricity	$49,100	$49,100	$34,800	$34,800	$43,100
Chemicals	$2,600	$2,600	$400	$400	$155,200
Media / Equipment Replacement	$13,300	$13,300	$119,200	$70,600	$16,700
Waste Handling/Disposal	$5,100	$5,100	$200	$200	$120,800
TOTAL ANNUAL COSTS	**$108,900**	**$108,900**	**$177,400**	**$128,800**	**$382,600**
Life-Cycle Cost (2011 USD)					
Capital Cost	$2,020,000	$1,970,000	$1,330,000	$1,590,000	$2,370,000
Annualized O&M Cost	$1,480,000	$1,480,000	$2,411,000	$1,750,000	$5,200,000
TOTAL VALUE	**$3,500,000**	**$3,450,000**	**$3,741,000**	**$3,340,000**	**$7,570,000**

2

Table 6 **Capital and O&M Cost Summary for Alternative No. 1 (Full Treatment) for Well No. 13**
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Capital Cost					
Site Work	$228,000	$216,000	$153,000	$244,000	$339,000
Yard Piping	$365,000	$365,000	$365,000	$365,000	$365,000
Treatment Equipment	$291,000	$372,000	$380,000	$721,000	$471,000
E&IC	$320,000	$310,000	$110,000	$160,000	$410,000
Ancillary Systems	$84,000	$84,000	$23,000	$23,000	$206,000
Waste Storage / Treatment	$295,000	$204,000	$91,000	$91,000	$243,000
Direct Costs	**$1,580,000**	**$1,550,000**	**$1,120,000**	**$1,600,000**	**$2,030,000**
Contingency	$320,000	$310,000	$220,000	$320,000	$410,000
General Conditions	$190,000	$190,000	$130,000	$190,000	$240,000
Sales Tax	$40,000	$40,000	$30,000	$40,000	$50,000
Indirect Costs	**$550,000**	**$540,000**	**$380,000**	**$550,000**	**$700,000**
TOTAL CONSTRUCTION COSTS	**$2,130,000**	**$2,090,000**	**$1,500,000**	**$2,150,000**	**$2,730,000**
Annual O&M Cost					
Labor	$38,800	$38,800	$22,800	$22,800	$46,800
Electricity	$53,600	$53,600	$59,100	$59,100	$54,900
Chemicals	$2,900	$2,900	$700	$700	$197,600
Media / Equipment Replacement	$13,400	$13,400	$149,600	$117,300	$19,100
Waste Handling/Disposal	$5,600	$5,600	$200	$200	$153,700
TOTAL ANNUAL COSTS	**$114,300**	**$114,300**	**$232,400**	**$200,100**	**$472,100**
Life-Cycle Cost (2011 USD)					
Capital Cost	$2,130,000	$2,090,000	$1,500,000	$2,150,000	$2,730,000
Annualized O&M Cost	$1,553,000	$1,553,000	$3,158,000	$2,719,000	$6,416,000
TOTAL VALUE	**$3,683,000**	**$3,643,000**	**$4,658,000**	**$4,869,000**	**$9,146,000**

Table 7 Capital and Life-Cycle Cost Summary for Alternative No. 1 and No. 2 for Well No. 13
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Alternative No. 1 (Partial Treatment)					
Construction Cost	$2,020,000	$1,970,000	$1,330,000	$1,590,000	$2,370,000
Life-Cycle Cost	$3,500,000	$3,450,000	$3,741,000	$3,340,000	$7,570,000
Alternative No. 2 (Full Treatment)					
Construction Cost	$2,130,000	$2,090,000	$1,500,000	$2,150,000	$2,730,000
Life-Cycle Cost	$3,683,000	$3,643,000	$4,658,000	$4,869,000	$9,146,000

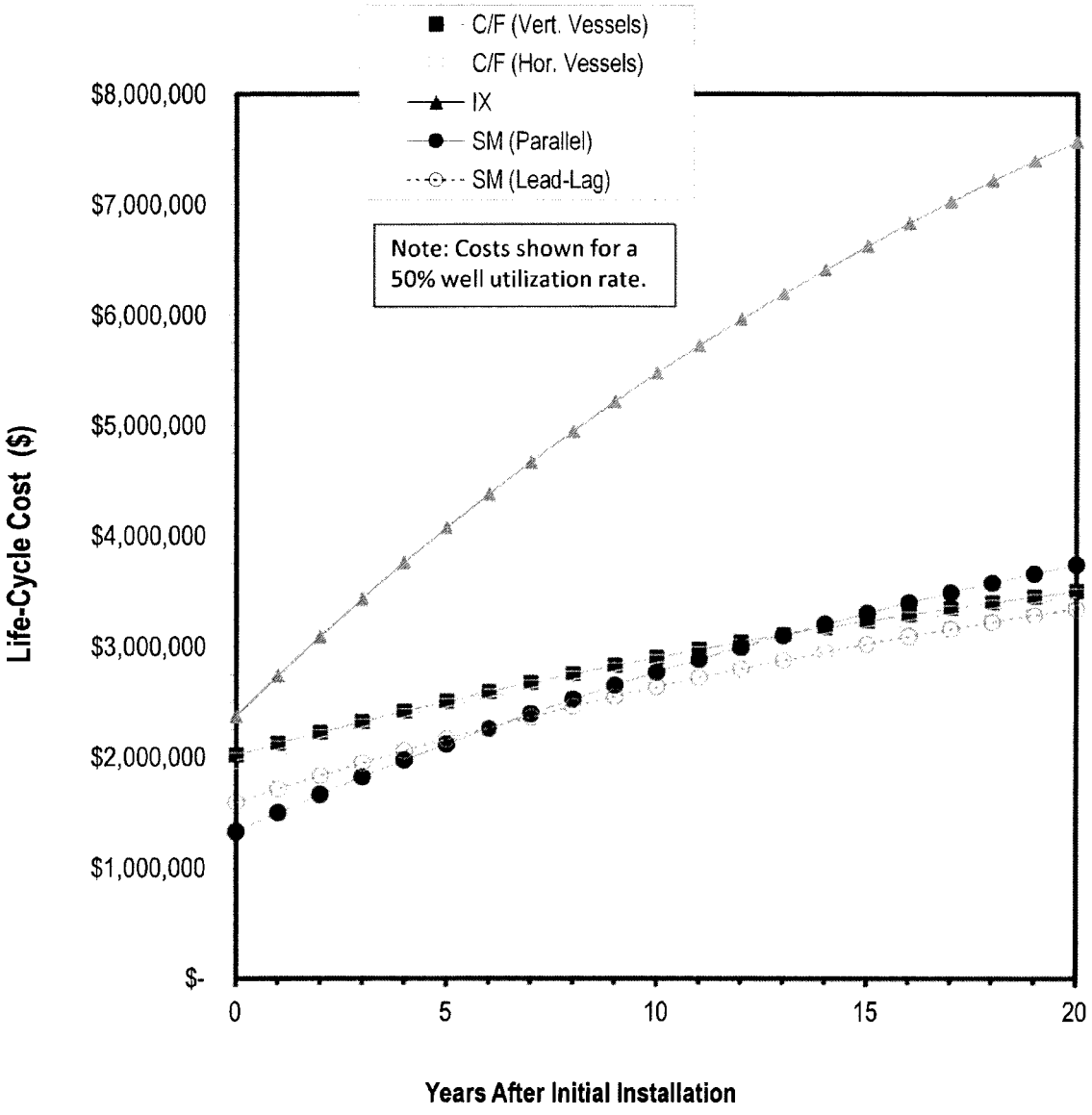


Figure 14
LIFE-CYCLE COSTS FOR ALTERNATIVE NO. 1 (Partial Treatment)
Arsenic Removal Facility Alternatives Evaluation
ARIZONA WATER COMPANY

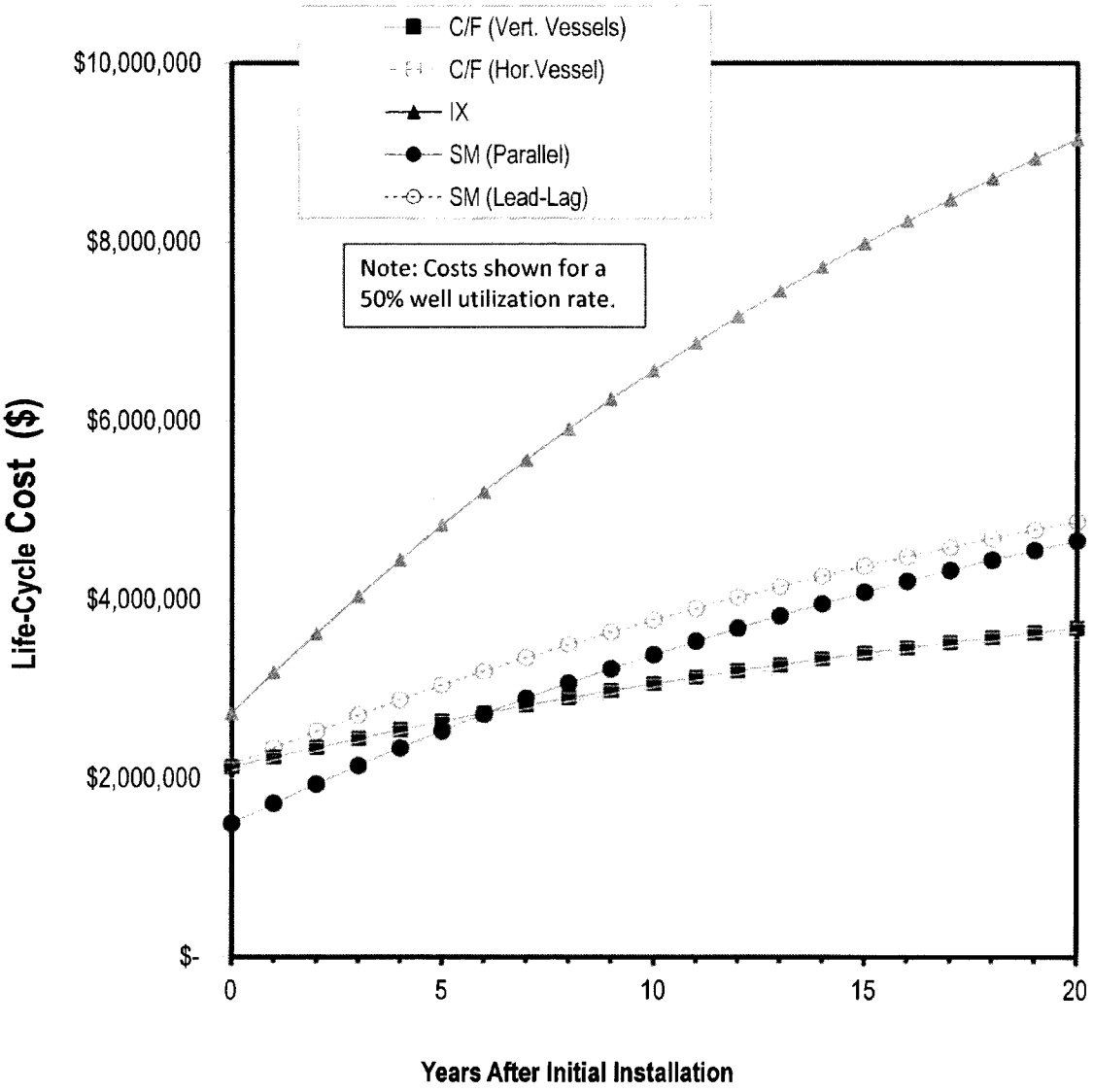


Figure 15
LIFE-CYCLE COSTS FOR ALTERNATIVE NO. 2 (Full Treatment)
Arsenic Removal Facility Alternatives Evaluation
ARIZONA WATER COMPANY

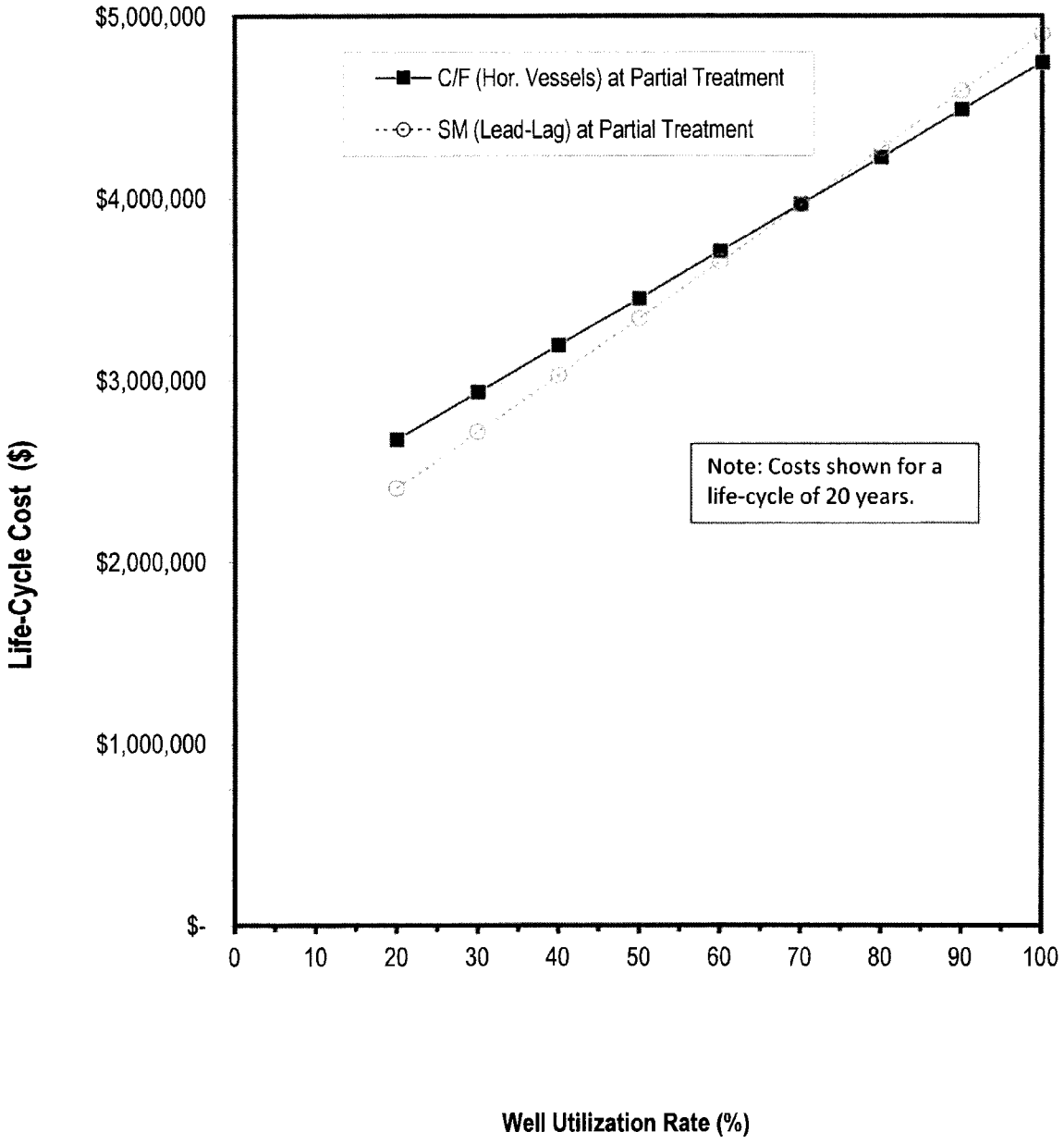


Figure 16
LIFE-CYCLE COSTS FOR C/F AND SM AT VARIOUS WELL UTILIZATION RATES
Arsenic Removal Facility Alternatives Evaluation
ARIZONA WATER COMPANY

Table 8 Capital and O&M Cost Summary for Alternative No. 1 (Partial Treatment) for Well No. 11
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Capital Cost					
Site Work	$216,000	$205,000	$139,000	$196,000	$313,000
Yard Piping	$354,000	$354,000	$336,000	$307,000	$336,000
Treatment Equipment	$286,000	$345,000	$337,000	$557,000	$428,000
E&IC	$300,000	$290,000	$100,000	$130,000	$360,000
Ancillary Systems	$84,000	$84,000	$20,000	$16,000	$182,000
Waste Storage / Treatment	$281,000	$193,000	$80,000	$68,000	$182,000
Direct Costs	**$1,520,000**	**$1,470,000**	**$1,010,000**	**$1,270,000**	**$1,800,000**
Contingency	$300,000	$290,000	$200,000	$250,000	$360,000
General Conditions	$180,000	$180,000	$120,000	$150,000	$220,000
Sales Tax	$40,000	$40,000	$30,000	$30,000	$50,000
Indirect Costs	**$520,000**	**$510,000**	**$350,000**	**$430,000**	**$630,000**
TOTAL CONSTRUCTION COSTS	**$2,040,000**	**$1,980,000**	**$1,360,000**	**$1,700,000**	**$2,430,000**
Annual O&M Cost					
Labor	$38,800	$38,800	$22,800	$22,800	$46,800
Electricity	$50,400	$50,400	$40,300	$40,300	$46,200
Chemicals	$6,800	$6,800	$3,400	$3,400	$166,400
Media / Equipment Replacement	$13,300	$13,300	$139,300	$85,500	$17,400
Waste Handling/Disposal	$5,200	$5,200	$200	$200	$129,500
TOTAL ANNUAL COSTS	**$114,500**	**$114,500**	**$206,000**	**$152,200**	**$406,300**
Life-Cycle Cost (2011 USD)					
Capital Cost	$2,040,000	$1,980,000	$1,360,000	$1,700,000	$2,430,000
Annualized O&M Cost	$1,556,000	$1,556,000	$2,800,000	$2,068,000	$5,522,000
TOTAL VALUE	**$3,596,000**	**$3,536,000**	**$4,160,000**	**$3,768,000**	**$7,952,000**

Table 9 Capital and O&M Cost Summary for Alternative No. 1 (Full Treatment) for Well No. 11
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Capital Cost					
Site Work	$228,000	$216,000	$153,000	$244,000	$339,000
Yard Piping	$365,000	$365,000	$365,000	$365,000	$365,000
Treatment Equipment	$291,000	$372,000	$380,000	$721,000	$471,000
E&IC	$320,000	$310,000	$110,000	$160,000	$410,000
Ancillary Systems	$84,000	$84,000	$23,000	$23,000	$209,000
Waste Storage / Treatment	$295,000	$204,000	$91,000	$91,000	$243,000
Direct Costs	**$1,580,000**	**$1,550,000**	**$1,120,000**	**$1,600,000**	**$2,040,000**
Contingency	$320,000	$310,000	$220,000	$320,000	$410,000
General Conditions	$190,000	$190,000	$130,000	$190,000	$250,000
Sales Tax	$40,000	$40,000	$30,000	$40,000	$50,000
Indirect Costs	**$550,000**	**$540,000**	**$380,000**	**$550,000**	**$710,000**
TOTAL CONSTRUCTION COSTS	**$2,130,000**	**$2,090,000**	**$1,500,000**	**$2,150,000**	**$2,750,000**
Annual O&M Cost					
Labor	$38,800	$38,800	$22,800	$22,800	$46,800
Electricity	$53,600	$53,600	$59,100	$59,100	$54,900
Chemicals	$7,200	$7,200	$5,000	$5,000	$197,600
Media / Equipment Replacement	$13,400	$13,400	$163,900	$123,600	$19,200
Waste Handling/Disposal	$5,600	$5,600	$200	$200	$153,700
TOTAL ANNUAL COSTS	**$118,600**	**$118,600**	**$251,000**	**$210,700**	**$472,200**
Life-Cycle Cost (2011 USD)					
Capital Cost	$2,130,000	$2,090,000	$1,500,000	$2,150,000	$2,750,000
Annualized O&M Cost	$1,612,000	$1,612,000	$3,411,000	$2,863,000	$6,417,000
TOTAL VALUE	**$3,742,000**	**$3,702,000**	**$4,911,000**	**$5,013,000**	**$9,167,000**

Table 10 Capital and Life-Cycle Cost Summary for Alternative No. 1 and No. 2 for Well No. 11
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

DESCRIPTION	Treatment Technologies				
	Coagulation/Filtration (Vertical Vessel)	Coagulation/Filtration (Horizontal Vessel)	Sorptive Media (Parallel)	Sorptive Media (Lead-Lag)	Ion Exchange
Alternative No. 1 (Partial Treatment)					
Construction Cost	$2,040,000	$1,980,000	$1,360,000	$1,700,000	$2,430,000
Life-Cycle Cost	$3,596,000	$3,536,000	$4,160,000	$3,768,000	$7,952,000
Alternative No. 2 (Full Treatment)					
Construction Cost	$2,130,000	$2,090,000	$1,500,000	$2,150,000	$2,750,000
Life-Cycle Cost	$3,742,000	$3,702,000	$4,911,000	$5,013,000	$9,167,000

6.0 QUALITATIVE EVALUATION OF ARSENIC TREATMENT ALTERNATIVES

In addition to site footprint and cost evaluations, each of the alternatives was evaluated based on qualitative criteria including impact on neighbors (noise, truck traffic), ease of operation, and residuals disposal. The comparison evaluation is summarized in Table 11. Since partial treatment with blending is viable and costs much less than the full treatment alternatives, the qualitative evaluation foc used primarily on Alternatives 1 and 2.

Table 11 presents the various evaluation components and criteria, and rates each alternative according to a relative scale. The color ranking designations are as follows: green is easiest or best, red is challenging or worst, and yellow is some challenges or average. Therefore, alternatives with more green designations than red indicate more overall advantages. Table 6 shows that the Alternative 1 SM options were the most positively ranked qualitatively in terms of the evaluation components established for this study. These include:

- Treatment Effectiveness/Robustness: SM provides effective treatment for the given water quality. Severn Trent has projected that their E-33 media would provide at least 76,000 bed volumes between media exchanges with an influent arsenic of 0.018 mg/L and when operated with vessels in parallel.

- Treatment Effectiveness/Robustness: C/F and IX technologies have many more moving parts and instruments than does SM due to additional ancillary processes and the use of automatic valves. It is anticipated that the O&M costs will be higher as it is likely that items such as plastic pipe and valve actuators would probably need replacement within a few years. AWC has observed at their other IX and C/F sites that maintenance requirements in general are much higher for these technologies, than for SM.

- Chemical Deliveries: SM does not require chemical deliveries. C/F and IX will require frequent chemical deliveries which is an important consideration given the that the entrance to Well No. 13 site will be directly off residential street in a subdivision.

- Site Restrictions/Footprints: SM has the overall smallest footprint over the other technologies.

- Constructability / Installation Complexity: SM is the least complex system to install, since it has fewer process components.

Table 11 Comparison of Arsenic Treatment Alternatives
Arsenic Removal Facility Alternatives Evaluation
Arizona Water Company

	Treatment Effectiveness / Robustness	Chemical Delivery	Site Restrictions / Footprint	Constructability / Installation Complexity	Aesthetics/ Noise / Odors	Ease of Operation	Residuals Generation / Disposal	Ease of Start-up following off-time
CF (partial) - w/ Solids Handling								
IX (partial)								
SM - Parallel (partial)								
SM - Lead Lag (partial)								
CF (full) w/ Solids Handling								
IX (full)								
SM - Parallel (full)								
SM - Lead lag (full)								

Green=Easiest or best
Yellow = Some challenges or average
Red=Challenging or worst

- Aesthetics / Noise / Odors: Since the C/F and IX systems require chemicals for operation, and off-site disposal of residuals, they received red ratings compared, especially when compared to SM. At other AWC sites salt delivery trucks have had minor spills which is still enough to kill nearby landscaping. Additionally, delivery trucks will bring noise and exhaust fumes through the residential areas.

- Ease of Operation: SM was rated the best since it is the easiest to operate (e.g., manually operated valves). C/F and IX have many more moving parts (e.g., valve actuation daily) and ancillary process (e.g., ferric storage, brine storage and regeneration pumps) compared to SM.

- Residuals Generation / Disposal: C/F was rated the worst (red) with IX as yellow, and SM as green. C/F and IX will require more frequent truck trips for residuals disposal compared to SM. SM will require the least amount of truck traffic for residuals disposal at approximately once every 8 months (at 50% well utilization rate). All arsenic treatment technologies will produce waste residuals (either sludge or media) that contain arsenic. Eventually waste residuals for all technologies are landfilled with origination paperwork linked to the original source of production. AWC currently mitigates this risk by contracting with third-part waste handlers who indemnify AWC, decreasing the risk associated with landfilling arsenic-laden residuals.

- Ease of Start-Up Following Off Time: AWC's water production requirements in the winter months are much less than in the summer, and this allows AWC to not operate some of their wells during this time period. Arsenic treatment systems often require additional attention and maintenance after an extended off-period. Instruments need to be recalibrated, tubing and pipes verified for no leakage, chemical tanks need to be refilled, etc. The more complex the treatment process, the more time it takes to re-start a system after an outage. Since SM has the least amount of moving parts and instrumentation compared to IX and C/F, its start-up will be easier. AWC confirms this has been their experience at their existing arsenic treatment systems.

6.1 Current State of Filter Medias

The C/F treatment process may utilize a variety of medias both of proprietary nature (i.e., single supplier) and readily available on the market place. Table 12 presents a list of C/F medias that have been used to remove arsenic from water. All these medias are acceptable contingent upon proof testing at the Coolidge Well No. 13 site.

Table 12 Current Status of Medias Used for Coagulation/Filtration [1] Arsenic Removal Facility Alternatives Evaluation Arizona Water Company		
Media Name	**Manufacturer**	**Status**
Anthracite	(none)	•Standard product with AWWA specification. • Multiple suppliers located nationwide.
Electromedia	Filtronics	• Proprietary media from one supplier. • Capable of filtration rates of up to 12 gpm/ft^2.[3]
Greensand	Hungerford & Terry	• Proprietary media from one supplier.
High-density Sand	Several	• Also known as garnet, hematite, ilmenite, and magnetite. •Typically used as part of support system for Anthractite/Sand media beds.
Macrolite	Kinetico	• Ceramic-based media. • Capable of filtration rates of up to 10 gpm/ft^2.[3] • Lower backwash rates (8 gpm/ft^2) • Focus on small systems (POU/POE). • Does not provide system packages.
Manganese Dioxide	Several	• Packaged by several suppliers (e.g., LayneOx, Pureflow, Prince Minerals, Birm, Catalox)
Sand	(none)	• Standard product with AWWA specification. • Multiple suppliers located nationwide.

Note:

(1) Any of the following suppliers may be used to provide a system package: Everfilt, Hungerford & Terry, Loprest, Pureflow, Severn-Trent, Siemens, Tonka, WesTech.

(2) Shaded entries indicate those medias that appear viable for use at the Coolidge Well No. 13 site based on water quality and performance record.

(3) Vendors typically require field testing before providing a performance warranty as part of the system.

6.2 Current State of Sorptive Medias

Carollo previously conducted a review of sorptive medias in spring 2011 for AWC. Since then there have been no new suppliers brought to the market place that have any significant full-scale installations. Although the initial promulgation of the Arsenic Rule by the U.S. EPA in 2001, saw a rush of potential medias, these medias were primarily at the research level. Now in 2011, there are only a few medias that have the track record and ability to provide a complete system package.

ARIZONA WATER COMPANY

3805 N. BLACK CANYON HIGHWAY, PHOENIX, ARIZONA 85015-5351 • P.O. BOX 29006, PHOENIX, AZ 85038-9006
PHONE: (602) 240-6860 • FAX: (602) 240-6874 • TOLL FREE: (800) 533-6023 • www.azwater.com

June 24, 2015

Mr. Randy Gates
MGC Contractors, Inc.
4110 E. Elwood Street
Phoenix, AZ 85040

Re: Coolidge Well No. 13 Arsenic Removal Facility

Dear Mr. Gates:

Enclosed is a Request for Proposal ("RFP") for the above referenced project. Arizona Water Company ("Company") requests your submission of a proposal for Coolidge Well No. 13 Arsenic Removal Facility.

A mandatory pre-proposal meeting will be held at Coolidge Well No. 13, 2107 W. Vah Ki Inn Road, Coolidge, AZ 85128 on July 9, 2015, at 10:00 a.m. Proposals must be submitted no later than 2:00 p.m. on July 30, 2015. Submit the original proposal plus three (3) copies to the attention of James Wilson at the Phoenix Office located at 3805 N. Black Canyon Highway, Phoenix, AZ 85015. Company will not consider incomplete or late submittals for evaluation.

RFP evaluation will be weighted as follows:

- Work History and Experience of Consultant and Project Manager – 40%
- RFP/Scope thoroughness – 30%
- Consultant Proposed Fee – 30%

The following documents are attached for your review:

- Proposal/Contract (two copies)
- Request for Proposal
- Adsorptive Media Technical Specifications and Exhibits A thru N
- Coagulation/Filtration Technical Specifications and Exhibits A thru N

The Company anticipates issuing a notice of award for Coolidge Well No. 13 Arsenic Removal Facility on or around September 3, 2015, following evaluation of the submitted qualifications and fees. The Company intends to select the successful contractor directly from the submitted RFP. However, the Company reserves the right to have a formal interview process following review of the submitted RFPs. If you have any questions regarding this request, please contact me at (602) 240-6860.

Very truly yours,

James T. Wilson, P. E.
Senior Engineer
jwilson@azwater.com

afh
Enclosures

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street

PROPOSAL/CONTRACT

CONTRACTOR: MGC CONTRACTORS, INC.	SYSTEM: PINAL VALLEY
ADDRESS: P. O. BOX 61748	W.A. No(s): 1-4806
CITY ST ZIP: PHOENIX, AZ 85082	BID DUE DATE: July 30, 2015

CONTRACTOR SUBMITS this PROPOSAL/CONTRACT to ARIZONA WATER COMPANY, an Arizona corporation (the "Company"), to perform the work and complete the project described on Page 2 (the "Project"), as an independent prime contractor.

1. Contractor certifies that it has a complete copy of, and has read, understands and accepts, the Company's General Conditions of Contract, and the Company's Construction Specifications and Standard Specification Drawings, (the "Specifications"), all of which are attached hereto. Contractor has examined the specific plans and related construction drawings for the Project (the "Drawings"), copies of which are also attached hereto. The General Conditions of Contract, Specifications and Drawings are incorporated into this Proposal/Contract. Contractor affirms that all work and materials to be furnished or purchased for the Project will be in strict conformance with the General Conditions of Contract, Specifications and Drawings.

2. Contractor represents and warrants that it has satisfied and complied with the provisions of Section 6, Contractor Understands Work and Working Conditions, of the General Conditions of Contract prior to submitting this Proposal/Contract.

3. Contractor represents that this Proposal/Contract is fair and honest in all respects, is submitted in good faith and is not submitted in collusion with any other company, entity or person.

4. Contractor acknowledges that one hundred percent (100%) Performance and Payment Bonds are required and must be provided to the Company prior to the commencement of work.

5. Prior to the commencement of work, Contractor will submit to the Company a list of all materials to be used in the Project. The materials list will include the manufacturer, part number, price and quantity included in this Proposal/Contract.

6. Contractor will furnish all labor, tools, equipment and materials required to complete the Project according to the General Conditions of Contract, Specifications and Drawings. No materials purchased by Contractor to be incorporated into the Project are subject to tax at the time of purchase and Contractor will not charge the Company for any such tax. Contractor will pay the applicable transaction privilege tax (the "Contracting Tax") on the Project after Contractor receives payment of the final Project invoice from the Company. The cost of materials incorporated into the Project which are exempt by Arizona Revised State Statues ("A.R.S.") from the Contracting Tax, for example, pipes or valves having a diameter of four (4) inches or larger, including equipment, fittings and any other related part that is used in operating the pipes or valves (A.R.S. §42-5061 B.6.), will not be included in the total cost of the labor and materials upon which the Contracting Tax is computed. Contractor retains full liability and obligation to pay the Contracting Tax and will defend and indemnify the Company against any demand or obligation to pay the Contracting Tax.

7. Contractor will maintain detailed accounting records of all materials purchased and incorporated into the Project. Such records will include all supporting original vendor invoices for all materials purchased. Following completion of the Project, Contractor will submit an itemized accounting to the Company which will include all supporting original vendor invoices and satisfactory evidence of payment thereof. The Company will not pay Contractor for materials not actually incorporated into the Project, and the disposition of such materials will remain Contractor's responsibility.

8. The Estimated Total Cost of the Project, shown on Page 2, is based on estimated labor and material quantities to be furnished. It includes an estimate of the Contracting Tax and the cost of the required Performance and Payment Bonds. Contractor will not cancel, modify or withdraw this Proposal/Contract during a ninety-day (90) period commencing on the Bid Due Date. The Company may accept this Proposal/Contract by signing and mailing, or otherwise delivering, a copy hereof to Contractor during such ninety-day (90) period. If the Company does not accept this Proposal/Contract during such ninety-day (90) period, Contractor may cancel this Proposal/Contract by giving written notice of cancellation to the Company.

9. Prior to the commencement of work, Contractor will provide the Company with a detailed construction schedule, in either Gantt or CPM form, identifying all tasks to be performed from the date of the written Commencement Notice through completion of the Project, including testing, training of Company Personnel and final Project invoicing. Contractor will provide the Company with a copy of such construction schedule documenting the progress of work on the Project at least monthly.

10. Contractor will not commence work on the Project until the Company gives Contractor a written Commencement Notice. Contractor will complete the Project within _____ calendar days after the Commencement Notice is issued.

11. Following the Company's written notice of satisfactory completion of the Project, and upon receipt of the final Project invoice from Contractor, the Company shall pay Contractor the actual total cost of the Project, which will be calculated as shown on Page 2, except that actual labor and material quantities installed/constructed will be substituted for the estimated labor and materials quantities and the Contracting Tax will be recalculated based on such actual labor and materials quantities.

12. The amount of applicable liquidated damages for Contractor's failure to deliver or perform within the time limit shown in Paragraph 10 may be deducted from the Company's payment of the final Project invoice. This provision shall not limit the Company's ability to terminate this Proposal/Contract for Contractor's unsatisfactory performance or failure to perform as provided in the General Conditions of Contract, Specifications or Drawings, or in this Proposal/Contract.

SPECIAL CONDITIONS:

See attached Request for Proposal and Technical Specifications dated June 23, 2015. Company will make five (5) progress payments.

CONTRACTOR	PROPOSAL/CONTRACT ACCEPTED:
MGC CONTRACTORS, INC.	***ARIZONA WATER COMPANY***
By:	By:
Print Name:	Print Name: Fredrick K. Schneider, PE
Title:	Title: Vice President - Engineering
Date:	Date:

sm

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street
Casa Grande, AZ 85122 PH: 520-836-8785

PROPOSAL/CONTRACT

CONTRACTOR: MGC CONTRACTORS, INC.	SYSTEM: PINAL VALLEY
AZ CONTRACTOR LICENSE NO: CLASSIFICATION:	W A No(s): 1-4806
ADDRESS: P. O. BOX 61748	BID DUE DATE: July 30, 2015
CITY ST ZIP PHOENIX, AZ 85082	BID BOND REQUIRED ☑ Yes ☐ No

DESCRIPTION OF PROJECT: Design, permit and construct an Arsenic Removal Facility at Coolidge Well No. 13 in the Pinal Valley water system.

1-2. MATERIALS EXEMPT FROM CONTRACTING TAX (per Paragraph 6)	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Provide and install on-site piping, valves and related appurtenances.	1				
				1	2
3. Total Labor to Install Exempt Materials (add the amounts in column 1)				3	
4. Total Exempt Materials (add the amounts in column 2)					4

5-6. NON-EXEMPT MATERIALS	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Perform design phase services and obtain ATC and other required permits and approvals.	1				
Mobilization, demobilization, site maintenance and closeout.	1				
Perform grading, drainage and site improvements.	1				
Provide and install ARF vessels with media, piping and related appurtenances.	1				
Provide and install chemical injection system including tanks, piping and related appurtenances.	1				
Provide and install backwash system including tanks, pumps, piping and related appurtenances.	1				
Provide and install solids handling facilities including dewatering bin, pumps and related appurtenances (coagulation/filtration only).	1			5	6
Perform disinfection, testing, commissioning and on-site operator training.	1				
Provide and install SCADA system, perform PLC programming and integrate ARF and Well No. 13 site into Pinal Valley SCADA system.	1				
Prepare record drawings, O&M manual and obtain AOC.	1				
7. Total Labor to Install Non-Exempt Materials (add the amounts in column 5)				7	
8. Total Non-Exempt Materials (add the amounts in column 6)					8
9. Subtotal A (add lines 3, 7 and 8)					9
10. Contracting Tax Base (multiply the amount on line 9 by 0.65)				10	
11. Applicable Contracting Tax Rate				11	
12. Contracting Tax (multiply the amount on line 10 by line 11)					12
13. Subtotal B (add lines 4, 9 and 12)					13
14. 100% Performance and Payment Bonds Cost					14
15. Estimated Total Cost (add lines 13 and 14)					15

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street

PROPOSAL/CONTRACT

CONTRACTOR: MGC CONTRACTORS, INC.	SYSTEM: PINAL VALLEY
ADDRESS: P. O. BOX 61748	W.A. No(s): 1-4806
CITY ST ZIP: PHOENIX, AZ 85082	BID DUE DATE: July 30, 2015

CONTRACTOR SUBMITS this PROPOSAL/CONTRACT to ARIZONA WATER COMPANY, an Arizona corporation (the "Company"), to perform the work and complete the project described on Page 2 (the "Project"), as an independent prime contractor.

1. Contractor certifies that it has a complete copy of, and has read, understands and accepts, the Company's General Conditions of Contract, and the Company's Construction Specifications and Standard Specification Drawings, (the "Specifications"), all of which are attached hereto. Contractor has examined the specific plans and related construction drawings for the Project (the "Drawings"), copies of which are also attached hereto. The General Conditions of Contract, Specifications and Drawings are incorporated into this Proposal/Contract. Contractor affirms that all work and materials to be furnished or purchased for the Project will be in strict conformance with the General Conditions of Contract, Specifications and Drawings.

2. Contractor represents and warrants that it has satisfied and complied with the provisions of Section 6, Contractor Understands Work and Working Conditions, of the General Conditions of Contract prior to submitting this Proposal/Contract.

3. Contractor represents that this Proposal/Contract is fair and honest in all respects, is submitted in good faith and is not submitted in collusion with any other company, entity or person.

4. Contractor acknowledges that one hundred percent (100%) Performance and Payment Bonds are required and must be provided to the Company prior to the commencement of work.

5. Prior to the commencement of work, Contractor will submit to the Company a list of all materials to be used in the Project. The materials list will include the manufacturer, part number, price and quantity included in this Proposal/Contract.

6. Contractor will furnish all labor, tools, equipment and materials required to complete the Project according to the General Conditions of Contract, Specifications and Drawings. No materials purchased by Contractor to be incorporated into the Project are subject to tax at the time of purchase and Contractor will not charge the Company for any such tax. Contractor will pay the applicable transaction privilege tax (the "Contracting Tax") on the Project after Contractor receives payment of the final Project invoice from the Company. The cost of materials incorporated into the Project which are exempt by Arizona Revised State Statues ("A.R.S.") from the Contracting Tax, for example, pipes or valves having a diameter of four (4) inches or larger, including equipment, fittings and any other related part that is used in operating the pipes or valves (A.R.S. §42-5061 B.6.), will not be included in the total cost of the labor and materials upon which the Contracting Tax is computed. Contractor retains full liability and obligation to pay the Contracting Tax and will defend and indemnify the Company against any demand or obligation to pay the Contracting Tax.

7. Contractor will maintain detailed accounting records of all materials purchased and incorporated into the Project. Such records will include all supporting original vendor invoices for all materials purchased. Following completion of the Project, Contractor will submit an itemized accounting to the Company which will include all supporting original vendor invoices and satisfactory evidence of payment thereof. The Company will not pay Contractor for materials not actually incorporated into the Project, and the disposition of such materials will remain Contractor's responsibility.

8. The Estimated Total Cost of the Project, shown on Page 2, is based on estimated labor and material quantities to be furnished. It includes an estimate of the Contracting Tax and the cost of the required Performance and Payment Bonds. Contractor will not cancel, modify or withdraw this Proposal/Contract during a ninety-day (90) period commencing on the Bid Due Date. The Company may accept this Proposal/Contract by signing and mailing, or otherwise delivering, a copy hereof to Contractor during such ninety-day (90) period. If the Company does not accept this Proposal/Contract during such ninety-day (90) period, Contractor may cancel this Proposal/Contract by giving written notice of cancellation to the Company.

9. Prior to the commencement of work, Contractor will provide the Company with a detailed construction schedule, in either Gantt or CPM form, identifying all tasks to be performed from the date of the written Commencement Notice through completion of the Project, including testing, training of Company Personnel and final Project invoicing. Contractor will provide the Company with a copy of such construction schedule documenting the progress of work on the Project at least monthly.

10. Contractor will not commence work on the Project until the Company gives Contractor a written Commencement Notice. Contractor will complete the Project within _____ calendar days after the Commencement Notice is issued.

11. Following the Company's written notice of satisfactory completion of the Project, and upon receipt of the final Project invoice from Contractor, the Company shall pay Contractor the actual total cost of the Project, which will be calculated as shown on Page 2, except that actual labor and material quantities installed/constructed will be substituted for the estimated labor and materials quantities and the Contracting Tax will be recalculated based on such actual labor and materials quantities.

12. The amount of applicable liquidated damages for Contractor's failure to deliver or perform within the time limit shown in Paragraph 10 may be deducted from the Company's payment of the final Project invoice. This provision shall not limit the Company's ability to terminate this Proposal/Contract for Contractor's unsatisfactory performance or failure to perform as provided in the General Conditions of Contract, Specifications or Drawings, or in this Proposal/Contract.

SPECIAL CONDITIONS:

See attached Request for Proposal and Technical Specifications dated June 23, 2015. Company will make five (5) progress payments.

CONTRACTOR	PROPOSAL/CONTRACT ACCEPTED:
MGC CONTRACTORS, INC.	***ARIZONA WATER COMPANY***
By:	By:
Print Name:	Print Name: Fredrick K. Schneider, PE
Title:	Title: Vice President - Engineering
Date:	Date:

arh

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street
Casa Grande, AZ 85122 PH: 520-836-8785

PROPOSAL/CONTRACT

CONTRACTOR: MGC CONTRACTORS, INC.	SYSTEM: PINAL VALLEY
AZ CONTRACTOR LICENSE NO: CLASSIFICATION:	W A No(s): 1-4806
ADDRESS: P. O. BOX 61748	BID DUE DATE: July 30, 2015
CITY ST ZIP PHOENIX, AZ 85082	BID BOND REQUIRED ☑ Yes ☐ No

DESCRIPTION OF PROJECT: Design, permit and construct an Arsenic Removal Facility at Coolidge Well No. 13 in the Pinal Valley water system.

1-2. MATERIALS EXEMPT FROM CONTRACTING TAX (per Paragraph 6)	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Provide and install on-site piping, valves and related appurtenances.	1				
				1	2

3. Total Labor to Install Exempt Materials (add the amounts in column 1)	3	
4. Total Exempt Materials (add the amounts in column 2)		4

5-6. NON-EXEMPT MATERIALS	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Perform design phase services and obtain ATC and other required permits and approvals.	1				
Mobilization, demobilization, site maintenance and closeout.	1				
Perform grading, drainage and site improvements.	1				
Provide and install ARF vessels with media, piping and related appurtenances.	1				
Provide and install chemical injection system including tanks, piping and related appurtenances.	1				
Provide and install backwash system including tanks, pumps, piping and related appurtenances.	1				
Provide and install solids handling facilities including dewatering bin, pumps and related appurtenances (coagulation/filtration only).	1				
Perform disinfection, testing, commissioning and on-site operator training.	1			5	6
Provide and install SCADA system, perform PLC programming and integrate ARF and Well No. 13 site into Pinal Valley SCADA system.	1				
Prepare record drawings, O&M manual and obtain AOC.	1				

7. Total Labor to Install Non-Exempt Materials (add the amounts in column 5)	7	
8. Total Non-Exempt Materials (add the amounts in column 6)		8
9. Subtotal A (add lines 3, 7 and 8)		9
10. Contracting Tax Base (multiply the amount on line 9 by 0.65)	10	
11. Applicable Contracting Tax Rate	11	
12. Contracting Tax (multiply the amount on line 10 by line 11)		12
13. Subtotal B (add lines 4, 9 and 12)		13
14. 100% Performance and Payment Bonds Cost		14
15. Estimated Total Cost (add lines 13 and 14)		15

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street

PROPOSAL/CONTRACT

CONTRACTOR:	SYSTEM: PINAL VALLEY
ADDRESS:	W.A. No(s): 1-4806
CITY ST ZIP:	BID DUE DATE: July 30, 2015

CONTRACTOR SUBMITS this PROPOSAL/CONTRACT to ARIZONA WATER COMPANY, an Arizona corporation (the "Company"), to perform the work and complete the project described on Page 2 (the "Project"), as an independent prime contractor.

1. Contractor certifies that it has a complete copy of, and has read, understands and accepts, the Company's General Conditions of Contract, and the Company's Construction Specifications and Standard Specification Drawings, (the "Specifications"), all of which are attached hereto. Contractor has examined the specific plans and related construction drawings for the Project (the "Drawings"), copies of which are also attached hereto. The General Conditions of Contract, Specifications and Drawings are incorporated into this Proposal/Contract. Contractor affirms that all work and materials to be furnished or purchased for the Project will be in strict conformance with the General Conditions of Contract, Specifications and Drawings.
2. Contractor represents and warrants that it has satisfied and complied with the provisions of Section 6, Contractor Understands Work and Working Conditions, of the General Conditions of Contract prior to submitting this Proposal/Contract.
3. Contractor represents that this Proposal/Contract is fair and honest in all respects, is submitted in good faith and is not submitted in collusion with any other company, entity or person.
4. Contractor acknowledges that one hundred percent (100%) Performance and Payment Bonds are required and must be provided to the Company prior to the commencement of work.
5. Prior to the commencement of work, Contractor will submit to the Company a list of all materials to be used in the Project. The materials list will include the manufacturer, part number, price and quantity included in this Proposal/Contract.
6. Contractor will furnish all labor, tools, equipment and materials required to complete the Project according to the General Conditions of Contract, Specifications and Drawings. No materials purchased by Contractor to be incorporated into the Project are subject to tax at the time of purchase and Contractor will not charge the Company for any such tax. Contractor will pay the applicable transaction privilege tax (the "Contracting Tax") on the Project after Contractor receives payment of the final Project invoice from the Company. The cost of materials incorporated into the Project which are exempt by Arizona Revised State Statues ("A.R.S.") from the Contracting Tax, for example, pipes or valves having a diameter of four (4) inches or larger, including equipment, fittings and any other related part that is used in operating the pipes or valves (A.R.S. §42-5061 B.6.), will not be included in the total cost of the labor and materials upon which the Contracting Tax is computed. Contractor retains full liability and obligation to pay the Contracting Tax and will defend and indemnify the Company against any demand or obligation to pay the Contracting Tax.
7. Contractor will maintain detailed accounting records of all materials purchased and incorporated into the Project. Such records will include all supporting original vendor invoices for all materials purchased. Following completion of the Project, Contractor will submit an itemized accounting to the Company which will include all supporting original vendor invoices and satisfactory evidence of payment thereof. The Company will not pay Contractor for materials not actually incorporated into the Project, and the disposition of such materials will remain Contractor's responsibility.
8. The Estimated Total Cost of the Project, shown on Page 2, is based on estimated labor and material quantities to be furnished. It includes an estimate of the Contracting Tax and the cost of the required Performance and Payment Bonds. Contractor will not cancel, modify or withdraw this Proposal/Contract during a ninety-day (90) period commencing on the Bid Due Date. The Company may accept this Proposal/Contract by signing and mailing, or otherwise delivering, a copy hereof to Contractor during such ninety-day (90) period. If the Company does not accept this Proposal/Contract during such ninety-day (90) period, Contractor may cancel this Proposal/Contract by giving written notice of cancellation to the Company.
9. Prior to the commencement of work, Contractor will provide the Company with a detailed construction schedule, in either Gantt or CPM form, identifying all tasks to be performed from the date of the written Commencement Notice through completion of the Project, including testing, training of Company Personnel and final Project invoicing. Contractor will provide the Company with a copy of such construction schedule documenting the progress of work on the Project at least monthly.
10. Contractor will not commence work on the Project until the Company gives Contractor a written Commencement Notice. Contractor will complete the Project within _____ calendar days after the Commencement Notice is issued.
11. Following the Company's written notice of satisfactory completion of the Project, and upon receipt of the final Project invoice from Contractor, the Company shall pay Contractor the actual total cost of the Project, which will be calculated as shown on Page 2, except that actual labor and material quantities installed/constructed will be substituted for the estimated labor and materials quantities and the Contracting Tax will be recalculated based on such actual labor and materials quantities.
12. The amount of applicable liquidated damages for Contractor's failure to deliver or perform within the time limit shown in Paragraph 10 may be deducted from the Company's payment of the final Project invoice. This provision shall not limit the Company's ability to terminate this Proposal/Contract for Contractor's unsatisfactory performance or failure to perform as provided in the General Conditions of Contract, Specifications or Drawings, or in this Proposal/Contract.

SPECIAL CONDITIONS:

See attached Request for Proposal and Technical Specifications dated June 23, 2015. Company will make five (5) progress payments.

CONTRACTOR	**PROPOSAL/CONTRACT ACCEPTED:** ***ARIZONA WATER COMPANY***
By:	By:
Print Name:	Print Name: Fredrick K. Schneider, PE
Title:	Title: Vice President - Engineering
Date:	Date:

aln

ARIZONA WATER COMPANY

Pinal Valley - Casa Grande Division
220 E. 2nd Street
Casa Grande, AZ 85122 PH: 520-836-8785

PROPOSAL/CONTRACT

CONTRACTOR:	SYSTEM: PINAL VALLEY
AZ CONTRACTOR LICENSE NO: . CLASSIFICATION:	W.A. No(s): 1-4806
ADDRESS:	BID DUE DATE: July 30, 2015
CITY ST ZIP	BID BOND REQUIRED ☑ Yes ☐ No

DESCRIPTION OF PROJECT: Design, permit and construct an Arsenic Removal Facility at Coolidge Well No. 13 in the Pinal Valley water system.

1-2. **MATERIALS EXEMPT FROM CONTRACTING TAX (per Paragraph 6)**	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Provide and install on-site piping, valves and related appurtenances.	1				
				1	2
3. Total Labor to Install Exempt Materials (add the amounts in column 1)				3	
4. Total Exempt Materials (add the amounts in column 2)					4

5-6. **NON-EXEMPT MATERIALS**	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Perform design phase services and obtain ATC and other required permits and approvals.	1				
Mobilization, demobilization, site maintenance and closeout.	1				
Perform grading, drainage and site improvements.	1				
Provide and install ARF vessels with media, piping and related appurtenances.	1				
Provide and install chemical injection system including tanks, piping and related appurtenances.	1				
Provide and install backwash system including tanks, pumps, piping and related appurtenances.	1				
Provide and install solids handling facilities including dewatering bin, pumps and related appurtenances (coagulation/filtration only).	1				
Perform disinfection, testing, commissioning and on-site operator training.	1			5	6
Provide and install SCADA system, perform PLC programming and integrate ARF and Well No. 13 site into Pinal Valley SCADA system.	1				
Prepare record drawings, O&M manual and obtain AOC.	1				
7. Total Labor to Install Non-Exempt Materials (add the amounts in column 5)				7	
8. Total Non-Exempt Materials (add the amounts in column 6)					8
9. Subtotal A (add lines 3, 7 and 8)					9
10. Contracting Tax Base (multiply the amount on line 9 by 0.65)				10	
11. Applicable Contracting Tax Rate				11	
12. Contracting Tax (multiply the amount on line 10 by line 11)					12
13. Subtotal B (add lines 4, 9 and 12)					13
14. 100% Performance and Payment Bonds Cost					14
15. Estimated Total Cost (add lines 13 and 14)					15

ARIZONA WATER COMPANY

SPECIFICATIONS

GENERAL CONDITIONS OF CONTRACT: E-4-1

CONSTRUCTION SPECIFICATIONS: E-8-1

STANDARD SPECIFICATION DRAWINGS: E-9-1

7/10/15

2007 EDITION WITH **2010** REVISIONS;
2012 GENERAL CONDITIONS OF CONTRACT

A copy of this entire Spec Book was sent out with MGC Contractors invitation to bid package for 1-4806 Coolidge Well #13 ARF on 7/17/15

REQUEST FOR PROPOSAL

Design, Permitting and Construction of Arsenic Removal Facility and Related Appurtenances Coolidge Well No. 13 Site Coolidge, Arizona

June 23, 2015

Project No. 1-4806

Arizona Water Company
3805 N. Black Canyon Highway
Phoenix, Arizona 85015
(602) 240-6860

Table of Contents

1. PROJECT DESCRIPTION 1
   - A. Background 2
   - B. Scope of Services 2

2. PROPOSAL SUBMITTAL REQUIREMENTS 3
   - A. General Requirements 3
   - B. Proposal Requirements 4

Technical Specifications – Adsorptive Media

Technical Specifications – Coagulation/Filtration

Request for Proposal
Design, Permitting and Construction of
Arsenic Removal Facility and Related Appurtenances
Coolidge Well No. 13 Site

June 23, 2015

1. PROJECT DESCRIPTION

Through the issuance of this request for proposal ("RFP"), Arizona Water Company ("Company") is soliciting competitive, sealed bids from Contractors to design, construct, and obtain all permits and governmental approvals for an Arsenic Removal Facility and related appurtenances ("ARF") for the Company's Coolidge Well No. 13 Site ("Site") located at 2107 W. Vah Ki Inn Road, Coolidge, Pinal County, Arizona (Assessor's Parcel No. 209-20-001P) (see Exhibit "A" of the Technical Specifications). Acceptable ARF treatment technologies include:

1. Adsorptive Media
2. Coagulation/Filtration

The contractor, its engineer and subcontractors (collectively referred to as "Contractor") are responsible for the overall design/build project, including construction and all design disciplines necessary to deliver the ARF "turnkey" to the Company. The Contractor, at its option, may select one ARF technology to use as the basis for its proposal. Technical Specifications for both ARF technologies are attached.

The Contractor is responsible for the design, construction, permitting, programming, commissioning, record drawings, and Operations and Maintenance ("O&M") manual for the ARF included in this RFP. Contractor shall provide design submittals to Company at the 30, 60, 90 and 100 percent complete submittals. See the enclosed Technical Specifications for a detailed Scope of Services.

It is the Contractor's responsibility to obtain any information it requires regarding existing facilities, utility locations and site conditions prior to responding to this RFP. The Contractor may collect samples and perform its own water quality analyses for design purposes.

Design criteria for the ARF are provided in Exhibit "E" of the Technical Specifications. The ARF vessels shall have full flow treatment capacity. A portion of the raw groundwater from Well No. 13 ("the well") will bypass the ARF and blend with the treated water to produce water with an arsenic concentration of less than 7 micrograms per liter ("µg/L") prior to discharge to the distribution system. The distribution system will provide the water necessary to backwash the ARF vessels when required. The design includes, but is not limited to: vessel layout, chemical equipment, sludge handling equipment

(coagulation/filtration only), backwash storage and recycling, electrical equipment, communications equipment, instrumentation, programming, piping, site work and drainage. A conceptual site plan, site survey and sample designs that are acceptable to the Company are provided in the exhibits of the Technical Specifications for the Contractor's use.

A. Background

The well is located in a rural area near the Heartland residential subdivision on the south side of Vah Ki Inn Road, approximately 1,000 feet west of Skousen Road. The Site is approximately 0.9 acres and is enclosed by a concrete masonry unit block wall. Other existing facilities at the Site include a storage building, a liquid chlorinator, electrical equipment and a retention basin. Future facilities planned for the Site include two 0.5 million gallon water storage reservoirs and a booster pump station (see Exhibit "D" of the Technical Specifications). The Company has completed an ALTA and topographical survey of the Site, which is available for the Contractor's use.

Well No. 13 is equipped to produce 1,250 gpm and is currently not in service. The Company will replace the existing well pump with a new well pump that produces 800 gpm. When the groundwater from the well was last sampled in October 2011; the arsenic concentration was 14 µg/L. From September 2009 through October 2011; the highest concentration of arsenic was approximately 18 µg/L (see Exhibit "F" of the Technical Specifications).

B. Scope of Services

See Scope of Services in Technical Specifications.

2. PROPOSAL SUBMITTAL REQUIREMENTS

A. General Requirements

The Contractor must deliver proposals to the Company's Phoenix office (address provided below) before 2:00 p.m., Mountain Standard Time, on July 30, 2015. The Company may not accept late proposals.

Arizona Water Company
Attention: James T. Wilson
3805 N. Black Canyon Hwy.
Phoenix, Arizona 85015

An onsite pre-proposal meeting is scheduled for Thursday, July 9, 2015, beginning promptly at 10:00 a.m., Mountain Standard Time, at the Coolidge Well No. 13 site located at:

2107 W. Vah Ki Inn Road
Coolidge, AZ 85128

The pre-proposal meeting is mandatory. The Company may not accept proposals from Contractors who do not attend the meeting.

The schedule for this project is shown below. Proposals must include a detailed design and construction schedule with the completion date on or before the date shown below.

Pre-Proposal Meeting:	July 9, 2015
RFI's Due	July 23, 2015
Proposal Due:	August 6, 2015
Contract Awarded:	September 3, 2015

Proposals must include a completed Proposal/Contract. The Company may reject incomplete Proposal/Contracts. The Contractor must submit questions regarding this RFP in writing by mail or email to:

Arizona Water Company
Attention: James T. Wilson, P.E.
3805 N. Black Canyon Hwy.
Phoenix, Arizona 85015
E-mail: jwilson@azwater.com

Company will only respond to written questions and requires a minimum of 48 hours to provide written responses. Company will send responses to all written questions received to each contractor who is provided a RFP package. Oral statements or instructions

made by the Company shall not constitute an amendment or addendum to this RFP. The Company will provide all amendments or addendums to each Contractor in writing.

For the Adsorption treatment technology, the Company requires a completed form of Exhibit "B" of the Technical Specifications. The contract term of the Proposal/Contract in Exhibit "B" of the Technical Specifications is no less than 5 years from the completion of the ARF which is renewable for an additional 5 year term at the Company's discretion. The Contractor shall provide a performance guarantee on the treatment media per Exhibit "B" of the Technical Specifications.

B. Proposal Requirements

The Contractor shall submit a proposal of no more than 15 typed pages in length (excluding resumes, project schedule, fee schedule, hourly rate schedule and, for the adsorptive option only, Exhibit "B" of the Technical Specifications) and in font of no smaller than 11 point.

The Contractor shall submit the following information with the proposal. The Company will use this information to select the successful bidder.

i. Relevant Experience and Qualifications of the Contractor and Engineer.

a. The Contractor shall provide with its proposal submittal the following information to the Company, along with other pertinent information the Contractor may deem necessary to demonstrate its qualifications in the design, permitting, and construction of the ARF as described in this RFP:

1. Name and address of Contractor.

2. Number of years Contractor has been in business.

3. Information concerning the Contractor's financial capacity and stability to assure the full and timely performance of the Contract.

4. Number of ARFs Contractor has designed, permitted, constructed, and made operational for the removal of arsenic.

5. Name and address of Engineer.

6. Number of years Engineer's key personnel has been registered engineers.

7. Number and description of ARFs the Engineer has designed.

8. List a minimum of three (3) similar projects that Contractor has successfully completed. This list must include at a minimum:

a) Name and address of Engineer.

b) The dates of work (note if pending and status of completion).

c) Project Description including the type of work performed, including the contaminant removed, capacity of water treated and the influent and effluent contaminant levels.

d) The name and telephone number of a contact person or owner of the facility.

e) Contractor's role in the project.

f) Engineer's role in the project.

g) Construction cost.

ii. Key Personnel Qualifications.

a. Organizational chart including key personnel from the Contractor and Engineer.

b. Position descriptions and one page resumes of key personnel assigned to this project. Include resumes in an appendix to the proposal.

c. List of Arizona professional and contractor licenses held by the Contractor, Engineer, and key personnel assigned to this project.

d. Type and amount of work Contractor will self-perform.

e. Proposed subcontractors.

iii. Performance Record and Reputation.

a. Litigation and claims history relating to performance, completion, and progress for all projects.

b. Willingness to abide by Contract Documents with no objections or changes.

iv. Contractor's Understanding of, and Approach to Project.

a. Contractor's understanding of the project.

b. Approach to dealing with potential problems.

v. **Contractor's ability to Manage Project.**

a. Quality control, dispute resolution, and safety management.

b. Subcontractor selection plan.

c. Planning, scheduling, estimating, and construction management tools.

vii. Contractor's Ability to Meet Project Schedule Deadlines and Complete the Project on Budget. Provide a preliminary schedule, in Gantt chart form, beginning with the award of the contract and ending with the completion of construction Include time for reviews and applicable regulatory agency approvals.

viii. Twenty Year Life Cycle Analysis. Include the construction costs, media replacement costs, chemical costs, and any other operating and maintenance costs. Assumptions for the 20-year life cycle cost analysis are provided in Exhibit "L" of the Technical Specifications.

i**x. Hourly Rates.** Provide supplemental hourly rates with overhead for all levels of staff members by discipline, including subcontractors and consultants, for use in determining appropriate compensation or reimbursement for any changes in the Scope of Services.

x. Task Additions and/or Deletions. If, during the course of the Contractor's preparation of this proposal, modifications to the Scope of Services are identified that would better facilitate the design, construction and/or operation and maintenance, provide a brief description and justification for the recommended change along with a corresponding addendum to the fee schedule.

xi. Permit List. Prepare a list of all Federal, State, and local permits required for design and construction. The list must state the name of the permit, the respective regulatory agency or municipality, a brief description of the purpose of the permit, and the typical or legal review time required by each respective agency.

xii. Preliminary Drawing List. Provide a preliminary drawing list that indicates the drawing type and sheet count for all drawings proposed for this project.

Note: The Company at its sole discretion reserves the right to reject or accept any bid proposal.

ARIZONA WATER COMPANY

Technical Specifications – Adsorptive Media
Design, Permitting and Construction of
Arsenic Removal Facility and Related Appurtenances
Coolidge Well No. 13 Site

Table of Contents

1. Summary of Work 1
2. Scope of Services 1
   - A. Project Management 1
   - B. Permits and Approvals 2
   - C. Design Phase Submittals 2
   - D. 30% Design 2
   - E. 60% Design 4
   - F. 90% Design 4
   - G. 100% Design 4
   - H. Construction Phase Submittals 5
   - I. Construction 6
3. Treatment Performance Requirements 8
   - A. General 8
   - B. Design Criteria 8
   - C. Water Quality Data 8
   - D. Media Change-Out Contract 8
4. Process Design Requirements 8
   - A. Special Site Conditions 8
   - B. ARF Configuration 8
   - C. Media Flux Rate 8
   - D. Empty Bed Contact Time 9
   - E. Bypassing and Blending 9
   - F. Backwashing and Recycling 9
   - G. Chemical Feed Systems 9
   - H. pH Adjustment 10
   - I. Programming and SCADA 10
5. ARF Component Design 10

A. Filter Vessels 10
B. External Piping 12
C. Valves and Appurtenances 13
D. Flow Meters 14
E. HDPE Backwash Tank 16
F. Welded Steel Backwash Tank 16
G. Chemical Feed Systems 17
H. Backwash Recycle Pumps 19
I. Ecternal Component Paint 20
8. Electrical and Instrumentation 20
A. General 20
B. SCADA 20
C. Equipment Monitoring 20

Exhibit A: Location Map
Exhibit B: Media Change-Out Agreement and Proposal/Contract
Exhibit C: Site Survey
Exhibit D: Conceptual Site Plan
Exhibit E: Design Criteria
Exhibit F: Water Quality
Exhibit G: Approved Adsorptive Media
Exhibit H: Arizona Water Company Water Storage Tank Coating Specifications O-12-2
Exhibit I: Sample Design of Adsorptive Media ARF
Exhibit J: Sample Design of Chemical Feed System
Exhibit K: Sample Design of Sodium Hypochlorite Feed System
Exhibit L: 20-Year Life Cycle Cost Assumptions
Exhibit M: Arizona Water Company EI&C Design Guidelines Technical Specification
Exhibit N: ADEQ Initial Start-Up Monitoring Form

ARIZONA WATER COMPANY

Technical Specifications – Adsorptive Media
Design, Permitting and Construction of
Arsenic Removal Facility and Related Appurtenances
Coolidge Well No. 13 Site

1. SUMMARY OF WORK

An Arsenic Removal Facility and Related Appurtenances ("ARF") is required at the Coolidge Well No. 13 Site ("Site") located at 2017 W. Vah Ki Inn Road, Coolidge, Arizona 85128, Assessor's Parcel Number ("APN") 209-20-001P (Exhibit "A"). The ARF is necessary to treat groundwater to comply with the maximum contaminant level ("MCL") for arsenic. The intent of these Technical Specifications is to provide general descriptions and establish minimum requirements for the ARF. It is the Contractor's responsibility to design, permit and construct a complete, fully functional, and reliable ARF which complies with Treatment Performance Requirements and specifications set forth herein ("Work").

The ARF shall include, but is not limited to, vessels, media, piping, valves, storage tanks, concrete pads, meters, controls, electrical equipment, chemicals, start-up, training and commissioning. Contractor shall perform due diligence as needed to design, permit and construct the ARF. Any analysis of water quality parameters that may affect performance of the ARF, life-cycle of any media, or waste produced, are the responsibility of the Contractor. Contractor is responsible for all site improvements associated with construction of the ARF, including grading and drainage and partial resurfacing of the Site. Contractor is responsible for integration of the ARF into the Company's Pinal Valley SCADA system.

Contractor is responsible for paying for and obtaining all permits and approvals necessary to begin and complete construction of the ARF. Contractor shall enter into a 5-year Media Change-Out Contract with the Company, which is extendable for an additional 5 years (Exhibit "B").

2. SCOPE OF SERVICES

A. Project Management

i. Contractor shall submit to Company a detailed critical path schedule, in Gantt chart form, beginning with the award of contract and ending with the completion of construction and commissioning. Contractor shall identify applicable regulatory agency approvals and project milestones. Contractor shall update the schedule at a minimum of once per month.

ii. Contractor shall attend all project design and construction meetings including, but not limited to, kick-off meetings, bi-weekly design phase

meetings/workshops, bi-weekly construction phase meetings and special meetings as required. Contractor shall conduct meetings, distribute meeting minutes within three (3) business days after each meeting/workshop, and monitor progress of project versus schedule.

iii. Company will confirm schedule for project meetings and review and approve schedule updates.

B. Permits and Approvals

i. Contractor shall pay for and obtain all permits and approvals for the ARF including, but not limited to: Approval to Construct ("ATC"), Approval of Construction ("AOC") and an approval of a blend plan from the Arizona Department of Environmental Quality ("ADEQ"), building permit, use permit or setback variance, right-of-way encroachment permit and dust control permit. Contractor shall submit design reports, construction drawings applications, certifications, record drawings, and any other documentation required to obtain the permits and approvals required to construct, startup and commission the ARF.

ii. Contractor shall prepare and submit a Storm Water Pollution Prevention Plan, Traffic Control Plan and any other plan required for approval prior to commencing construction.

iii. Contractor must obtain Company approval prior to submitting permit applications, construction drawings, reports and any other required supplemental materials to regulatory agencies.

C. Design Phase Submittals

i. Contractor shall submit to Company a minimum of four (4) design package submittals (30%, 60%, 90% and 100%). Company will review all required design package submittals and requires a review period of a minimum of ten (10) working days for the 30% submittal, twenty (20) working days for both the 60% and 90% submittals and fifteen (15) working days for the 100% submittal.

ii. Contractor shall incorporate Company review comments with each subsequent design submittal package. Contractor shall return redlines and provide a comment response letter with each subsequent design submittal package.

D. 30% Design

i. Data Gathering: Contractor shall perform data gathering activities that includes, but is not limited to obtaining as-built drawings, water use records, water quality samples, surveys and other information as required; obtaining permit application forms and requirements from approval agencies; requesting utility information and maps from utility companies; locating and potholing for utilities; obtaining local design

requirements and standard details; meeting with the City of Coolidge, Pinal County, ADEQ and other permitting and reviewing agencies to determine the design requirements for approvals and permitting; and visiting the Site and noting conditions that may impact the design. An ALTA and topographical survey of the Site is provided in Exhibit "C". Sample plans for an adsorptive media ARF, a chemical feed system and a standalone sodium hypochlorite feed system are provided in Exhibits "I", "J" and "K", respectively. Company will provide example technical specifications in CSI format for Contractor's use as a model for the preparation of technical specifications. The Company, upon receipt of written request of the Contractor, will provide supplemental information if sufficient information is not available.

ii. Base Map Preparation: Contractor shall prepare a base map showing the locations of all existing utilities and structures with dimensions from the site property line and roadway monument line. Contractor shall identify diameter, type of material and type of utility. Contractor shall show the locations of all existing valves and structures.

iii. Geotechnical Investigation: Contractor shall perform geotechnical investigation to determine soil characteristics, excavation and compaction requirements, soil bearing capacities, electrical conductivity and other information needed to establish design parameters for construction. Contractor shall prepare a report that presents the findings and recommendations of the geotechnical investigation.

iv. Design Report: Contractor shall prepare a draft design report that provides a design narrative for the ARF and addresses detailed design criteria that includes, but not limited to: chemical dosages, hydraulic loading rates, empty bed contact times, backwashing rates and frequencies, type of media, media volumes, backwash volumes, tank and vessel capacities, pumping capacities and other related process information. Contractor shall provide the maximum pressure drop through the ARF throughout the full life-cycle of media. Contractor shall provide calculations to confirm the design of the ARF will comply with the Treatment Performance Requirements set forth herein. The design report shall also include, but is not limited to, design description, equipment selection, performance specifications for all equipment, controls description, site improvements and required permits and approvals. Contractor shall provide figures and supplemental information including, but not limited to, design calculations, site layout, details, process flow schematic, equipment cut sheets with name of manufacturer, model numbers and dimensions and weights; list of chemicals used in the treatment process and the quantity, concentration, and storage requirements for each.

v. Blend Plan: Contractor shall prepare a draft blend plan for the ARF.

vi. Submittals: Contractor shall submit to Company for review a 30% design package that includes, but is not limited to: base map, 30% construction drawings, design report, blend plan and geotechnical report.

E. 60% Design

i. Construction Drawings: Contractor shall prepare scaled construction drawings that include, but are not limited to, general, civil, mechanical, structural, electrical and instrumentation plans, sections and details. Contractor shall produce construction drawings in MicroStation Version 8i or AutoCad in 2-D format.

ii. Blend Plan: Contractor shall revise blend plan as required.

iii. Design Report: Contractor shall revise design report as required.

iv. Technical Specifications: Contractor shall prepare draft technical specifications in CSI format.

v. Submittals: Contractor shall submit to Company for review a 60% design package that incorporates Company 30% review comments from the previous review and includes, but is not limited to, two (2) hard copies and one (1) CD of the 60% construction drawings, design report, blend plan and technical specifications.

F. 90% Design

i. Construction Drawings: Contractor shall revise construction drawings as required.

ii. Design Report: Contractor shall revise design report.

iii. Blend Plan: Contractor shall revise blend plan.

iv. Technical Specifications: Contractor shall revise technical specifications as required.

v. Permits and Approvals: Contractor shall prepare permit and review applications required by regulatory agencies.

vi. Submittals: Contractor shall submit to Company for review a 90% design package that incorporates Company 60% review comments from the previous review and includes, but is not limited to, two (2) hard copies and one (1) CD of the 90% construction drawings, design report, blend plan, technical specifications and permit applications. Upon approval from the Company, Contractor shall submit permit applications and supplemental materials as required to regulatory agencies for review and approval.

G. 100% Design

i. Construction Drawings: Contractor shall finalize construction drawings.

ii. Design Report: Contractor shall finalize design report.

iii. Blend Plan: Contractor shall finalize blend plan.

iv. Technical Specifications: Contractor shall revise technical specifications.

v. Permits and Approvals: Contractor shall obtain all permits and approvals granted from regulatory agencies.

vi. Submittals: Contractor shall submit the 100% design package to Company that incorporates Company 90% review comments, regulatory review comments and includes, but is not limited to: two (2) hardcopy sets of signed and sealed full size (24"x36") plans; two (2) hard copy sets of technical specifications, design report, blend plan, permits; and electronic versions of each on CD for in-house reproduction needs.

H. Construction Phase Submittals

i. Company requires a minimum of ten (10) working days for each submittal review. Contractor shall submit equipment and materials submittals that require longer lead times prior to submittals for equipment and materials that require shorter lead times.

ii. Contractor shall submit to Company for review a construction safety plan, shop drawings, samples, and engineering data covering all equipment and fabricated materials which will become a permanent part of the ARF. Data shall include drawings and descriptive information in sufficient detail to show the type, size, arrangement, and operation of component materials and devices; external connections, anchorages, weights and support required; performance characteristics and dimensions needed for installation and correlation with other materials and equipment. Submittals in electronic format are preferred. Hard copies, binders and actual samples are acceptable when electronic copies are not possible.

iii. Contractor shall identify any deviations from the approved plans and specifications on each submittal. Contractor shall accept full responsibility for the completeness of each submittal, and, in the case of a re-submittal, shall verify that all exceptions previously noted by Company are addressed.

iv. Company will not grant extensions of contract time for submittals.

v. Contractor's letter of re-submittal shall list the date of its original submittal letter, Company's submittal response date(s), and re-submittal dates.

vi. Company's review of drawings and data submitted by Contractor will cover only general conformity to the construction drawings and technical specifications, external connections, and dimensions which affect the layout. Company's review does not indicate a thorough review of all dimensions, quantities, and details of the material, equipment, device, or item shown. Company's review of submittals shall not relieve Contractor from responsibility for errors, omissions, or deviations, or responsibility for compliance with the construction drawings and technical specifications.

vii. Contractor shall number submittals by CSI division and sequence of submittal and without division by subcontracts or trades (i.e., 15000-xxx-xxx).

I. Construction

i. General: Contractor shall mobilize to the site; locate existing utilities; prepare site; perform construction staking; construct ARF; perform materials, pipe and equipment testing; and perform flushing, disinfection and hydrostatic testing.

ii. Requests for Information, Change Orders and Pay Requests: Contractor shall submit requests for information, change order and payment applications to Company in writing. Company will maintain the administrative files and logs for the project during construction including submittals, correspondence, payment applications, etc. Company will review all Contractor payment applications in accordance with Contract documents. Company's project manager will interface with the Contractor and coordinate and delegate construction related questions. Company will review and issue all change orders in accordance with the General Conditions of Contract.

iii. Inspection: Company will provide on-site representation during construction.

iv. Work Hours: Normal working hours are 8am-5pm Monday-Friday. Company may consider working hour exemptions on a case by case basis and will provide approval in writing.

v. Staging: Contractor shall coordinate construction staging locations and acquire the required approvals to use such locations.

vi. Wastewater: Contractor is responsible for capturing and disposing of all wastewater generated during construction and for obtaining proper approvals to do so. Contractor shall not discharge any water, backwash water, wastewater, or any other discharge onto or off the site without written approval from the Company and the governing regulatory agencies.

vii. Grading and Drainage: Contractor shall grade the site to drain and compact the subgrade and surface improvements within the limits shown on the

Conceptual Site Plan in Exhibit "D". Contractor shall provide a minimum of 8-inches of aggregate base course compacted to 95% standard proctor density for the surface improvements.

viii. O&M Manual and Warranties: Contractor shall submit an O&M manual for the ARF including, but not limited to: recommended spare parts list, equipment warranties, and guarantees for Company for review four (4) weeks prior to startup. Company requires a minimum of two weeks to complete its review. Contractor shall provide written procedures detailing the ARF start-up, shutdown, backwash, operation, control, and monitoring.

ix. Spare Parts: Contractor shall submit a list of recommended spare parts for an operating period of 3 years. The list shall describe each part; include the manufacturer's part number, the quantity recommended, vendor to purchase from and the unit price of the part. Company may purchase from Contractor all, some, or none of the recommended spare parts at the Company's option.

vii. Testing: Contractor shall notify Company a minimum of 48 hours prior to any testing. Contractor shall submit a Field Acceptance Test Report including the results of all field tests conducted on the ARF within two weeks of completion of each test required. Contractor shall pay for all testing services required.

viii. Startup and Training: Contractor shall startup the ARF. Prior to Contractor's application for the AOC, Company will assist Contractor during startup by collecting water quality samples while Contractor runs the ARF to waste. Contractor shall conduct operator training consisting of two (2) 8-hour sessions on separate days, conduct pre-final walkthrough, prepare punch list of items for correction, and load facility with media and chemicals. Contractor shall video tape each training session and provide a DVD to the Company. Contractor shall pay for all testing, startup and training services.

ix. Project Closeout: Contractor shall correct all deficiencies, demobilize from site, submit record drawings, commission the ARF, prepare Engineer's Certification of Completion and obtain the AOC and Certificate of Occupancy. Contractor shall submit to Company the Certificate of Occupancy, Engineer's Certificate of Completion, AOC and record drawings on CD, three (3) hard copies of the O&M manual and an electronic copy on CD, and the results of testing. Company will assist Contractor during commissioning by collecting water samples as required in ADEQ's Initial Start-Up Monitoring Form (Exhibit "N"). Contractor shall submit record drawings drawn in MicroStation Version 8i or AutoCAD 2D and signed and sealed by the Engineer of Record.

x. Acceptance of ARF: The Company may accept the ARF after the latest of the following: 1) Receipt of the AOC from ADEQ; 2) Receipt of Certificate of Occupancy from Pinal County or the City of Coolidge; 3) The Company's written confirmation that the ARF meets the Treatment Performance Requirements described

herein; or 4) completion of successful commissioning of the ARF.

3. TREATMENT PERFORMANCE REQUIREMENTS

A. General

The ARF shall reduce the effluent arsenic level to less than or equal to seven (7) micrograms per liter ("µg/L") throughout the full life-cycle of all media. The ARF shall maintain or improve the quality of the treated water as it relates to other chemical constituents. Contractor shall submit, in writing, all changes to treated water quality and their respective impact on the water distribution system for Company approval during design. Contractor shall fully mitigate negative impacts to water quality or the distribution system in the ARF design.

B. Design Criteria

Design flow rates, storage volumes, system pressures, treated water quality requirements and other design criteria are provided in Exhibit "E".

C. Water Quality Data

Water quality data for Coolidge Well No. 13 is provided in Exhibit "F".

D. Media Change-Out Contract

Contractor shall complete and sign a 5-year Media Change-Out Contract, extendable at the Company's sole discretion for an additional 5 years (Exhibit "B").

4. PROCESS DESIGN REQUIREMENTS

A. Special Site Conditions

The ARF shall treat full flow from Well No. 13. Two 0.5 million gallon storage reservoirs and a booster pump station are planned for construction on the site in the future.

B. ARF Configuration

The ARF shall consist of parallel treatment vessels containing one of the approved adsorptive media in Exhibit "G". The Contractor shall provide all necessary controls, piping, and all other appurtenances. Contractor shall design the ARF for expansion in the future.

C. Media Flux Rate

Contractor shall design the filter vessels and controls to conform to the manufacturer's minimum and maximum recommended media flux rate during all operating conditions, but shall not exceed the maximum design media flux rate per Exhibit "E" during any operating condition, including during backwash reinjection.

D. Empty Bed Contact Time

Contractor shall design the filter vessels and controls in conformance with the media and equipment manufacturer's requirements and the minimum empty bed contact time per Exhibit "E" during all operating conditions, including backwash reinjection.

E. Bypassing and Blending

Contractor shall design an ARF bypass with an operator adjustable bypass flow rate set point. Contractor shall use ClaVal control valves to control flow rate through the bypass line and ARF.

F. Backwashing and Recycling

Contractor shall design the ARF so that the media is backwashed in place without removal in accordance with the hydraulic design criteria in Exhibit "E". Manual operation of the backwash procedure is required. The Contractor shall design the on-site piping to utilize the distribution system as the backwash water source. An on-site backwash tank shall capture all backwash water. Sufficient time is required for any fines in the backwash water to adequately settle. A backwash recycle pump shall transfer water from the backwash tank and blend with the raw well water on the influent side of the ARF for treatment. Level controls in the backwash tank shall control the operation of the backwash recycle pump but at no time shall the backwash water recycle rate exceed 10 percent treated water flow rate. Backwash recycle pump shall only operate when the well is operating and water is being treated.

G. Chemical Feed Systems

If the chemical feed system only utilizes sodium hypochlorite, Contractor will utilize the existing FRP enclosure and provide a sodium hypochlorite chemical feed system similar to the example plans provided in Exhibit "K". If, in addition to, sodium hypochlorite other chemicals are required for the ARF, Contractor shall install each chemical feed pump and chemical storage tank required for the ARF on a concrete pad with a shade canopy with side panels to protect from direct sunlight and 6-inch containment curb capable of storing a minimum of 10 percent of the tank capacity. Contractor shall mount chemical feed pumps and chemical storage tanks on elevated concrete pedestals within the containment curb. Contractor shall provide double-walled chemical storage tanks for 100% secondary containment. Chemical tanks shall include visual and ultrasonic level indicators (see Exhibit "J" for a sample design). All chemicals provided for use must conform to NSF 60 standards. Contractor shall provide

emergency eyewash and shower in the vicinity of the chemical storage area in accordance ANSI Z358.1 and 29 CFR 1910.151.

H. pH Adjustment

If required to meet the Treatment Performance Requirements, Contractor shall provide pH adjustment upstream and/or downstream of the ARF. Effluent water quality must match historical pH levels as shown in Exhibit "F". Contractor shall install one pH analyzer for each pH injection point. Approved chemicals for pH adjustment are: sulfuric acid (93 to 91 percent) and sodium hydroxide (50 percent in summer and 25 percent in winter).

I. Programming and SCADA

The Contractor shall integrate the ARF signals and alarms into the Pinal Valley SCADA system. Contractor shall design a SCADA system to send water production data, pH data, alarms and any other information as required to the Casa Grande office. Contractor shall sub-contract and coordinate all SCADA programming with Delta Systems Engineering and all ARF programming with Brown and Caldwell.

5. ARF COMPONENT DESIGN

A. Filter Vessels

i. Design ARF for parallel operation. Make provisions for ultimate expansion with vessels of equal size and appurtenances.

ii. Carbon steel ASME and National Code stamped pressure vessels with vertical orientation and minimum vessel pressure rating per Exhibit "E".

iii. Contractor shall line the filter vessel interiors with Carboline 4500S (30-40 mil) epoxy coating in accordance with the manufacturer's recommendations. Contractor shall coat the filter vessel exteriors in accordance with Company's Water Storage Tank Coating Specifications O-12-2 (Exhibit H) or approved equal.

iv. Contractor shall subcontract with one of the Company's approved inspectors to inspect and approve blasting, coating and condition of vessels prior to shipment. Contractor shall pay initial and subsequent re-inspections, if required. Contact information Company's inspectors are as follows:

a. Mr. Greg Sprinkle
Industrial Inspection and Consulting, LLC
P. O. Box 51026
Phoenix, AZ 85076-1026

b. Mr. Patrick Sweeney

v. Manual backwash with manual handwheel operated butterfly valves for all service, backwash, and rinse cycles.

vi. Stainless steel sample ports with for operator monitoring of raw water, treated water from each vessel and blended water sample location.

vi. Three (3) side-mounted media sample ports for obtaining media samples for testing.

viii. Magnetic flow/totalizer meters on each vessel for measuring individual instantaneous gallons per minute and total gallons through the system in service and in backwash cycles.

ix. Contractor shall design all internal vessel piping and fittings, including the underdrain system and laterals, of Type 316 grade stainless steel.

x. Contractor shall provide isolation kits at all dissimilar metal connections, including stainless steel connections to any other metal, and address any dissimilar metal concerns within the vessel to the Company's satisfaction. Welded connections between stainless steel and mild steel are not acceptable.

xi. All vessel penetrations shall have flanged connections.

xii. Contractor shall provide hub and laterals with support launchers attached to vessel or false bottom with nozzles.

xiii. Contractor shall size internal laterals or nozzles appropriately to distribute flow uniformly across the cross sectional area of the filter vessels during treatment and backwashing. Contractor shall obtain approval of the treatment vessels, internal laterals, and ground support bed designs in writing from the adsorptive media manufacturer, filter vessel manufacturer and the Company.

xiv. Contractor shall design all internal piping and fasteners of Type 316 stainless steel. Contractor shall powder coat all stainless steel components internal to vessel, with exception of the laterals or nozzles.

xv. Contractor shall design internal laterals appropriately for proper operation with all of the approved adsorptive media in Exhibit "G".

xvi. Contractor shall equip all vessels with air release valves and pressure relief valves sized for the maximum flow rate to the vessel. Rupture discs are not acceptable.

xvii. The adsorptive media manufacturer must state, in writing, if gravel under bed is required. The adsorptive media manufacturer, filter vessel manufacturer, and the Company must approve the gravel under bed design in writing.

xviii. Contractor shall provide a hinged access manway on the side and hinged inspection hatch on the top. The access manway shall have vertical davit arm or similar hinge that will support the weight of the hatch without sagging when opened.

xx. Contractor shall permanently attach filter vessels to an engineered concrete slab.

xxi. Vessel shall provide a passive cathodic protection system utilizing sacrificial anodes to protect the vessels from corrosion.

B. External Piping

i. Contractor shall provide external connections that consist of flanged pipe connections or restrained flanged coupling adaptors (raw water inlet, finished water outlet, backwash feed inlet, and backwash waste outlet).

a. Manufacturers:

1) StarFlange Series 3200
2) Romac Industries, Inc. Style RFCA
3) Approved equal

ii. Contractor shall provide external aboveground and belowground piping that is ductile iron pipe ("DIP") for pipe 3-inches and larger and conforms to the Company's Construction Specifications: E-8-1 and Standard Specification Drawings: E-9.

iii. Contractor shall provide corrosion protection of the piping from corrosive soils and/or stray current based on recommendations provided in the geotechnical investigation.

iv. Contractor shall provide seamless copper external piping for pipes smaller than 3-inches that conforms to ASTM B88, Type K, soft temper. Contractor shall provide fittings that are compression type per the Company's Construction Specification: E-8-1 and Standard Specification Drawings: E-9.

vi. Contractor shall paint all external above ground pipe and fittings with Tnemec or approved equal with an approved tan color determined by the Company.

vii. Contractor shall inform Company in writing of any conflict in specifications, and Company will determine the prevailing specification.

C. Valves and Appurtenances

All valves and appurtenances shall conform to the Company's Construction Specifications: E-8-1 and Standard Specification Drawings: E-9, unless otherwise specified.

i. Aboveground Manual Butterfly Valves

a. Contractor shall provide manually actuated butterfly valves with hand wheels at aboveground locations for the control of flows for backwash, rinse, and normal treatment operations. Contractor shall provide chain wheel actuators on valves greater than 5 feet in height above the ground surface. Gate valves are required for all isolation and belowground installations.

b. Manufacturers:

1) Mueller.
2) Dezurik.
3) Pratt

ii. Pressure Switch High

a. Contractor shall install high pressure cut-off switches between the well discharge head and the inlet of the ARF.

b. Manufacturers:

1) Mercoid

ii. Pressure Gauges

a. Contractor shall install Ashcroft stainless steel pressure gauges with 4-inch dials on the ARF inlet, outlet and bypass lines, pressure vessels and at all locations as required.

D. Flow Meters

i. Contractor shall provide one supply flow meter with remote mounted transmitter per filter vessel.

ii. General

a. Type: Magnetic flow meter conforming to NSF 61

b. Materials:

1) Liner: PTFE (Teflon)
2) Electronics Housing: Wal Alu, IP67 NEMA4X
3) Electrodes: Alloy C-22, bullet nose

iii. Flow rate display indication in gpm and totalized flow in gallons

iv. Accuracy: +/-0.5% of flow rate or better

v. End Connection: Flanged

vi. Manufacturer:

a. Endress + Hauser – Promag 53P.

E. HDPE Backwash Tank

i. Contractor shall provide tank of virgin polyethylene resin as compounded and certified by the manufacturer, rotationally molded, one-piece seamless construction, cylindrical in cross-section and vertical in axis, with a design specific gravity of 1.9 and fully conform to ASTM D 1998-04.

ii. The manufacturer shall mold the top head integrally with the cylinder straight shell and the bottom head integrally with the cylinder straight shell.

iii. Resin shall contain a minimum of a UV 8 stabilizer as compounded by the resin manufacturer.

iv. Contractor shall provide an 18-inch threaded polyethylene, vented and easily accessible manway.

v. Contractor shall provide all tank fitting attachments with flexible couplings or other provisions to allow for movement without rupture or separation of connections. Flexible couplings shall allow deflection in all directions per manufacturer's requirements. Support all connections larger than 2-inches independently from the tank to prevent weight transfer to the tank flange.

vi. Contractor shall provide an ultrasonic, radar type level transducer with antenna and transmitter displaying water level on an LCD screen as manufactured by Endress+Hauser Micropilot M FMR231.

vii. Contractor shall provide tank with clearly marked with manufacturer, date of manufacture, and serial number.

viii. Contractor shall provide tank with all opening cut edges trimmed smooth.

ix. Uncoated or exposed carbon steel appurtenances, fasteners, or anchorage are not acceptable.

x. Contractor shall provide anchor bolts sized by the manufacturer and install on engineered concrete slab or other anchoring point approved by the Company.

xi. Contractor shall provide tank with minimum required wall thickness for the cylinder sufficient to support its own weight in an upright position without any external support.

xii. Contractor shall provide tank with a sloped floor and side molded outlet to provide complete drainage of the tank.

xiii. Tank shall have a minimum of three (3) lifting lugs integrally molded in the cylinder straight shell. Contractor shall provide lifting lugs made of Type 316 stainless steel.

xiv. Contractor shall provide a minimum of four (4) tie-down lugs integrally molded into the top head. Provide tie-down lugs designed to allow tank retention in wind and seismic loading without damage to the tank.

xv. Contractor shall provide a level and smooth concrete tank pad within the tolerances recommended by the tank manufacturer.

xvi. Contractor shall provide tank that is vented for the material, flow, and withdrawal rates expected.

xvii. Design Loads

a. Contractor shall design to resist both wind and seismic for both tank full and tank empty conditions.

b. The design and provision of adequate an anchorage system for the service conditions is the responsibility of the Contractor.

c. Contractor shall submit design calculations signed and sealed by an Arizona registered engineer that are approved in writing by the tank manufacturer.

d. Anchorage systems requiring tank penetrations are not acceptable.

e. Contractor shall provide galvanized carbon steel anchorage systems unless otherwise specified.

xviii. Fittings

a. Threaded bulkhead fittings are not allowed for connections greater than 2 inches in diameter.

b. Bolted double 150 lb. flange fittings shall consist of two (2) 150 lb. flanges and two (2) 150 lb. flange gaskets, and the correct number and size of all-thread bolts for the flange specified by the flange manufacturer.

xix. Tank color shall match pipe, vessels and other ARF components. Contractor shall provide colors available from manufacturer.

F. Welded Steel Backwash Tank (Alternate to HDPE Tank)

i. Contractor shall design welded steel tanks, accessories and foundation in accordance with ANSI/AWWA D100 and build in accordance with OSHA.

ii. Contractor shall place the tank shell on a concrete footing adequately sized to support the tank structure when filled with backwash water.

iii. Tank walls and roof shall have a thickness designed according to submitted engineering calculations in accordance with AWWA D100. Minimum steel plate thicknesses are as follows:

a.	Walls	1/4 inch
b.	Roof	3/16 inch
c.	Floor	3/8 inch

Contractor shall design self supporting roof without the need for a center column with a minimum pitch of 1-inch rise to 12-inch run.

iv. Contractor shall provide tank accessories in accordance with all applicable safety and building codes, including AWWA D100, Code of Federal Regulations, 29 CFR 1910.27, OSHA and IBC.

v. Contractor shall provide at a minimum one (1) 24-inch hinged manhole near tank base and one (1) 24-inch roof hatch with hinges an, handle, hold open device, hasp lock and weather tight seal.

vi. Contractor shall provide an exterior ladder in accordance with ANSI A14.3-Q4 and 29 CFR 1910.27 and in accordance with any other applicable OSHA requirement complete with ladder up safety post as manufactured by Bilco, a LAD-SAF

flexible cable ladder safety system as manufactured by DBI SALA and a 36-inch side swing ladder door.

vii. Contractor shall provide personal fall arrest system extending from the center of the tank to the outer edge of the tank. The personal fall arrest system shall allow for safe access to the vent on the tank roof.

viii. Contractor shall provide an ultrasonic, radar type level transducer with antenna and transmitter displaying water level on an LCD screen as manufactured by Endress+Hauser Micropilot M FMR231.

ix. Contractor shall provide flanged pipe connections per ASTM A53, Grade B, Type E or S, or ASTM 106, Grade B.

x. Contractor shall provide Welding Inspectors certified by American Welding Society to Standard AWS QC-1-88 with prior inspection experience using governing welding codes. Provide Weld Testing Personnel certified to perform nondestructive testing (NDT) in accordance with current American Society of Nondestructive Testing (4153 Arlingate Plaza, Columbus, OH 432128) Recommended Practice No. SNT-TC-1A and all supplements, NDT Level II.

xi. Contractor shall provide coating in accordance with the Company's Water Storage Tank Coating Specifications: O-12-2 (Exhibit "H") or approved equal.

G. Chemical Feed Systems

i. General – Contractor shall design, furnish and install NSF/ANSI 61 compliant chemical feed systems as required, complete with metering pumps, motors, drives, meters, calibration chambers, piping, valves, controls and all accessories and appurtenances as required for a complete and operable system.

ii. Chemical Pumps

a. Contractor shall provide Grundfos DDA chemical pumps compatible for use with sodium hypochlorite, sulfuric acid, ferric chloride and/or any other chemical used.

b. Contractor shall size for the appropriate chemical feed rate and system pressure.

c. Contractor shall provide one (1) duty and one (1) standby chemical pump for each application.

iii. Tubing and Conduit

a. For liquid chemical service, Contractor shall provide tubing compatible with chemicals used in the treatment process. Contractor shall install tubing in electrical conduit for ease of installation/replacement, as well as non-pressure rated secondary containment. Tubing manufacturer shall confirm chemical compatibility of tubing with chemical system being served. Contractor shall provide UV resistant tubing.

b. Contractor shall provide tubing adequately sized for the flow and pressure requirements of this application with the minimum following dimensions and pressure rating:

1) Outside diameter: 3/8 inch.

2) Inside diameter: ¼ inch.

3) Pressure Rating at 120° Fahrenheit: 200 psi.

c. Contractor shall provide 3-inch conduit for chemical tubing made of PVC electrical conduit with sweeps instead of elbows.

d. Contractor shall provide all necessary fittings clamps, and adapters for connection of tubing at the chemical metering pump outlet, chemical feed point, and any other connections. Contractor shall provide barbed or compression-style fittings, specifically designed for use with the tubing being provided, and compatible with the service (both with the fluid being carried in pipe and pressure rating). Contractor shall provide fittings at locations that are accessible at all times. Do not locate fittings in the carrier pipe. Contractor shall construct all connections per the tubing manufacturer's recommendations that provides a connection that is equal to or greater than tubing pressure rating. Contractor shall ensure that parts and fittings that are in contact with the fluid in the tubing are compatible with the chemical being carried.

e. Contractor shall provide an injector quill with ball valve and static mixer at the point of injection of each chemical at an appropriate aboveground location.

iv. Chemical Storage Tanks

a. Contractor shall provide tanks that are rotationally molded, vertical, high density cross-linked polyethylene, one-piece seamless construction, cylindrical in cross-section with flat bottoms.

b. Contractor shall provide tanks that are double walled and designed for aboveground, vertical, outdoor installation. Provide tanks manufactured from virgin materials.

c. Contractor shall provide tanks that are designed to store approved chemicals at atmospheric pressure and vented as recommended by the manufacturer of the chemicals.

d. Contractor shall provide tanks equipped with level indicators.

e. Contractor shall provide tanks sized for a minimum 30 day storage capacity.

f. Contractor shall provide tanks equipped with a restraint system composed of the type of metal that compatible with the chemical being stored in the tank and designed to meet the proper seismic zone.

g. Contractor shall provide tank fittings and gaskets that are compatible with the chemical being stored as recommended by the chemical manufacturer.

h. Contractor shall provide tank fitting attachments with flexible couplings or other provisions to allow for movement without rupture or separation of connections in accordance with the manufacturer's recommendations. Contractor shall support all connections larger than 2-inches independently from the tank to prevent weight transfer to the tank flange.

i. Contractor shall provide an ultrasonic, radar type level transducer with antenna and transmitter displaying water level on an LCD screen as manufactured by Endress+Hauser Micropilot M FMR231.

j. Contractor shall provide a reverse float with sight glass for installation on each tank.

k. Contractor shall provide tanks manufactured by:

1) Poly Processing Company
2) Snyder
3) Approved equal.

l. Tank color shall be tan. Contractor shall provide colors available from manufacturer.

v. Safety Equipment

a. Contractor shall provide an emergency eyewash and shower and locate in the vicinity of the chemical storage area.

b. Contractor shall provide a first aid kit, protective gear and any additional safety equipment as recommended by the chemical manufacturer.

H. Backwash Recycle Pumps

i. Contractor shall provide two Grundfos centrifugal backwash recycle pumps (one duty, one standby) with variable frequency drive units.

ii. Contractor shall provide pumps capable of outdoor installation and operation.

iii. Contractor shall submit performance curves with design set points.

I. External Component Paint

i. Contractor shall paint all external aboveground pipe and components of the ARF a Company approved tan color with the exception of flow meters, Cla-Vals, gauges, displays, equipment data plates and equipment identification tags.

6. ELECTRICAL AND INSTRUMENTATION

A. General

All electrical components shall comply with the Company's EI&C Design Guidelines Technical Specification (Exhibit "M"). Contractor shall submit complete electrical instrumentation control schematics, wiring diagrams, load calculations and terminal strip information. Contractor shall provide factory pre-wired panels only.

B. SCADA

i. Contractor shall provide and install a complete and functional SCADA system with alarms, displays and controls in substantial conformance with SCADA controls at the Company's existing ARFs, wells and pump stations.

ii. Contractor shall integrate the Coolidge Well No. 13 Site into the existing Pinal Valley SCADA system by replacing the existing radio and PLC with a GE I-net II radio and Modicon M340 PLC so all analog values are historized at the Casa Grande master SCADA computer (Master Computer).

iii. Contractor shall provide 20% available spare I/O.

iv. Contractor shall provide runtime and totalized flow values to have current day, previous day, current week, previous week, current month, and previous month values calculated and displayed locally and at the Master Computer.

v. Contractor shall send all alarms to the Master Computer for operator notification via Win911. Alarms include, but are not limited to, high and low

liquid levels, motor high temperature, high and low pressure, equipment/motor failure, intrusion and valve sequencing.

C. Equipment Monitoring

i. Contractor shall provide and install one (1) Schneider Electric 15" OIT for onsite SCADA monitoring and control.

ii. The Contractor shall provide the necessary software and programming to monitor and control the following equipment and processes:

a. One well pump including all phase voltage, current, and power readings from the existing Motor Saver 777 Ethernet base power quality meter; local/remote, auto/manual, run/stopped, alarm, fail-to-run, and start/stop count; one (1) Cla-Vals and well discharge flow meter.

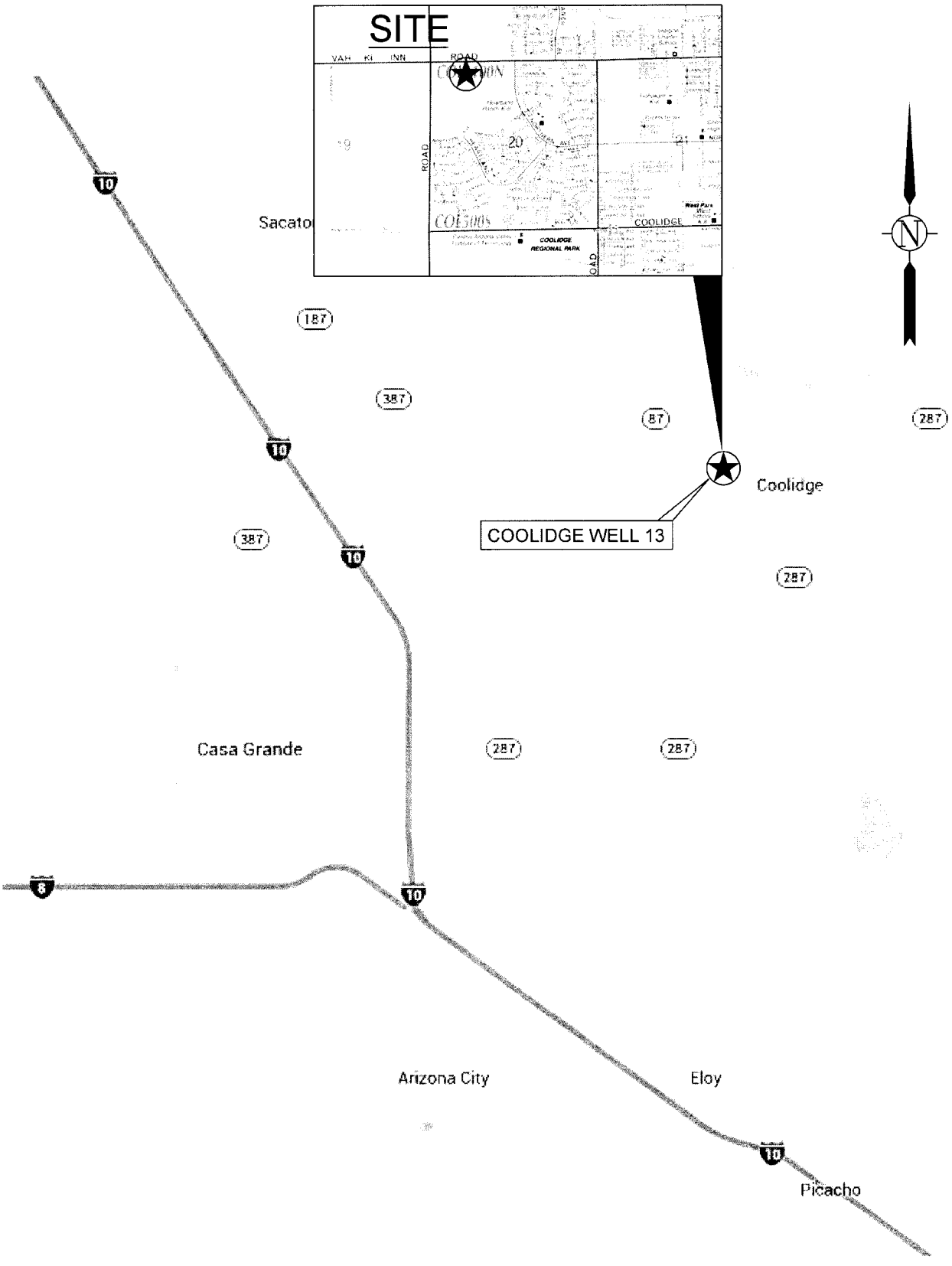
b. ARF influent flow meter, bypass flow meter, backwash flow meter, bypass flow control valve with operator adjustable set points, influent pressure, and effluent chlorine and pH levels.

c. Backwash tank level and backwash recycle pump run/stopped, alarm, fail-to-run.

d. Each chemical feed system shall include injection pump operator adjustable chemical dosing rate set point, run/stopped, alarm, fail-to-run (display only), tank level indication and set points.

Exhibit "A"

Location Map



LOCATION MAP

Exhibit "B"

Media Change-Out Agreement and Proposal Contract

ARIZONA WATER COMPANY

INPUT DIVISION INFORMATION
DIVISION ADDRESS

PROPOSAL/CONTRACT

CONTRACTOR:	SYSTEM: Pinal Valley
ADDRESS:	W.A. No(s): 1-4806
CITY ST ZIP:	BID DUE DATE:

_____, an _____, ("CONTRACTOR") SUBMITS this PROPOSAL/CONTRACT to ARIZONA WATER COMPANY, an Arizona corporation (the "Company"), to perform the work as specifically described in Attachment "A" hereto, which by this reference is incorporated herein ("Work") as an independent prime contractor.

1a. Contractor certifies that it has a complete copy of, and has read, understands and accepts, the Company's General Conditions of Contract, and the Company's Construction Specifications and Standard Specification Drawings, (the "Specifications"), all of which are attached hereto as Attachment "B". The General Conditions of Contract and Specifications are incorporated into this Proposal/Contract. Contractor affirms that all work and materials to be furnished or purchased for the Project will be in strict conformance with the General Conditions of Contract, Specifications and Drawings.

1b. Section 2 and 36 in General Conditions of Contract are modified as provided in Attachment "A", and Section 41 of the General Conditions of Contract is replaced in its entirety by paragraph 4.3 of Attachment "A". In all other respects the General Conditions of Contract remain in full force and effect.

2. Contractor represents and warrants that it has satisfied and complied with the provisions of Section 6, Contractor Understands Work and Working Conditions, of the General Conditions of Contract prior to submitting this Proposal/Contract.

3. Contractor represents that this Proposal/Contract is fair and honest in all respects, is submitted in good faith and is not submitted in collusion with any other company, entity or person.

4. Contractor acknowledges that one hundred percent (100%) Performance and Payment Bonds are required and must be provided to the Company prior to the commencement of work.

5. Prior to the commencement of Work, Contractor will submit to the Company a list of all materials to be used in the Project. The materials list will include the manufacturer, part number, price and quantity included in this Proposal/Contract.

6. Contractor will furnish all labor, tools, equipment and materials required to complete the Work according to this Proposal/Contract and the General Conditions of Contract and Specifications. No materials purchased by Contractor to be incorporated into the Project are subject to tax at the time of purchase and Contractor will not charge the Company for any such tax. Contractor will pay the applicable transaction privilege tax (the "Contracting Tax") on the Work after Contractor receives payment of the final invoice from the Company. The cost of materials incorporated into the Work which are exempt by Arizona Revised State Statues ("A.R.S.") from the Contracting Tax, for example, pipes or valves having a diameter of four (4) inches or larger, including equipment, fittings and any other related part that is used in operating the pipes or valves (A.R.S. §42-5061 B.6.), will not be included in the total cost of the labor and materials upon which the Contracting Tax is computed. Contractor retains full liability and obligation to pay the Contracting Tax and will defend and indemnify the Company against any demand or obligation to pay the Contracting Tax.

7. Contractor will maintain detailed accounting records of all materials purchased and incorporated into the Work. Such records will include all supporting original vendor invoices for all materials purchased. Following completion of the Work, Contractor will submit an itemized accounting to the Company which will include all supporting original vendor invoices and satisfactory evidence of payment thereof. The Company will not pay Contractor for materials not actually incorporated into the Work, and the disposition of such materials will remain Contractor's responsibility.

8. The Estimated Total Cost of the Work, shown on Page 2, is based on estimated labor and material quantities to be furnished. It includes an estimate of the Contracting Tax and the cost of the required Performance and Payment Bonds. Contractor will not cancel, modify or withdraw this Proposal/Contract during a ninety-day (90) period commencing on the Bid Due Date. The Company may accept this Proposal/Contract by signing and mailing, or otherwise delivering, a copy hereof to Contractor during such ninety-day (90) period. If the Company does not accept this Proposal/Contract during such ninety-day (90) period, Contractor may cancel this Proposal/Contract by giving written notice of cancellation to the Company.

9. Prior to the commencement of the Work, Contractor will provide the Company with a detailed construction schedule, in either Gantt or CPM form, identifying all tasks to be performed from the date of the written Commencement Notice through completion of the Work, including testing, training of Company Personnel and the final Project invoice.

10. Contractor will not commence the Work until the Company gives Contractor a written Commencement Notice. Contractor will complete the Work within the time specified in Section 5 of Attachment A.

11. Following the Company's written notice of satisfactory completion of the Work, and upon receipt of the final invoice from Contractor, the Company shall pay Contractor the actual total cost of the Work, which will be calculated as shown on Page 2, except that actual labor and material quantities installed/constructed will be substituted for the estimated labor and materials quantities and the Contracting Tax will be recalculated based on such actual labor and materials quantities.

12. The Company may deduct from the Company's payment of the final invoice the amount of applicable liquidated damages if Contractor does not deliver or perform within the time limit shown in Paragraph 10. This provision shall not limit the Company's ability to terminate this Proposal/Contract for Contractor's unsatisfactory performance or failure to perform as provided in the General Conditions of Contract, Specifications or Drawings, or in this Proposal/Contract.

13. This Proposal/Contract shall continue until _____, unless terminated earlier as provided in paragraph 14, (the "Term").

14. The Company, at its option, may terminate this Proposal/Contract at any time prior to the end of the Term upon thirty (30) days notice to Contractor.

SPECIAL CONDITIONS:

CONTRACTOR	**PROPOSAL/CONTRACT ACCEPTED:** ***ARIZONA WATER COMPANY***
By:	By:
Print Name:	Print Name: Fredrick K. Schneider, PE
Title:	Title: Vice President - Engineering
Date:	Date:

AFH

ARIZONA WATER COMPANY

INPUT DIVISION INFORMATION
DIVISION ADDRESS
DIVISION PHONE NUMBERS

PROPOSAL/CONTRACT

CONTRACTOR:	SYSTEM: Pinal Valley
AZ CONTRACTOR LICENSE NO: CLASSIFICATION:	W.A. No(s): 1-4806
ADDRESS:	BID DUE DATE:
CITY ST ZIP	BID BOND REQUIRED ☑ Yes ☐ No

DESCRIPTION OF PROJECT: Provide all equipment, material and labor necessary and appropriate to remove and replace the used adsorptive media at the Coolidge Well No. 13 Arsenic Treatment Facility in the Pinal Valley water system.

1-2. MATERIALS EXEMPT FROM CONTRACTING TAX (per Paragraph 6)	QUANTITY	UNIT PRICE LABOR	UNIT PRICE MATERIALS	TOTAL COST LABOR	TOTAL COST MATERIALS
Media Change-Out Contract per Attachment "B"	1				
				1	2
3. Total Labor to Install Exempt Materials (add the amounts in column 1)				3	
4. Total Exempt Materials (add the amounts in column 2)					4

5-6. NON-EXEMPT MATERIALS	QUANTITY	LABOR	MATERIALS	LABOR	MATERIALS
				5	6
7. Total Labor to Install Non-Exempt Materials (add the amounts in column 5)				7	
8. Total Non-Exempt Materials (add the amounts in column 6)					8
9. Subtotal A (add lines 3, 7 and 8)					9
10. Contracting Tax Base (multiply the amount on line 9 by 0.65)				10	
11. Applicable Contracting Tax Rate				11	
12. Contracting Tax (multiply the amount on line 10 by line 11)					12
13. Subtotal B (add lines 4, 9 and 12)					13
14. 100% Performance and Payment Bonds Cost					14
15. Estimated Total Cost (add lines 13 and 14)					15

NOTE: The Estimated Total Cost includes all labor and materials for backfill, pavement replacement, chip seal, and traffic control necessary for the Project.

Attachment "A"

Coolidge Well No. 13 Site
Media Change-Out Contract

The Company's Coolidge Well No. 13 is equipped with an adsorption media treatment system (the "Facilities") used to reduce the concentration of arsenic (the "Contaminant") to ensure that the water from Well No. 13 complies with Safe Drinking Water Standards.

1. Site.

The Facilities are located at 2107 W. Vah Ki Inn Road, Coolidge, AZ 85128 ("Site").

2. Removal and Replacement of Used Media.

As more specifically set forth below, Contractor will provide all equipment, material and labor necessary and appropriate to remove and replace the used media in the Facilities ("Media Change-Out"). Used media may contain arsenic and other substances.

2.1 Characterization and Classification of Used Media.

Contractor shall obtain from the Site a representative sample of the used media. Contractor will obtain a laboratory analysis of the used media using a method of analysis approved by the United States Environmental Protection Agency or State of Arizona. Such analysis must be performed by an Arizona Department of Health Services certified laboratory. Contractor will use the laboratory results to complete all characterization, classification and documentation required by all regulatory agencies. Characterization, classification and documentation shall be conducted in accordance with all federal, state, and local requirements. Contractor will provide, or arrange for its laboratory to provide copies of the test results to Company within three (3) days of Contractor's receipt of such test results. Company will provide the following information to Contractor at the time of Media Change-Out:

A. Flow totalizer readings at the time of initial media installation or previous Media Change-Out.

B. Flow totalizer reading at time the Facilities are removed from service for current Media Change-Out.

C. Most recent laboratory test results for the Contaminant.

2.2 Removal of Used Media from the Vessels.

Contractor will make the necessary arrangements to remove the used media. Contractor will use a vacuum extractor to remove all used media from the vessels and thoroughly clean out the backwash tanks. Contractor will remove all residual media from the vessel by spraying residual media off the sides of the vessel and interior of the backwash tank with a hose. Contractor shall handle and dispose of all water used at the Site during the removal of the used media, in compliance with all applicable laws and regulations. No water will be discharged onto or from the Site. After each vessel and backwash tank is cleaned, Contractor will notify Company that the vessels and backwash tanks are clean and ready for inspection. Contractor will clean up any spilled media and restore the Site to its original condition.

2.3 Packaging, Transportation and Disposal of Used Media.

Contractor will remove, package, transport and dispose of the used media from the Site in compliance with all applicable federal, state and local laws, regulations and standards. Contractor will transport and dispose of used media in a disposal facility that is expressly authorized to receive used media. Contractor will provide waste manifests and all other waste documentation required under all laws applicable to the used media to Company within thirty (30) days of the date the used media is removed from the Site or with Contractor's Approval to Bill, whichever is earlier. No payments will be made to Contractor before Company receives all required documentation.

2.4 Inspection of the Vessels.

Contractor will inspect the interior of each vessel, distribution laterals and nozzles of the empty vessels upon each Media Change-Out at no additional cost to Company. Contractor will enter each vessel and visually inspect the interior of the vessel, including the distribution laterals and nozzles, after removing the used media from the vessel per Section 2.2. Contractor must comply with all applicable confined space entry requirements established by the Occupational Safety and Health Administration or other governing agencies with jurisdiction over Contractor's work. Contractor will identify any corrosion, accumulation of scale or other buildup that may be present inside the vessels or backwash tanks during its inspection. If Contractor finds any clogged or obstructed distribution laterals or nozzles, Contractor will immediately notify Company. The Company will be present or available by telephone during the inspection. Company may choose to repair or replace internal components prior to the replacement of the media. Company will separately negotiate the price and terms of such repairs or replacements of distribution laterals, nozzles or coating, if any, directly with Contractor or others. Within fifteen (15) days after the Media Change-Out is completed, Contractor will submit a written report to Company for each inspection completed. Contractor will not charge Company for any stand-by costs incurred while Company completes the repairs or replacements.

Contractor will supply all tools, labor, and equipment necessary to inspect the vessels and backwash tank at its own cost. Contractor is responsible for determining the details of vessel entry and access at the Site prior to commencement of the Work. Contractor must properly reinstall any part(s) removed to gain entry or

access to the vessels after completing its inspection and restore the vessels to working order.

2.5 Replacement of Used Media.

After Contractor removes used media and the vessels are determined to be in good condition or after repairs have been completed, Contractor will load new media into the vessels.

Contractor will load new _____ media into each empty vessel in accordance with all applicable manufacturer recommendations, specifications and warranty requirements. Contractor will provide any necessary hoses, pumping equipment and piping for water needed to load or rinse any new media. Contractor must take all necessary precautions to prevent spills of used media, liquid, or new media.

2.6 Disinfection and Coliform Testing.

After completing the inspection and all necessary repairs, Contractor shall notify Company when vessels are ready for disinfection. Contractor will disinfect all vessels to comply with the Company's requirements. Contractor must document and verify adequate disinfection of all media and vessels. Contractor shall place the Facilities back in service when authorized by Company.

3. Water Quality.

After Contractor completes a Media Change-Out, Contractor will return Facilities to full operation and all water produced by the Facilities must comply with the Water Quality Specification in 4.3.C. Contractor further warrants and guarantees that its performance under this Proposal/Contract will at all times comply with the terms and provisions of the Media Performance Guarantee described below.

4. Modifications to the General Conditions of Contract.

4.1 Section 2, "Bonds", is modified as follows:

Contractor shall furnish Company with a performance bond and a material payment bond in the amount of $200,000 in a form and from a surety acceptable to Company.

4.2 Section 36, "Working Hours", is modified to include the following:

Work shall only be performed between the hours of 8 a.m. and 4 p.m., Monday through Friday, unless otherwise authorized by the Company in writing.

4.3 In addition to all implied or expressed warranties and guarantees, whether set forth in the General Conditions of Contract or otherwise:

Contractor also provides a Media Performance Guarantee (defined below), which guarantees that the adsorptive media ("Media") it provides and loads into the Facilities will remove arsenic to a concentration less than or equal to 7 micrograms per liter. Contractor further guarantees that Media shall continue to remove arsenic to comply with the Water Quality Specification for a minimum volume of water treated of not less than _____ gallons ("Media Performance Guarantee"). In the event that the Media does not treat the minimum volume of water before a Media Change-Out is required, Contractor will provide a prorated savings ("Discount") on the future purchases and installations of Media for use in the Facilities for the Term. At its sole discretion, Company may require Contractor to pay Discount in cash in lieu of future Media purchases. In the event that Contractor proposes a new, improved, or different Media that would have a performance benefit to Company over the present Media, Contractor will offer such new, improved, or different Media at an equal Discount, if accepted by Company.

Design Parameters for Media Performance Guarantee:

A. Company's Coolidge Well No. 13 supplying the Facilities

B. Total Flow – 800 gpm

C. Treatment Requirement – Treated water arsenic concentration less than or equal to 7 micrograms per liter.

D. Configuration – Vessel(s) in parallel

E. Pretreatment – Chlorination with liquid sodium hypochlorite ("NaOCl")

F. _____-ft. diameter vessel with _____ cubic feet of Media

Wells	Total Media Volume, cubic feet	Media Change-Out Fee	Media Type	Media Performance Guarantee, Gallons
Coolidge Well No. 13	_____	$_____	_____	_____

G. Company and Contractor agree that the raw water quality set forth below is representative of the water being treated in the Facility. This water quality is the basis for the media Performance Guarantee. Variances greater than ten percent (10%) above these values (or +0.3 pH units) may result in recalculation of the Media Performance Guarantee. In such event, Company and Contractor will meet and confer and mutually agree to such recalculated Media Performance Guarantee. Contractor bears the responsibility to demonstrate the impacts to the Media Performance Guarantee.

Coolidge Well No. 13

Inorganics	Sample Date	Concentration (mg/L – unless stated otherwise)
Arsenic	28-Sep-09	0.020
Arsenic III	23-Aug-11	0.004
Arsenic V	19-Oct-11	0.0113
Cadmium	08-Aug-07	< 0.0002
Calcium	23-Aug-11	58
Calcium Hardness as CaCO3	23-Aug-11	144
Chromium	23-Aug-11	0.012
Iron	17-Oct-11	<0.05
Lead	08-Aug-07	0.008
Magnesium	25-May-11	7
Manganese	25-May-11	< 0.02
pH	08-Oct-07	8
Phosphate	19-Oct-11	< 0.15
Selenium	25-May-11	0.005
Silica, Total	23-Aug-11	31.8
Sulfate	25-May-11	234
Sulfide, Total	25-May-11	< 0.04
Total Alkalinity as CaCO3	17-Oct-11	85
Total Phosphorous	19-Oct-11	0.02
Total Suspended Solids	19-Oct-11	< 1
Turbidity (NTU)	23-Aug-11	< 1.00
Vanadium	13-Oct-09	0.024
Uranium (pci/L)	23-Aug-11	6.8 +/- 1.1

If the treated water arsenic concentration from the treatment vessels exceeds 9 micrograms per liter before the media treats _____ gallons, Contractor will replace the Total Media Volume stated above at the current Media Change-Out Fee less the Discount, as set forth by the following formula:

Discount equals Media Change-Out Fee multiplied by
[(Media Performance Guarantee (gallons) minus
Actual gallons of water treated) divided by
Media Performance Guarantee (gallons)]

<u>Example of Discount Calculation</u>

Media Change-Out Fee = $77,925.00
Media Performance Guarantee = 67,200,000 gallons
Actual quantity of water treated = 60,000,000 gallons
Discount = $77,925.00 x [(67,200,000 - 60,000,000)/ 67,200,000]
Discount = $8,349.11

If Contractor replaces any Media pursuant to this Media Performance Guarantee or otherwise, such replacement Media will also be guaranteed under the Media Performance Guarantee throughout the Term. Contractor will credit or deduct the full amount of the Discount provided by the Media Performance Guarantee from the final invoice.

5. Time for Performance.

Contractor will perform its obligations under this Agreement in a diligent, lawful, prompt, timely, and professional manner. Company will monitor the water quality of water produced from the Facilities and will notify Contractor when a Media Change-Out is required.

Contractor will provide Company with a written schedule for Media Change-Out within five (5) business days of receipt of Company's notice. Contractor will coordinate the Media Change-Out by contacting Company's Division Manager at the following address:

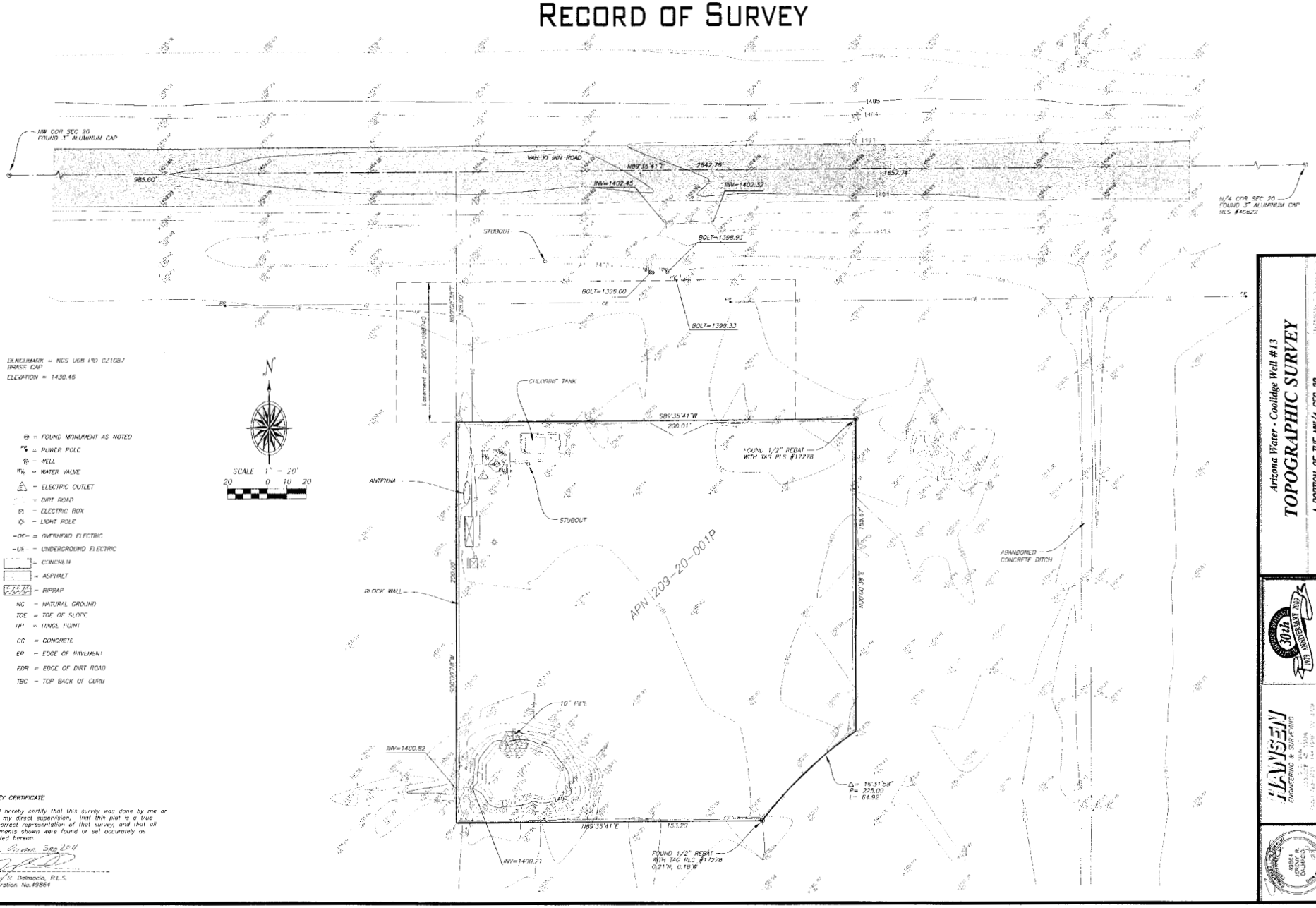
Arizona Water Company
220 East 2nd Street
Casa Grande, AZ 85122
Attn: Manager
Phone: 520-836-8785
Fax: 520-836-2850

Contractor must complete any Media Change-Out within fifteen (15) days of receipt of notice to perform a Media Change-Out, but no later than two (2) days after starting any Media Change-Out.

Exhibit "C"

Site Survey

RECORD OF SURVEY



SURVEY CERTIFICATE

I hereby certify that this survey was done by me or under my direct supervision, that this plat is a true and correct representation of that survey, and that all monuments shown were found or set accurately as indicated hereon.

Dated: Friday, Sep 2 '11

Jeremy R. Dalmacio, R.L.S.
Registration No.49864

Arizona Water - Coolidge Well #13

TOPOGRAPHIC SURVEY

A PORTION OF THE NW/4 SEC 20
T5S, R8E, G&SRPM, PINAL COUNTY, ARIZONA

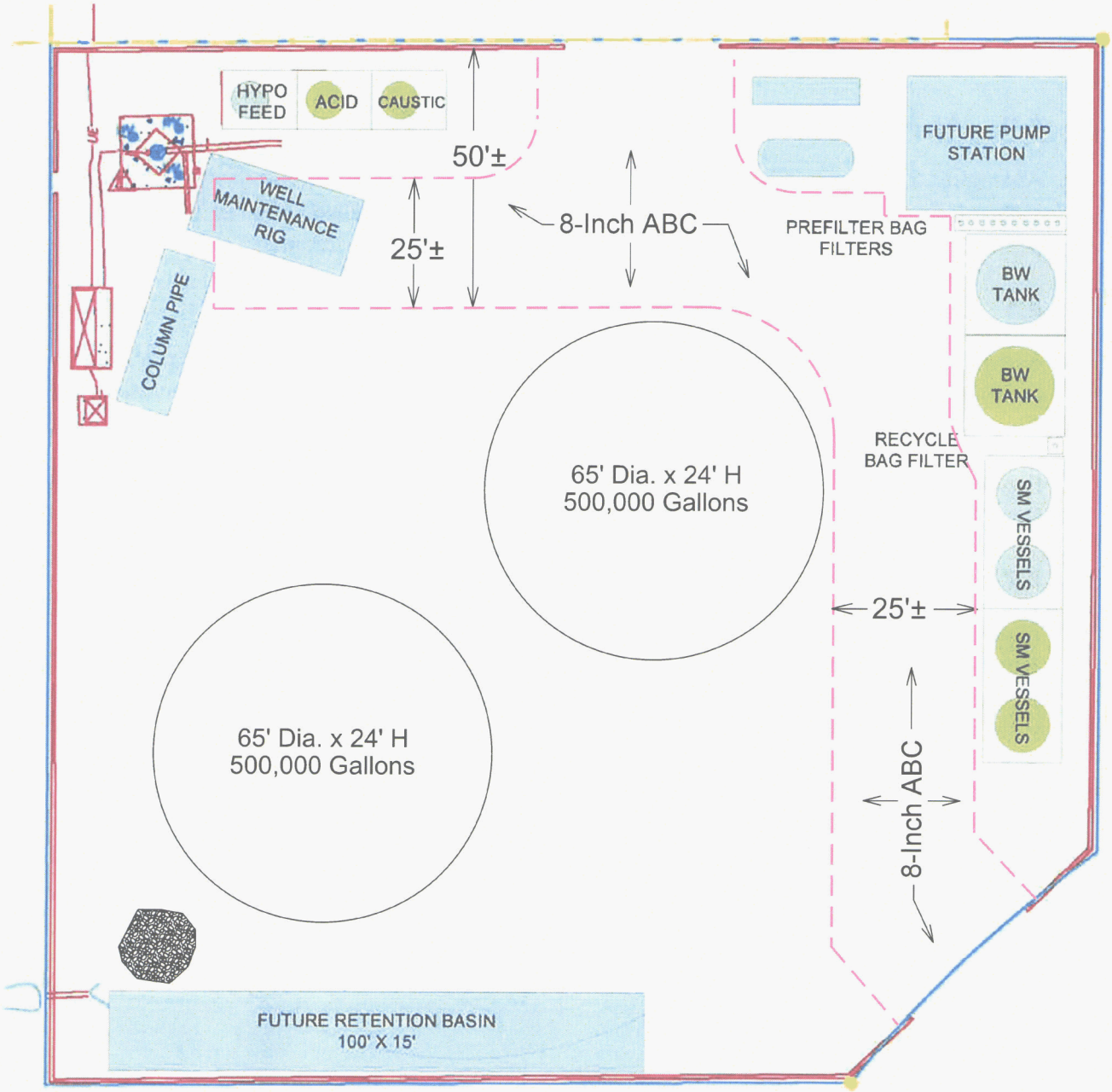
SHEET 1 OF 1

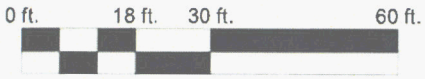
HAWSEN
ENGINEERING & SURVEYING

49864
JEREMY R.
DALMACIO

Exhibit "D"

Conceptual Site Plan





LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

Coolidge Well 13
Adsorptive Conceptual Site Plan

Exhibit "E"

Design Criteria

Exhibit "E"

Design Criteria

1. ARF Design Capacity:	
a. Initial:	800 gpm (plus max 10% recycled water)
b. Build-Out:	2,400 gpm (plus max 10% recycled water)
2. Arsenic Concentration:	
a. Influent:	20 µg/L
b. Maximum Blended Effluent:	7 µg/L
3. Number of Vessels:	2
4. Vessel Orientation:	Vertical
5. Well No. 13 Pump Capacity:	800 gpm
6. Minimum Pipe Hydrostatic Testing Pressure:	200 psi
7. Minimum Pressure Vessel Rating:	150 psi at 120°F
8. Minimum Empty Bed Contact Time:	3.5 minutes
9. Maximum Flux Rate:	6 gpm/sf
10. Backwash Rate:	12 gpm/sf
11. Available Backwash Supply Flow Rate:	920 gpm @ 32 psi dynamic; 62 psi static
12. Maximum Pipe Velocity:	5 fps
13. Maximum Headloss through ARF:	10 psi
14. Minimum Backwash Tank Capacity:	1.5 X Backwash Volume

Exhibit "F"

Water Quality

ARIZONA WATER COMPANY
COOLIDGE WELL NO. 13 WATER QUALITY DATA

Contaminant	Sample Date	Result (mg/L unless stated otherwise)
Arsenic	20-Sep-09	0.016
Arsenic	28-Sep-09	0.0177
Arsenic	10-May-10	0.0079
Arsenic	25-May-11	0.0152
Arsenic	30-Jun-11	0.0098
Arsenic	06-Jul-11	0.011
Arsenic	23-Aug-11	0.014
Arsenic	18-Oct-11	0.014
Arsenic	19-Oct-11	0.014
Arsenic III	25-May-11	0.004
Arsenic III	23-Aug-11	0.004
Arsenic III	18-Oct-11	0.0035
Arsenic III	19-Oct-11	0.0027
Arsenic V	18-Oct-11	0.0105
Arsenic V	19-Oct-11	0.0113
Cadmium	08-Aug-07	< 0.0002
Cadmium	25-May-11	< 0.0001
Cadmium	23-Aug-11	< 0.0001
Calcium	08-Aug-07	47
Calcium	25-May-11	56
Calcium	23-Aug-11	58
Calcium	18-Oct-11	57
Calcium Hardness as CaCO3	08-Aug-07	117
Calcium Hardness as CaCO3	25-May-11	141
Calcium Hardness as CaCO3	23-Aug-11	144
Chromium	08-Aug-07	0.007
Chromium	25-May-11	0.012
Chromium	23-Aug-11	0.012
Iron	13-Oct-09	< 0.05
Iron	25-May-11	< 0.05
Iron	23-Aug-11	< 0.05
Iron	18-Oct-11	< 0.05
Iron	19-Oct-11	< 0.05

ARIZONA WATER COMPANY
COOLIDGE WELL NO. 13 WATER QUALITY DATA

Contaminant	Sample Date	Result (mg/L unless stated otherwise)
Lead	08-Aug-07	0.008
Lead	25-May-11	< 0.001
Lead	23-Aug-11	< 0.001
Magnesium	08-Aug-07	5
Magnesium	25-May-11	7
Manganese	13-Oct-09	< 0.02
Manganese	25-May-11	< 0.02
pH	08-Aug-07	8
pH	17-Oct-11	7.8
pH	18-Oct-11	7.9
pH	19-Oct-11	7.8
Phosphate	13-Oct-09	< 0.15
Phosphate	19-Oct-11	< 0.15
Selenium	08-Aug-07	< 0.002
Selenium	25-May-11	0.005
Selenium	23-Aug-11	0.003
Silica, Total	13-Oct-09	27.9
Silica, Total	25-May-11	30.5
Silica, Total	23-Aug-11	31.8
Sulfate	08-Aug-07	200
Sulfate	25-May-11	234
Sulfate	23-Aug-11	212
Sulfide, Total	25-May-11	< 0.04
Total Alkalinity as CaCO3	08-Aug-07	83
Total Alkalinity as CaCO3	13-Oct-09	73
Total Alkalinity as CaCO3	25-May-11	77
Total Alkalinity as CaCO3	23-Aug-11	75
Total Alkalinity as CaCO3	17-Oct-11	85
Total Alkalinity as CaCO3	18-Oct-11	77
Total Alkalinity as CaCO3	19-Oct-11	76

ARIZONA WATER COMPANY
COOLIDGE WELL NO. 13 WATER QUALITY DATA

Contaminant	Sample Date	Result (mg/L unless stated otherwise)
Total Phosphorous	13-Oct-09	< 0.05
Total Phosphorous	19-Oct-11	0.02
Total Suspended Solids	25-May-11	< 1
Total Suspended Solids	19-Oct-11	< 1
Turbidity	25-May-11	< 1.00 NTU
Turbidity	23-Aug-11	< 1.00 NTU
Vanadium	13-Oct-09	0.024
Vanadium	25-May-11	0.022
Vanadium	23-Aug-11	0.023
Uranium	08-Aug-07	3.9 +/- 0.9 pci/L
Uranium	25-May-11	4.9 +/- 1.0 pci/L
Uranium	23-Aug-11	6.8 +/- 1.1 pci/L

Exhibit "G"

Approved Adsorptive Media

Exhibit "G"

Approved Adsorptive Media

Media Requirements

1. Adsorptive media shall be discardable as solid waste in a RCRA subtitle D (non-hazardous) landfill when saturated and pass all TCLP tests.
2. Adsorptive media shall be a durable, attrition resistant media suitable for backwashing and removal of Arsenic.

Approved Manufacturers

1. Severn Trent - Bayoxide E-33 Granular Ferric Oxide
2. Evoqua - GFH

Exhibit "H"

Arizona Water Company Water Storage Tank Coating Specifications O-12-2

ARIZONA WATER COMPANY
O-12-2
WATER STORAGE TANK COATING SPECIFICATIONS

DEFINITIONS

A. *Company* — The words "Company" or "Arizona Water Company" mean Arizona Water Company and, where applicable, any division of Arizona Water Company, whose principal place of business is located at 3805 North Black Canyon Highway, Phoenix, Arizona 85015-5351 (Post Office Box 29006, Phoenix, Arizona 85038-9006).

B. *Company's Authorized Representative* — The words "Company's Authorized Representative" mean any officer of the Company, any Division Manager and/or such other person(s) designated in writing as the "Company's Authorized Representative" by the President or any Vice President of the Company.

C. *Contractor* — The word "Contractor" means either an individual or other entity contracted with to provide the services detailed in the Contract and as specified herein.

D. *Contract* — The word "Contract" means the written document titled "Contract" when such document has been signed by an officer or other authorized representative of both the Contractor and the Company.

E. *General Conditions of Contract* — The words "General Conditions of Contract" refer to the Company's Operating Order O-12-3 in the Company's Operating Memorandums.

F. *Independent Coating Inspector* — The words "Independent Coating Inspector" mean any Certified NACE III inspector hired by the Company to inspect coatings on water storage tanks.

1. GENERAL

These specifications identify the material and workmanship necessary to produce a quality coating system. All work shall be completed in a safe, workmanlike manner in strict accordance with:

a. Product manufacturer's instructions
b. General Conditions of Contract (E-4-1)
c. American Water Works Association Standard AWWA C652
d. Applicable sections of ANSI/AWWA D102-11, "Standard for Coating Steel Water Storage Tanks"
e. ANSI/AWWA D101-53 (R86), "Standard for Inspecting and Repairing Steel Water Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage"
f. ANSI/NSF Std. 61, Section 5, "Protective (Barrier) Materials"
g. SSPC-SP1 – Solvent Cleaning
   SSPC-SP2 – Hand Tool Cleaning
   SSPC-SP3 – Power Tool Cleaning
   SSPC-SP5 – White Metal Blast Cleaning
   SSPC-SP6 – Commercial Blast Cleaning
   SSPC-SP7 – Brush-off Blast Cleaning

SSPC-SP10 – Near White Metal Blast Cleaning
SSPC-SP11 – Power Tool Cleaning to Bare Metal
SSPC-SP12 – Hydroblasting

h. SSPC PA2 –Dry Paint Thickness with Magnetic Gauges
i. SSPC-Guide 7 – Guide for the Disposal of Lead-Contaminated Surface Debris

2. QUALITY OF PAINT

The protective coatings identified in these specifications are set up as standards of quality. The standard "or equal" clause shall apply.

No substitution shall be considered unless the Company's Authorized Representative has received a written request for approval at least ten (10) days prior to the date for receipt of bids. Each such request must include: (a) the name of the specified material for which a substitution is being requested; (b) the name and number of the proposed substitution material; (c) a complete description of the proposed substitute, including performance and test data; and (d) any other information necessary for an evaluation. The burden of proof of the merit of the proposed substitute is upon the Contractor. Approval or disapproval of the proposed substitution rests solely with the Company's authorized representative and his decision shall be final.

Protective coatings for interior wet applications must be listed by NSF International as approved for potable water contact according to ANSI/NSF Std. 61, Section 5, "Protective (Barrier) Materials."

The Contractor shall be responsible for assuring that all materials are delivered to the job site in the original sealed and labeled containers of the protective coating manufacturer. All material on the job shall be subject to inspection by the Company's Authorized Representative.

The Company's Authorized Representative shall select colors not previously specified.

3. SPECIAL PROVISIONS

The Contractor shall be responsible for completing the removal of all remaining water, sediment, rust, etc. that is required prior to surface preparation. All preliminary preparation work will be at the Contractor's expense.

The Contractor shall:

a. Protect aluminum gauge boards and nametags during sandblasting and painting procedures.
b. Protect copper lines, light fixtures, valve threads, and electrical boxes.
c. Replace all manhole bolts with cadmium-plated or galvanized bolts if the Contractor opens a manhole.
d. Replace all gaskets.

The Contractor shall **NOT**:

a. Paint concrete unless otherwise specified.
b. Allow the use of silica sand for surface preparation.

The Contractor shall only mix FULL kits of approved coating. No partial kits will be saved or mixed at a later time.

4. MATERIALS TO BE PROVIDED AND PROCEDURES TO BE FOLLOWED BY THE CONTRACTOR

Unless otherwise specified in the contract, the Contractor shall supply all of the necessary materials to complete the work. The Contractor shall provide the following materials and services:

a. TANKS WITH EXISTING COATING SYSTEM: Interior Steel – Conventional Coating System; Surface Preparation: SSPC-SP 10 Near White Metal Blast Cleaning.

All abrasive materials shall be thoroughly removed from the surface of the tank in accordance with SSPC-SP 10 standards prior to coating.

Tnemec Coating

(1) Prime Coat*: Tnemec Series N140-1255 (Beige) Pota Pox Plus**, one (1) coat; spray applied; 6 to 8 mils dry film thickness ("DFT").

(2) Finish Coat: Tnemec Series N140-15BL (Tank White) Pota Pox Plus; one (1) coat; spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT.

*Weld Seams: All plate weld seams shall receive an additional brushed coat of Series N140 Pota Pox Plus in color 15BL (Tank White). This application will be made after the full prime coat. Additionally, brush coating shall be applied on all welds, corners, nuts, bolts, edges, or other irregular surfaces.

**Tnemec Series N140 Pota Pox Plus FC (fast cure) may be substituted for Series N140 Pota Pox Plus when conditions warrant. It may be beneficial when curing between 35° F and 56° F is required.

or

Devoe Coating

(1) Prime Coat*: Devoe Bar-Rust 233H1642 (Buff)**, one (1) coat; spray applied; 6 to 8 mils DFT.

(2) Finish Coat: Devoe Bar-Rust 233 H3501 (White), one (1) coat: spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT.

*Weld Seam: All plate weld seams shall receive an additional brushed coat of Devoe's Bar-Rust 233H in or 3501 (White) after the full prime coat.

Additionally, brush coating shall be applied on all corners, welds, nuts, bolts, edges, or other irregular surfaces.

**Devoe Bar-Rust 233H is a high solids (80%) advanced technology NSF International (National Sanitation Foundation) approved epoxy, which can be applied at steel temperatures down to 0° F (-18° C).

or

Carboline Coating

(1) Prime Coat*: Carbogurard 891 NSF Epoxy; one (1) coat; spray applied; 6 to 8 mils dry film thickness ("DFT").

(2) Finish Coat: Carbogurard 891 NSF Epoxy; one (1) coat; spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT

*Weld Seams: All plate weld seams shall receive an additional brushed coat of Carbogurard 891 NSF Epoxy. This application will be made after the full prime coat. Additionally, brush coating shall be applied on all welds, corners, nuts, bolts, edges, or other irregular surfaces.

b. TANKS WITH EXISTING COATING SYSTEM: Interior Steel – Alternative Floor Coating System for Badly Pitted Tank Floors. For floors in existing tanks that are highly corroded with severe pitting, the following floor system may be applied after completion of the NSF Epoxy system to the roof and shell, subject to prior approval by the Company's Authorized Representative.

Floor Surface Preparation: SSPC-SP10 Near White Metal Blast Cleaning.

All abrasive materials shall be thoroughly removed from the surface of the tank in accordance with SSPC-SP10 standards prior to coating.

Tnemec Coating

(1) Steel Conditioners: Wet the floor surface and up the wall a few inches with a fine mist of Tnemec Series 260 Tnemec-Bond. Allow to evaporate and apply the topcoat within four (4) hours.

(2) Elastomeric Urethane: After mixing according to the manufacturer's recommendations, pour out and level with trowels or notched squeegees, Tnemec Series 264 Elasto-Shield over the entire floor to DFT of 80 to 100 mils and bring up the wall to where there is a two- to three-inch (2" to 3") overlap on the newly applied epoxy coating system.

TOTAL DFT: 80 to 100 mils DFT

or

Tnemec Coating

(1) 100% Solids Epoxy Finish Coat: Apply Devoe's Devran 133 100% Solids Epoxy Tank Coating at 80 to 100 mils DFT.

TOTAL DFT: 80 mils minimum DFT

or

Tnemec Coating

(1) 100% Solids: Apply Reactamine 760 NSF 100% Solids Tank Coating at 80 to 100 mils DFT.

TOTAL DFT: 80 mils minimum DFT

c. TANKS WITH EXISTING COATING SYSTEM: Exterior Steel; Level 1 Re-coat: For aged epoxy/urethane systems that are in sound shape and where re-coat adhesion is assured, the following overcoat system applies:

Tnemec Coating

(1) Surface preparation: Remove all dust, dirt, grime, and chalk by power washing.

All rusted, abraded, and exposed steel shall be power tool cleaned to bare metal according to SSPC-SP 11. All loose paint shall be removed with the same power tools. Feather all edges. Existing runs and chips shall be sanded out.

(2) Spot Prime (exposed metal): Tnemec Series 135 Chembuild or Series N140 Pota Pox Plus; one (1) coat; roller, brush, or spray applied, overlapping to the feathered areas; 3 to 5 mils DFT.

(3) Finish Coat: Tnemec Series 73 (spec color) Endura-Shield or Tnemec 1075 Endura-Shield II; one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL ADDITIONAL DFT: 3 to 5 mils DFT
(on top of existing system)

or

Devoe Coating

(1) Surface preparation: Remove all dust, dirt, grime, and chalk by power washing.

All rusted, abraded, and exposed steel shall be power tool cleaned to bare metal according to SSPC-SP 11. All loose paint shall be removed with the same power tools. Feather all edges. Existing runs and chips shall be sanded out.

(2) Spot Prime (exposed metal): Devoe's 233H Bar-Rust one (1) coat; roller, brush, or spray applied, overlapping to the feathered areas; at 3 to 5 mil DFT.

(3) Finish Coat: Devoe's Devthane 378 aliphatic Acrylic Urethane (spec color), one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL ADDITIONAL DFT: 3 to 5 mils DFT
(on top of existing system)

or

Carboline Coating

(1) Surface preparation: Remove all dust, dirt, grime, and chalk by power washing.

All rusted, abraded, and exposed steel shall be power tool cleaned to bare metal according to SSPC-SP 11. All loose paint shall be removed with the same power tools. Feather all edges. Existing runs and chips shall be sanded out.

(2) Spot Prime (exposed metal): Carbogurard 891 NSF Epoxy one (1) coat; roller, brush, or spray applied, overlapping to the feathered areas; at 3 to 5 mil DFT.

(3) Finish Coat: Carbothane 133HB (spec color), one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL ADDITIONAL DFT: 3 to 5 mils DFT
(on top of existing system)

d. TANKS WITH EXISTING COATING SYSTEM: Exterior Steel; Level 2 Re-coat. If complete removal of the existing system is required, the following overcoat system applies:

Surface preparation: SSPC-SP 6 Commercial Abrasive Blast Cleaning.

All abrasive materials shall be thoroughly removed from the surface of the tank in accordance with SSPC-SP 10 standards prior to coating.

Tnemec Coating

(1) Prime Coat: Tnemec Series N140-1255 (Beige) Pota Pox Plus or Tnemec 1075 Endura-Shield II; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Tnemec Series 73 (spec color) Endura-Shield III; one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils.

or

Devoe Coating

(1) Prime Coat: Devoe's Bar-Rust 235 Epoxy; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Devoe's Devthane 378 aliphatic Acrylic Urethane (spec color); one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils DFT.

or

Carboline Coating

(1) Prime Coat: Carboguard 891 NSF Epoxy; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Carbothane 133HB; one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils.

e. TANKS WITH NEW STEEL: Exterior steel – Surface preparation: SSPC-SP 6 Commercial Abrasive Blast Cleaning.

All abrasive materials shall be thoroughly removed from the surface of the tank in accordance with SSPC-SP 10 standards prior to coating.

Tnemec Coating

(1) Prime Coat: Tnemec Series N140-1255 (Beige) Pota Pox Plus or Tnemec 1075 Endura-Shield II; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Tnemec Series 73 (spec color) Endura-Shield III; one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils.

or

Devoe Coating

(1) Prime Coat: Devoe's Bar-Rust 235 Epoxy; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Devoe's Devthane 378 aliphatic Acrylic Urethane (spec color); one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils DFT.

or

Carboline Coating

(1) Prime Coat: Carboguard 891 NSF Epoxy; one (1) coat; spray applied; 4 to 6 mils DFT.

(2) Finish Coat: Carbothane 133HB; one (1) coat; spray applied; 3 to 5 mils DFT.

TOTAL DFT: 7 to 11 mils.

f. TANKS WITH NEW STEEL: Interior Steel – Conventional Coating System; Surface Preparation: SSPC-SP 10 Near White Metal Blast Cleaning.

All abrasive materials shall be thoroughly removed from the surface of the tank in accordance with SSPC-SP 10 standards prior to coating.

Tnemec Coating

(1) Prime Coat*: Tnemec Series N140-1255 (Beige) Pota Pox Plus**, one (1) coat; spray applied; 6 to 8 mils dry film thickness ("DFT").

(2) Finish Coat: Tnemec Series N140-15BL (Tank White) Pota Pox Plus; one (1) coat; spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT.

*Weld Seams: All plate weld seams shall receive an additional brushed coat of Series N140 Pota Pox Plus in color 15BL (Tank White). This application will be made after the full prime coat. Additionally, brush coating shall be applied on all welds, corners, nuts, bolts, edges, or other irregular surfaces.

**Tnemec Series N140 Pota Pox Plus FC (fast cure) may be substituted for Series N140 Pota Pox Plus when conditions warrant. It may be beneficial when curing between 35° F and 56° F is required.

or

Devoe Coating

(1) Prime Coat*: Devoe Bar-Rust 233H1642 (Buff)**, one (1) coat; spray applied; 6 to 8 mils DFT.

(2) Finish Coat: Devoe Bar-Rust 233 H3501 (White), one (1) coat: spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT

*Weld Seam: All plate weld seams shall receive an additional brushed coat of Devoe's Bar-Rust 233H in or 3501 (White) after the full prime coat. Additionally, brush coating shall be applied on all corners, welds, nuts, bolts, edges, or other irregular surfaces.

**Devoe Bar-Rust 233H is a high solids (80%) advanced technology NSF International (National Sanitation Foundation) approved epoxy, which can be applied at steel temperatures down to 0° F (-18° C).

or

Carboline Coating

(1) Prime Coat*: Carbogurard 891 NSF Epoxy; one (1) coat; spray applied; 6 to 8 mils dry film thickness ("DFT").

(2) Finish Coat: Carbogurard 891 NSF Epoxy; one (1) coat; spray applied; 6 to 8 mils DFT.

TOTAL DFT: 12 to 16 mils DFT

*Weld Seams: All plate weld seams shall receive an additional brushed coat of Carbogurard 891 NSF Epoxy. This application will be made after the full prime coat. Additionally, brush coating shall be applied on all welds, corners, nuts, bolts, edges, or other irregular surfaces.

5. TANK REPAIRS PRIOR TO TANK COATING/PAINTING

The Contractor is required to notify the Company's Authorized Representative on a timely basis when tank repairs are necessary, and to identify the nature and extent of repairs that are required.

If repairs to the tank are necessary, the Contractor shall be responsible for coordinating all such repairs, and shall request a change order from the Company's Authorized Representative before initiating such repairs as required in the General Conditions of Contract.

All repairs are to be made according to ANSI/AWWA D101-53 (R86), "Standard for Inspection and Repairing Steel Water Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage."

The Company will not allow the Contractor to alter the structure of the tank.

6. SURFACE PREPARATION – DEBRIS CONTAINMENT AND DISPOSAL

When required by Federal, State, or local regulation, the Contractor shall enclose the entire tank and structure and contain surface preparation debris. Refer to SSPC-Guide 6, "Guide for Containing Debris Generated During Paint Removal Operations."

The Contractor shall dispose of all surface preparation debris according to applicable Federal, State, and local regulations. Refer to SSPC-Guide 7, "Guide for the Disposal of Lead-Contaminated Surface Debris."

Worker protection and environmental protection shall be followed in accordance with the following Federal Regulatory Standards and other applicable Federal, State, or local regulations:

1. 29 CFR 1910 – OSHA General Industry Standards
2. 29 CFR 1910.134 – Respiratory Protection
3. 29 CFR 1910.1000 – Air Contaminants – Permissible Exposure Limits
4. 29 CFR 1910.1020 – Employee Access to Exposure and Medical Records
5. 29 CFR 1926 – OSHA Construction Industry Standards
6. 29 CFR 1926.59 – Hazard Communications
7. 29 CFR 1926.62 – Lead Exposure in Construction; Interim Final Rule
8. 40 CFR 261 – Identification and Listing of Hazardous Waste
9. 40 CFR 262 – Standards Applicable to Generators of Hazardous Waste
10. 40 CFR263 – Standards Applicable to Transporters of Hazardous Waste
11. 40 CFR 264 – Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Cleaning

Surfaces that have been in contact with chemicals can be assumed to be contaminated. Depending on the type of chemical, it may be necessary to clean the surface before dry blasting and again after blasting in order to remove contaminants that can otherwise cause blistering of the coating system.

Most common methods are:

- Steam Cleaning
- Hot Water/Detergent Washing (Pressure)
- Solvent Washing
- Hydroblasting or Wet Sandblasting
- Prebaking at Very High Temperatures

The first two methods can efficiently remove most soluble and emulsified contaminants. Solvent cleaning is only feasible for small tanks or small areas. Solvent cleaning will not remove water-soluble materials. When detergents are used, a fresh water rinse is necessary to remove traces of the detergent left on the surface.

Hydroblasting will seldom be used for the cleaning of tanks due to the very high pressure involved. Wet sandblasting is possible. It can remove old coatings, water soluble contaminants, and corrosion products simultaneously. It cannot remove oil or grease products.

Before cleaning takes place, the surface must be free from oil, grease, salt deposits, and other foreign material that cannot be removed by abrasive blasting. These contaminants, which differ from mill scale and rust, would otherwise be forced into the profile and interfere with the adhesion and the chemical resistance.

Blasting

Steel surfaces must be blasted to white metal (SSPC-SP5/SA3) or as near as possible to white metal, but never less than near-white-metal (SSPC-SP10/SA2 ½).

Mill scale, when present on a ferrous surface, is cathodic to the surface, meaning the steel will sacrifice itself to save the mill scale. All mill scale MUST be removed prior to coating application. Although the surface may in fact already have a coating visible, the CONTRACTOR SHALL NOT assume that the previous contractor has removed the mill scale prior to applying the existing coating. All bids will be submitted with the understanding that mill scale MAY be present beneath the existing coating, and that an SP-10 (near-white) blast will be required prior to any new coating application unless otherwise specified. NO additional costs, above the bid price, will be submitted to Arizona Water Company for removal of any mill scale that is found on the surface. Arizona Water Company requires that ALL bids reflect this understanding by the CONTRACTOR.

Profile

The blast anchor profile must average 2 to 3 mils, but preferably 2.5 mils.

Abrasives

The abrasive media shall be garnet and shall be of sufficient grit size to attain a specified blast anchor profile between 2 to 3 mils DFT.

Pre-Preparation and Operational Testing of Abrasives for Soluble Salts Contamination:

Test abrasive media for chloride contamination using test kit as described below, entitled "Test Kit for Measuring Chlorides in Abrasives." The maximum allowable chloride concentration is 3 PPM. Test media immediately prior to use, and in no case more than 24 hours prior to use.

Pre-Application Testing for Soluble Salts Contamination

Test blasted surfaces for chloride contamination using the Test Kit described below, entitled "Test Kit for Measuring Chlorides on Steel Surfaces." Test all surfaces at the rate of three tests for the first 1000 square feet plus one test for each additional 3000 square feet or part thereof. Concentrate testing of bare steel at areas of coating failure to bare steel and areas of corrosion pitting. Perform 30% of tests on bare metal at welds, divided equally between horizontal and vertical welds. One or more readings greater than 3 micrograms per square centimeter of chlorides shall be cause for rejection of surface. Wash all surfaces with Chlor*Rid according to the manufacturer's recommendations, allow to dry and retest until all required test show allowable results. Re-blast tested and cleaned areas to required specifications. Label all test tubes and retain for test verification.

ALLOWABLE SOLUBLE SALTS TEST KITS

Test kit for measuring Chlorides on Steel Surfaces
(Test Kits called Chlor*Test, as manufactured by CHLOR*RID International. Inc. of Chandler, Arizona (www.chlor-rid.com)).

Test kit for measuring Chlorides in Abrasives

(Test Kits called Chlor*Test "A", as manufactured by CHLOR*RID International, Inc. of Chandler, Arizona (www.chlor-rid.com)).

Welds and Edges

These areas need special attention because they are often the first place where corrosion starts. Weld splatters must be removed by power tool grinding. Welds must be ground to a smooth radius and sharp edges must be rounded to prevent the coating from pulling away.

Dehumidification

Depending on the ambient conditions, it may be necessary to use dehumidifiers to prevent rustblooming of the blasted steel surface. In all instances the dewpoint must remain at least 5°F or 3°C below the steel temperature.

Although not very often the case with new steel, black spotrusting may occur shortly after blasting. This is a sign that the steel has been infected with sulfates or chlorides, etc., which cannot completely be removed by dry abrasive blasting. In such a case, refer to section B, Old Corroded and/or Previously Coated Steel Surfaces.

Dust Removal

After the blasted steel surface is approved, abrasive dust must be removed with a vacuum cleaner. A broom is insufficient. Most effective is the combination of blowing and vacuum cleaning in that order. Dust particles left on the surface will interfere with coating adhesion.

7. PREPARATION OF COATING MATERIAL

Storage

At least 24 hours before coating material will be used, the material must be placed in an area where the temperature is kept between 50°F and 86°F (10°C - 30°C).

Premixing

The coating system is a two-component thermosetting material that requires thorough mechanical mixing.

After opening the can of base component, it is necessary to premix the base until no sediment is left on the bottom of the can. A squirrel-cage-type mixer such as the Jiffy mixer is efficient. Care must be taken not to introduce air (foam). After sufficient premixing, the hardener component may be added to the base and mixed immediately.

Mixing Ratio

Unless otherwise indicated, base and hardener are supplied in the correct ratio: one can of hardener to one can of base. The use of the exact ratio is of prime importance for the chemical resistance of the cured coating film. Therefore, the hardener container must be emptied completely into the base. A very small amount of thinner may be used for cleaning the hardener can. The amount used must be deducted from the overall amount of thinner used for correction of spray viscosity.

Spray Equipment

Conventional air spray or airless spray may be used to apply coatings. Because airless spray is almost exclusively used, the following information will deal only with this method.

The airless pump must have a pressure ratio of at least 30 to 1, but preferably 45 to 1. A tip size between 0.018" and 0.021" is strongly recommended. A reversible tip is recommended.

All equipment and lines must be absolutely clean to prevent blocking of the tip and to prevent coating contamination.

8. APPLICATION OF PROTECTIVE COATINGS

The Contractor shall apply each coating according to the specifications and the protective coating manufacturer's recommendations.

The Contractor shall apply the coating at the specified thickness. If the specified thickness is not obtained, the Contractor shall apply an additional coating.

The Contractor shall apply all protective coatings in strict accordance with the applicable manufacturer's current printed product data sheet and container label. The Contractor shall not apply protective coatings above or below the minimum/maximum surface temperatures as stated on the product data sheet. The Contractor shall not apply protective coatings to wet or damp surfaces and shall not apply protective coatings in rain, snow, fog, or mist. Surface temperatures must be at least 5° F above the dew point and the Contractor shall delay painting until such condition exists. The Contractor shall complete the painting well in advance of the probable time of day when condensation may occur and/or the surface temperature may be expected to drop below the minimum listed on the applicable product data sheet.

The Contractor shall measure DFT according to current SSPC PA2, "Dry Paint Thickness with Magnetic Gauges."

It is essential that the first coat wet the steel surface perfectly. An addition of up to 10% thinner may be added, but confirm that if thinning, it is within the manufacturers printed data sheet and complies with all local, state and federal VOC laws. When wet film thickness gauges are used, it must be kept in mind that the steel profile will have an effect on the readings. Thinner ratios can vary from project to project due to application equipment, weather conditions, substrate conditions, etc.

Before starting the actual spray application, it is a good practice to observe the spray pattern on a separate piece of steel or cardboard. Good atomization without fingering, heavy spots, or insufficient flow, etc. must be obtained. If imperfections occur, corrections must be made quickly. Use a somewhat higher pressure or use the next size smaller tip. If this does not correct the problem, add a small amount of thinner.

Dry spray or coarse paint globules at extremes of the spay pattern are unacceptable.

Dry spray or overspray is often caused by spraying at improper angles to the surface. Move the gun parallel with the surface, releasing the trigger of the gun before reversing direction for the next stroke.

Measure the wet film thickness regularly.

The second coat is applied in the same way, and using the same thinning ratio, after sufficient drying time of the previous coat.

Stripe Coating

As an extra measure for corrosion protection, it is standard practice to apply a stripe coat of the primer with a brush in the welds, edges, and areas that are hard to reach with the spray gun. For that purpose, enough of the mixed primer must be thinned with approximately 25% thinner. The lower viscosity of this mixture will help to penetrate crevices and will prevent an undesirable film build-up. This stripe coating can best be done with a short round-tip bristle brush. Another stripe coat may be applied when the full primer coat has dried sufficiently.

Potlife and Thinning

No mixed material may be used beyond the potlife. No thinner may be used to increase the potlife. Methyl Ethyl Ketone shall not be used for thinning purposes. Thinners must be that as manufactured by the coating supplier utilized for each specific project.

Drying/Curing Interval

The ideal temperature of air and steel for the application and drying between coats is between 68°F and 77°F (20°C and 25°C).

Best results are obtained by drying for 16 to 24 hours at 68°F (20°C) between coats. Lower temperatures require longer drying intervals. When hot air blowers are used to bring the steel temperatures higher than 68°F (20°C), it is strongly recommended to let the coating dry for one (1) hour at ambient temperature with sufficient fresh air ventilation before application of heat. It is further recommended that only indirect fire heaters be used for forced air curing in order to prevent intercoat contamination.

Final Curing

At 68°F (20°C) the tank lining will cure enough for most services in 7 days minimum. Ventilation is required for the first 24 hours. When not enough time is available to cure at 68°F (20°C), hot air blowers should be used to continuously circulate heated fresh air to maintain a surface temperature of 140°F (60°C).

9. INSPECTION

The inspection during and after the tank lining job can be divided into two different functions:

A. Inspection on a pass/fail basis.
B. The above-mentioned function together with preventive actions during the application.

The following list gives the essential checkpoints for an inspection:

Test	Instruments
Blast Profile	Replica Tape of Comparator
Temperatures	Surface Thermometer
Humidity/Dew Point	Sling Psychrometer or Digital
Thickness of Each Coat	Magnetic Film Thickness Gauge
Pinhole/Sags/Runs/Dryspray/Flow	Holiday Detector and Magnifying Glass
Cure	MEK Rubs (50 rubs)

Preventive Inspection

Inspection service can be very helpful when attention is paid to all parts of the operation. Although not claimed to be complete, the following list may contribute:

– Type of abrasive and cleanliness of the abrasive
– Cleaning method used before blasting
– Check for salt contamination on the steel surface after blasting
– Dehumidification
– Mixing procedure
– Paint storage and consumption
– Spray pattern
– Wet film thickness
– Ventilation
– Pinhole and holiday detection
– Drying/curing procedures
– Safety procedures

Dry Film Thickness

One of the most controversial subjects of application and inspection is the measurement and judgment of DFT.

Highly skilled application techniques are required to keep the DFT within specified limits. It must be understood that most tank linings are exposed to severe conditions. In such a case, the idea "the thicker the better" is definitely false.

Five spot measurements must be taken over an area of 100 square feet. Each spot measurement consists of three gauge readings next to one another. The average of three readings is used to calculate the average of the spot readings.

The average of the spot readings has to be in the specified mil thickness range. According to SSPC-PA2, no spot reading lower than 80% of the specified milage is acceptable.

In addition, the maximum film thickness also is limited. No spot reading (average of a cluster of three gauge readings) higher than 120% of the specified film thickness is acceptable.

Where the film thickness is too low, an extra coat must be applied In accordance with procedures established in this guide.

In case of high film thickness, the thick area must be sanded (after sufficient curing) and a very light extra finish coat applied to "renew" the film.

The magnetic film thickness gauges must be calibrated frequently enough to ensure correct readings. The original calibration must take place with shims placed on the blasted surface as described in SSPC-PA2. This method prevents higher thickness readings found than are actually applied, especially with deeper profiles.

10. LITERATURE

Additional literature to be used in conjunction with these guidelines:

A. Steel Structures Painting Manual, Volume 1

In particular, chapters:

- 2.0 Surface Preparation
- 2.2 Metallic Abrasives
- 2.4 Abrasive Air Blast Cleaning
- 2.6 Hand and Power Tool Cleaning
- 2.9 Chemical Cleaning
  - a. Solvent Wipe
  - b. Steam Cleaning
  - c. High Pressure – Hot Detergent
- 5.3 Safety in Paint Application
- 6.0 Inspection
- 14.2 The Lining of Tanks

B. Steel Structures Painting Manual, Volume 2

Surface Preparation Standards
Chapter 5, Paint Application Specifications SSPC-PA2
A Guide to Safety in Paint Application SSPC-PA Guide 311

11. CURING, VENTILATION, AND DISINFECTION

The Contractor shall provide adequate ventilation to effectively remove solvent vapors for proper drying of paint on interior surfaces. The Contractor shall be required, upon request from the Company's Authorized Representative or the Independent Coating Inspector, during the pre-construction meeting to provide specific details on its plan to provide adequate curing and ventilation.

A combination of forced and natural ventilation shall be continued after coating application is completed to ensure complete curing and solvent removal. Coating life may be shortened if there is inadequate ventilation during the curing period and residual coating solvent may contribute to taste and odor problems in stored water. Lower temperatures or higher humidity may extend the time that ventilation is necessary. The Contractor shall use forced air ventilation with heating units when applying coatings at low temperatures and higher humidities.

The ventilation must be designed in such a way that no solvent vapors remain in corners, etc. The air used must be clean and dry enough to prevent any condensation of moisture on the coated surface. Good ventilation will prevent solvent entrapment in the film.

Following final coat application and final inspection, the Contractor shall not disinfect the tank until the coating system is fully cured and approved by the Independent Coating Inspector. Refer to the applicable product data sheet for dry time/temperature requirements. The Contractor shall disinfect the tank according to the current American Water Works Association Standard AWWA C652 – Method 2, or as instructed by the Company's Authorized Representative. The Contractor, at its expense, shall be responsible for disinfecting the tank immediately before placing the tank in service.

All cathodic protection systems shall be disabled and locked out before initiating tank draining and shall remain disabled until completion of the interior warranty inspection. Once the tank is placed back into service, the lock shall be removed and the cathodic protection system energized.

12. CLEAN UP

The Contractor shall remove from the Company's property and from all public and private property, at its own expense, all temporary structures, rubbish, and waste materials from its operations. In the event the Contractor fails to do so, the Company may remove same at the expense of the Contractor.

13. CONTAINMENT/DISPOSAL COSTS

The Contractor shall be responsible for all costs associated with containment and waste disposal, and for all waste removal as specified in the General Conditions of Contract.

14. GUARANTEE/INSPECTION

The Contractor shall guarantee all labor, workmanship, and materials it applies for the minimum guarantee period, as specified in the General Conditions of Contract.

Approximately eleven (11) months after the Contractor's completion of the work and the Company's acceptance of the completed work, the Company's Authorized Representative shall schedule with an Independent Coating Inspector a date for an inspection for all interior coating work completed, and shall notify the Contractor of such date at least thirty (30) days in advance.

If repairs are necessary, the Contractor shall be responsible for properly disinfecting the water storage tank prior to it being placed back into service. All such repair work will be subject to the conditions of the original Contract.

Exhibit "I"

Sample Design of Adsorptive Media ARF

ARIZONA WATER COMPANY

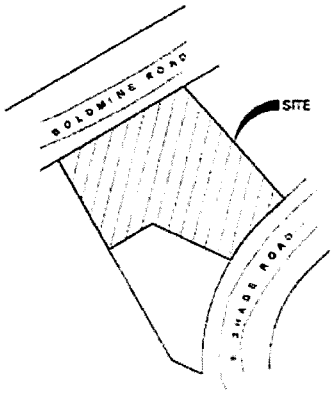
MONTEZUMA HAVEN WELLS NO. 2 AND NO. 3
ARSENIC REMOVAL FACILITY
4105 EAST GOLDMINE ROAD, LAKE MONTEZUMA, AZ 86335

RECORD DRAWINGS

THESE DRAWINGS REFLECT CHANGES FROM THE ORIGINAL CONTRACT DRAWINGS THAT WERE MADE DURING CONSTRUCTION AND HAVE BEEN PREPARED FROM INFORMATION PROVIDED TO THE ENGINEER BY THE CONSTRUCTION CONTRACTOR(S). THE ENGINEER DOES NOT WARRANT THESE DRAWINGS TO BE COMPLETE AND ACCURATE IN ALL RESPECTS.

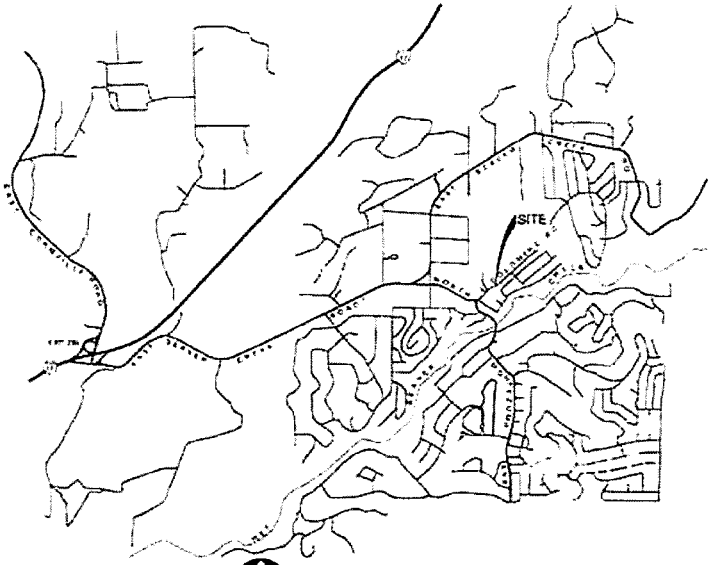
WATERWORKS ENGINEERS, LLC
BY: BENJAMIN W. LEE MARCH 4 2012

AWC PROJECT NO. 1-4874
DECEMBER 2011



NORTH

PROJECT LOCATION MAP
NTS



NORTH

VICINITY MAP
NTS

OWNER
ARIZONA WATER COMPANY
3805 N Black Canyon Hwy
Phoenix, AZ 85015

Phone: 602-240-6860
Fax: 602-254-7162

Contact: Andrew Hess

ENGINEER
WATERWORKS ENGINEERS
6640 E Cholla Road, Suite 280
Scottsdale, AZ 85260

Phone: (480) 551-4742 x112
Fax: (480) 551-4743

Contact: Ben Lee, P.E.

ARIZONA WATER COMPANY

CALL YOU DIG BEFORE YOU DIG
602-263-1100
1-800-STAKE-IT

ORIGINALLY SIGNED AND SEALED BY	ORIGINALLY SIGNED AND SEALED BY
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)	ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
JOHN H. MATTA	BENJAMIN W. LEE
39312	47982
ON 12/29/11	ON 12/29/11

GENERAL
COVER SHEET

DECEMBER 2011
1-4874
G-001

REUSE OF DOCUMENTS: THIS DRAWING AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF SERVICE, IS THE PROPERTY OF WATERWORKS ENGINEERS, LLC AND IS NOT TO BE USED IN WHOLE OR IN PART FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AGREEMENT OF WATERWORKS ENGINEERS, LLC

DRAWING INDEX

SHEET NUMBER	DRAWING NUMBER	TITLE
	GENERAL	
1	G-001	COVER SHEET
2	G-002	DRAWING INDEX AND NOTES
3	G-003	ABBREVIATIONS
4	G-004	STANDARD DESIGNATIONS
5	G-005	LEGEND
6	G-006	PROCESS FLOW DIAGRAM 1
7	G-007	PROCESS FLOW DIAGRAM 2
	CIVIL	
8	C-100	SITE PLAN
	STRUCTURAL	
9	S-001	NOTES AND ABBREVIATIONS
10	S-301	DETAILS
	MECHANICAL	
11	M-001	ISOMETRIC
12	M-100	SITE PLAN
13	M-101	PARTIAL PLAN 1
14	M-102	PARTIAL PLAN 2
15	M-201	SECTIONS
16	M-301	TYPICAL DETAILS 1
17	M-302	TYPICAL DETAILS 2
	ELECTRICAL	
18	E-101	SPECIFICATIONS AND LEGEND
19	E-102	SES AND MCC SINGLE LINE DIAGRAM
20	E-103	SITE PLAN
21	E-104	EXISTING WELL PUMP #3 SCHEMATIC DIAGRAM REVISIONS
22	E-105	MISCELLANEOUS SCHEMATIC DIAGRAMS
23	E-106	DETAILS

GENERAL NOTES

1. REFERENCES TO MAG STANDARD DETAILS REFER TO THE "UNIFORM STANDARD DETAILS FOR PUBLIC WORKS CONSTRUCTION" SPONSORED AND DISTRIBUTED BY THE MARICOPA ASSOCIATION OF GOVERNMENTS, LATEST VERSION.
2. ALL WORK UNDER THE PUBLIC WORKS PERMIT SHALL BE DONE IN ACCORDANCE WITH THE MAG SPECIFICATIONS AND DETAILS, UNLESS OTHERWISE STATED ON PLANS. MINIMUM COVER OVER WATER LINES IS 24" FOR PIPE DIAMETERS 2" AND LESS AND 36" FOR PIPE DIAMETERS LARGER THAN 2".
3. THE ARIZONA WATER COMPANY (AWC) OPERATIONS STAFF SHALL BE NOTIFIED 48 HOURS PRIOR TO STARTING CONSTRUCTION.
4. ACCEPTANCE OF THE COMPLETED IMPROVEMENTS WILL NOT BE GIVEN UNTIL RED LINE DRAWINGS "AS-BUILTS" HAVE BEEN GIVEN TO AWC APPROVED BY THE ENGINEER.
5. CONTRACTOR SHALL ENSURE CONSTRUCTION MATERIALS REMAIN ISOLATED FROM THE WATER DISTRIBUTION SYSTEM. ISOLATION VALVES CONNECTING TO THE DISTRIBUTION SYSTEM SHALL BE LOCKED IN CLOSED POSITION BY CONTRACTOR.
6. BACKFILL CONSOLIDATION BY FLOODING OR WATER IS PROHIBITED.
7. NO JOB WILL BE CONSIDERED COMPLETE UNTIL ALL CURB, PAVEMENT AND SIDEWALKS HAVE BEEN SWEPT CLEAN OF ALL DIRT AND DEBRIS AND ALL DISTURBED SURVEY MONUMENTS REPLACED.
8. ALL EXISTING MONUMENTATION SHALL BE PRESERVED.
9. THE CONTRACTOR WILL UNCOVER ALL EXISTING LINES BEING TIED INTO TO VERIFY THEIR LOCATION, MATERIAL TYPE, AND SIZE PRIOR TO ORDERING FITTINGS. THE CONTRACTOR WILL LOCATE OR HAVE LOCATED ALL EXISTING UNDERGROUND PIPELINES, TELEPHONE AND ELECTRIC CONDUITS, AND STRUCTURES IN ADVANCE OF CONSTRUCTION AND WILL OBSERVE ALL POSSIBLE PRECAUTIONS TO AVOID DAMAGE TO THE SAME.
10. BACKFILLING SHALL NOT BE STARTED UNTIL LINES ARE INSPECTED BY THE ENGINEER AND AWC INSPECTOR (48 HOURS PRIOR NOTIFICATION MUST BE GIVEN).
11. APPROVAL BY THE ENGINEER INDICATES REVIEW FOR GENERAL CONFORMANCE WITH STANDARDS. THIS APPROVAL SHALL NOT PREVENT AWC FROM REQUIRING CORRECTION OF ERRORS OR OMISSIONS OR VIOLATIONS OF ANY LAW OR ORDINANCE.
12. EXISTING UTILITIES AND OTHER FACILITIES SHOWN ON PLANS ARE BASED ON INFORMATION OBTAINED FROM FIELD SURVEY, EXISTING MAPS, AS-BUILTS AND OTHER PLANS WITHIN THE AREA OF THIS PROJECT. THE CONTRACTOR SHALL DETERMINE THE EXACT LOCATION AND/OR ELEVATION OF EXISTING UTILITIES WHICH PERTAIN TO AND MAY AFFECT CONSTRUCTION. NO ADDITIONAL PAYMENT FOR THIS ITEM WILL BE ALLOWED.
13. THE CONTRACTOR SHALL MAINTAIN AN APPROVED SET OF PLANS, WHICH SHALL BE ON THE JOBSITE AT ALL TIMES.
14. THE CONSTRUCTION FOREMAN SHALL BE ON THE JOB SITE AT ALL TIMES WHILE CONSTRUCTION ACTIVITIES ARE IN OPERATION.
15. IT IS THE CONTRACTOR'S RESPONSIBILITY TO NOTIFY THE ENGINEER AND AWC BEFORE THE FITTINGS ARE COVERED SO INDEPENDENT "AS-BUILT" MEASUREMENTS MAY BE TAKEN. ANY CHANGES TO THE APPROVED PLANS MUST BE AUTHORIZED BY THE ENGINEER AND AWC BEFORE THE CHANGE IS MADE IN THE FIELD.
16. CONTRACTOR IS RESPONSIBLE TO FOLLOW ALL APPLICABLE GUIDELINES AND RECOMMENDATIONS SET FORTH BY OSHA.
17. THE CONTRACTOR WILL PROVIDE ADEQUATE MEANS FOR CLEANING TRUCKS AND/OR OTHER EQUIPMENT OF MUD PRIOR TO ENTERING PUBLIC STREETS. CONTRACTOR SHALL MAINTAIN ROADS IMPACTED BY CONSTRUCTION ACTIVITIES IN A CLEAN AND DUST FREE CONDITION AT ALL TIMES.
18. CONTRACTOR TO VERIFY EXISTING UTILITIES WHICH MAY CONFLICT WITH CONTRACTOR'S WORK. ANY EXISTING UTILITY LOCATIONS WHICH MAY BE SHOWN ON THE DRAWINGS ARE APPROXIMATE ONLY AND SHALL BE FIELD VERIFIED. THE CONTRACTOR WILL LOCATE OR HAVE LOCATED ALL EXISTING UNDERGROUND PIPELINES, TELEPHONE AND ELECTRIC CONDUITS, AND STRUCTURES IN ADVANCE OF CONSTRUCTION AND WILL OBSERVE ALL POSSIBLE PRECAUTIONS TO AVOID DAMAGE TO SAME.
19. THE CONTRACTOR IS REQUIRED TO CALL THE "BLUE STAKE" CENTER PRIOR TO ANY WORK AND SHALL BE RESPONSIBLE TO MAINTAIN CURRENT "BLUE STAKE" MARKINGS THROUGHOUT CONSTRUCTION.
20. CONTRACTOR IS RESPONSIBLE FOR ALL TEMPORARY EROSION CONTROL MEASURES AS REQUIRED BY ALL REGULATORY AGENCIES.
21. CONTRACTOR TO COORDINATE INTERFACE OF EXISTING UTILITIES WITH THE APPROPRIATE UTILITY COMPANIES.
22. PROVIDE SEPARATION BETWEEN UTILITIES PER MAG STANDARD SPECIFICATIONS 610.
23. INSTALL NEW PIPELINES AT UNIFORM SLOPE BETWEEN POINTS FOR WHICH ELEVATIONS ARE GIVEN ON THE DRAWINGS.
24. PIPING ROUTING AND DIMENSIONS, AS SHOWN, DO NOT CONSTITUTE DETAILED LAYOUT DRAWINGS. CONTRACTOR TO DETAIL AND DETERMINE EXACT PIPE LENGTHS, FITTINGS AND JOINTS REQUIRED TO INSTALL PIPELINES IN ACCORDANCE WITH THE ROUTING SHOWN ON THE DRAWINGS.
25. COORDINATE BEGINNING OF PIPELINE AND END OF PIPELINE WITH ADJACENT WORK. IF ADJACENT WORK IS COMPLETE, TIE PIPELINE IN AS REQUIRED.
26. ALL MATERIALS IN CONTACT WITH POTABLE WATER SHALL CONFORM TO NATIONAL SANITATION FOUNDATION STANDARDS 60 AND 61.
27. THE FIELD ENGINEER AND AWC SHALL INSPECT AND APPROVE ALL TRENCHING, BEDDING, PIPE INSTALLATION, BACKFILL AND COMPACTION. FIELD ENGINEER AND AWC SHALL INSPECT AND APPROVE ALL PRESSURE TESTING, DISINFECTIONS AND ALL OPERATIONAL SYSTEMS TESTS BEFORE ACCEPTANCE BY AWC INTO THE WARRANTY PERIOD. ALL PUNCH LIST ITEMS MUST BE 100 PERCENT (100%) COMPLETED, AS GENERATED BY AWC AND ENGINEER.
28. CONTRACTOR SHALL ARRANGE FOR ALL INSPECTIONS REQUIRED BY REGULATORY AGENCIES.
29. ALL FRAMES, COVERS, VALVE BOXES SHALL BE ADJUSTED TO FINISHED GRADE PRIOR TO THE COMPLETION OF CONSTRUCTION.
30. PRESSURE & LEAKAGE TESTING SHALL CONFORM TO AWWA STANDARD SPEC. 9.2 HYDROSTATIC TESTING.
31. METERS - MINIMUM FITTING FREE PIPE DIA. UPSTREAM (UP) & DOWNSTREAM (DN) OF METER: PROPELLER - 5 UP & 3DN / MAG - 5UP & 2DN
32. IDENTIFY ALL ABOVE GROUND PIPING AS PER ADEQ BULLETIN NO. 10 CHAPTER 4.A.1.B. LABEL ALL ABOVE GROUND PIPING WITH DIRECTION OF FLOW ARROWS.
33. PAINT ALL ABOVE GROUND PIPING TO MATCH VESSELS / BACKWASH TANKS / ENCLOSURES.
34. CONTRACTOR SHALL CLEAN AND DISINFECT ALL NEWLY CONSTRUCTED AND REPAIRED PIPING AND EQUIPMENT IN ACCORDANCE WITH AWWA C651, C652 AND C653.

ORIGINALLY SIGNED AND SEALED BY: ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL) BENJAMIN W. LEE 47662 ON 12/21/11

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY

GENERAL

DRAWING INDEX AND NOTES

DECEMBER 2011

G-002

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATERWORKS ENGINEERS LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATERWORKS ENGINEERS LLC.

ABBREVIATIONS

@	AT
AB	ANCHOR BOLT, AGGREGATE BASE
AC	ASPHALTIC CONCRETE
ACI	AMERICAN CONCRETE INSTITUTE
ADD	ADDITIONAL
ADH AB	ADHESIVE ANCHOR BOLT
ADJ	ADJACENT, ADJUSTABLE
AFF	ABOVE FINISH FLOOR
AFG	ABOVE FINISH GRADE
AHP	AIR, HIGH PRESSURE
AISC	AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AL, ALUM	ALUMINUM
ALP	AIR LOW PRESSURE
ALTN	ALTERNATE
ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE
APPROX	APPROXIMATE
APVD	APPROVED
ARCH, A	ARCHITECTURAL
ARV	AIR RELEASE VALVE
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
AUTO	AUTOMATIC
AUX	AUXILIARY
AV	AIR/VACUUM ASSEMBLY
AVE	AVENUE
AWG	AMERICAN WIRE GAGE
AWWA	AMERICAN WATER WORKS ASSOCIATION
B	BORING
BC	BEGIN CURVE
BF	BLIND FLANGE, BOTTOM FACE
BFD	BUTTERFLY VALVE DAMPER
BFV	BUTTERFLY VALVE
BLDG	BUILDING
BLM	BUREAU OF LAND MANAGEMENT
BM	BENCH MARK, BEAM
BO	BLOW OFF
BOO	BOTTOM OF OPENING
BOT	BOTTOM
BRG	BEARING
BV	BALL VALVE
BVC	BEGINNING OF VERTICAL CURVE
B/P	BYPASS
C to C, CC	CENTER TO CENTER
C	CHANNEL (BEAM)
CAA/ARV	COMBINATION AIR ADMISSION/ AIR RELEASE VALVE
CARV	COMBINATION AIR RELEASE VALVE
CATH	CATHODIC PROTECTION
CATV	CABLE TELEVISION
CB	CATCH BASIN
CCP	CONCRETE CYLINDER PIPE
CCS	CENTRAL CONTROL SYSTEM
CFM	CUBIC FEET PER MINUTE
CFS	CUBIC FEET PER SECOND
CHEM	CHEMICAL
CI	CAST IRON
CIGC	CAST IRON GROOVED COUPLING
CIMJ	CAST IRON MECHANICAL JOINT
CIP	CAST IRON PIPE
CIRJ	CAST IRON RESTRAINED JOINT
CISP	CAST IRON SOIL PIPE
CJ	CONSTRUCTION JOINT, CONTRACTION JOINT
CLDIP	CEMENT LINED DUCTILE IRON PIPE
CLG	CEILING
CLR	CLEAR, CLEARANCE
CLSM	CONTROLLED LOW STRENGTH MATERIAL
CL	CENTERLINE
CML, CSP	CONCRETE MORTAR LINED AND COATED STEEL PIPE
CMLSP	CEMENT MORTAR LINED STEEL PIPE
CMP	CORRUGATED METAL PIPE
CMU	CONCRETE MASONRY UNIT
CO	CLEANOUT
COL	COLUMN
COM	COMMUNICATION
COMB	COMBINED
CONC	CONCRETE
CONN	CONNECTION
CONT	CONTINUOUS, CONTINUATION
COORD	COORDINATE
CPR	COPPER
CPLG	COUPLING
CTD	CENTERED
CTR	CENTER
CU FT	CUBIC FOOT
CU IN	CUBIC INCH
CU YD	CUBIC YARD
CULV	CULVERT
CV	CHECK VALVE
°C	CELSIUS
d	PENNY
DBA	DEFORMED BAR ANCHOR
DR	DRAIN
DBL	DOUBLE
DEC	DECANT
DET	DETAIL
DF	DOUGLAS FIR/LARCH
DI	DROP INLET, DUCTILE IRON
DIA	DIAMETER
DIAG	DIAGONAL
DIL	DILUTE
DIM	DIMENSION
DIMJ	DUCTILE IRON MECHANICAL JOINT
DIP	DUCTILE IRON PIPE
DIPPL	DUCTILE IRON PIPE, POLYETHYLENE LINED
DIR	DIRECTION
DIST	DISTANCE
DN	DOWN
do	DITTO
DWG	DRAWING
E	EAST, ELECTRIC, ELECTRICAL
EA	EACH
EC	END CURVE
ECC	ECCENTRIC
EF	EACH FACE, EXHAUST FAN
EFL	EFFLUENT
EJ	EXPANSION JOINT
EL	ELEVATION
ELB, ELL	ELBOW
ELC	ELECTRICAL LOAD CENTER
ELEC	ELECTRIC, ELECTRICAL
ENGR	ENGINEER
EO	EMERGENCY OVERFLOW
EQL SP	EQUALLY SPACED
EQPT	EQUIPMENT
ERW	EFFLUENT REUSE WATER
ESA	ENVIRONMENTALLY SENSITIVE AREA
EVC	END OF VERTICAL CURVE
EW	EACH WAY
EWEF	EACH WAY, EACH FACE
EXC	EXCAVATE
EXP	EXPOSED, EXPANSION
EXP JT	EXPANSION JOINT
EXST	EXISTING
FB	FLAT BAR
FC	FLEXIBLE COUPLING
FCA	FLANGED COUPLING ADAPTER
FCO	FLOOR CLEAN OUT
FD	FLOOR DRAIN
FDA	FLOOR DRAIN WITH INTEGRAL TRAP
FDN	FOUNDATION
FES	FLARED END SECTION
FEXT	FIRE EXTINGUISHER
FF	FINISH FLOOR
FG	FINISH GRADE
FHY	FIRE HYDRANT
FIG	FIGURE
FL	FLOOR, FLOW LINE
FLG	FLANGE
FLH	FLAT HEAD
FLL	FLOW LINE
FLTR	FILTER
FNSH	FINISH
FOC	FACE OF CONCRETE
FRP	FIBERGLASS REINFORCED PLASTIC
FT	FOOT OR FEET
FTG	FOOTING
FWD	FORWARD
°F	DEGREE FAHRENHEIT
G	GAS
GA	GAGE
GAL	GALLON
GALV	GALVANIZED
GB	GRADE BREAK
GC	GROOVED COUPLING
GCO	GRADE CLEAN OUT
GCF	GROOVED COUPLING FITTING
GE	GROOVED END
GL	GLASS
GPD	GALLONS PER DAY
GPH	GALLONS PER HOUR
GPM	GALLONS PER MINUTE
GRTG	GRATING
GSP	GALVANIZED STEEL PIPE
GV	GATE VALVE
GVL	GRAVEL
GW	GROUND WATER
HD	HUB DRAIN
HDPE	HIGH DENSITY POLYETHYLENE PIPE
HDR	HEADER
HDW	HARDWARE
HGT	HEIGHT
HM	HOLLOW METAL
HORIZ	HORIZONTAL
HP	HORSEPOWER
HR	HANDRAIL
HSS	HOLLOW STRUCTURAL STEEL
HV	HOSE VALVE
I&C	INSTRUMENTATION & CONTROL
ID	INSIDE DIAMETER
IF	INSIDE FACE
IN	INCH
INFL	INFLUENT
INSTM	INSTRUMENTATION
INSUL	INSULATE, INSULATION
INV	INVERT
JT	JOINT
KIP	THOUSAND POUNDS
KW	KILOWATT
L	LEFT, ANGLE, LENGTH
LAB	LABORATORY
LATL	LATERAL
LB	POUNDS
LB/CU FT	POUNDS PER CUBIC FOOT
LF	LINEAR FEET
LG	LONG
LONG	LONGITUDINAL
LP	LOW POINT
LR	LONG RADIUS
MAX	MAXIMUM
MCC	MOTOR CONTROL CENTER
MCJ	MASONRY CONTROL JOINT
MECH	MECHANICAL
MFR	MANUFACTURER
MGD	MILLION GALLONS PER DAY
MH	MANHOLE
MIN	MINIMUM, MINUTE
MISC	MISCELLANEOUS
MJ	MECHANICAL JOINT
MPH	MILES PER HOUR
MSNRY	MASONRY
MSP	MILL STEEL PIPE, MANUAL OF STANDARD PRACTICE
MTL	MATERIAL
MWS	MAXIMUM WATER SURFACE
N	NORTH
NC	NORMALLY CLOSED
NIC	NOT IN CONTRACT
NO	NUMBER, NUMBERING
NPT	NATIONAL PIPE THREAD
NTS	NOT TO SCALE
OC	ON CENTER
OD	OUTSIDE DIAMETER, OVERFLOW DRAIN
OF	OUTSIDE FACE, OVERFLOW
OFR	OVERFLOW RETURN
OG	ORIGINAL GROUND
OHE	OVERHEAD ELECTRIC
OMRF	ORDINARY MOMENT RESISTING FRAME
O TO O	OUT TO OUT
OPNG	OPENING
OZ	OUNCE
PC	POINT OF CURVE
PE	PLAIN END, POLYETHYLENE AND PERMANENT EASEMENT
PENT	PENETRATION
PI	POINT OF INTERSECTION
PJF	PREMOLDED JOINT FILLER
PL	PLATE, PROPERTY LINE
PLYWD	PLYWOOD
POB	POINT OF BEGINNING
PP, P&P	PLAN AND PROFILE, POWER POLE
PPM	PARTS PER MILLION
PRC	POINT OF REVERSE CURVE
PRCST	PRECAST
PREFAB	PREFABRICATED
PRESS	PRESSURE
PRC	POINT OF REVERSE CURVE
PRI	PRIMARY
PROP	PROPERTY
PSF	POUNDS PER SQUARE FOOT
PS	PUMP STATION
PSI	POUNDS PER SQUARE INCH
PSIG	POUNDS PER SQUARE INCH, GAUGE
PT	POINT OF TANGENCY
PV	PLUG VALVE
PVC	POLYVINYL CHLORIDE PLASTIC
PVCGS	POLYVINYL CHLORIDE PLASTIC GRAVITY SEWER TYPE
PVCW	POLYVINYL CHLORIDE PLASTIC WATER DISTRIBUTION SERVICE TYPE
PVMT	PAVEMENT
PVT	PRIVATE
PW	POTABLE WATER
R, RAD	RADIUS
RC	REINFORCED CONCRETE
RCP	REINFORCED CONCRETE PIPE
RD	ROAD, ROOF DRAIN
RDCR	REDUCER
REF	REFER OR REFERENCE
REINF	REINFORCED, REINFORCING REINFORCE
REQD	REQUIRED
RJ	RESTRAINED JOINT
RLS	RUBBER LINED STEEL
RM	ROOM
RMJ	RESTRAINED MECHANICAL JOINT
RO	ROUGH OPENING
RR	REMOVE AND REPLACE
RST	REINFORCING STEEL
RTN	RETURN
RV	ROOF VENT
RW	RAW WATER
R/W	RIGHT-OF-WAY
S	S BEAM, SOUTH, SLOPE
SA	SAMPLE
SAT	SUSPENDED ACOUSTIC TILE
SC	SCUM
SCFH	STANDARD CUBIC FEET PER HOUR
SCFM	STANDARD CUBIC FEET PER MINUTE
SCH	SCHEDULE
SD	STORM DRAIN
SEC	SECONDARY
SECT	SECTION
SH	SHEET
SIM	SIMILAR
SLD	SLUDGE
SLP	SLOPE
SOLN	SOLUTION
SP	SPACE OR SPACES
SPD	SUMP PUMP DRAIN
SPEC	SPECIFICATIONS
SPLY	SUPPLY
SQ	SQUARE
SQ FT	SQUARE FOOT
SQ IN	SQUARE INCH
SS	SANITARY SEWER
SSH	SAFETY SHOWER
SST	STAINLESS STEEL
STA	STATION
STD	STANDARD
STIF	STIFFENER
STL	STEEL, STEEL PIPE
STLS	STEEL PIPE (SPECIAL)
STR	STRAIGHT
STRL	STRUCTURAL
STRUCT	STRUCTURE
SUBFL	SUBFLOOR
SUSP	SUSPEND
SYMM	SYMMETRICAL
T	TANGENT, TELEPHONE LINE
TBG	TUBING
T&B	TOP AND BOTTOM
TC	TOP OF CURB, TOP OF CONCRETE
TCE	TEMPORARY CONSTRUCTION EASEMENT
TDH	TOTAL DYNAMIC HEAD
TECH	TECHNICAL
TEL	TELEPHONE
TEMP	TEMPORARY, TEMPERATURE
TF	TOP FACE
T&G	TONGUE AND GROOVE
THD	THREAD
THK	THICK
TP	TURNING POINT, TEST PIT
TRANS	TRANSITION
TRANSV	TRANSVERSE
TS	TUBE STEEL
TST	TOP OF STEEL
TT	THRUST TIE
TW	TOP OF WALL
TYP	TYPICAL
t	THICKNESS
UBC	UNIFORM BUILDING CODE
UD	UNDERDRAIN
UG	UNDERGROUND
UH	UNIT HEATER
UNK	UNKNOWN
V	VENT, VOLT, VALVE
VAC	VACUUM
VAR	VENT ACID RESISTANT
VC	VERTICAL CURVE
VERT	VERTICAL
VPI	VERTICAL POINT OF INTERSECTION
VPS	VENEER PLASTER SYSTEM
VTR	VENT THRU ROOF
W/	WITH
W	WIDE FLANGE (BEAM), WEST, WATER
WC	WATER CLOSET
WD	WOOD
WH	WATER HEATER
WM	WATER METER
WR	WATER RESISTANT
WS	WATER SURFACE, WATER STOP
WSH ST	WEATHERING SHEET STEEL
WSP	WELDED STEEL PIPE
WT	WATER TIGHT
WTR	WATER
WW	WASHWATER
WWF	WELDED WIRE FABRIC
YD	YARD

NOTES:

1. FOR ELECTRICAL AND INSTRUMENTATION ABBREVIATIONS, SEE E-401
2. CONTACT THE ENGINEER FOR ABBREVIATIONS NOT LISTED
3. THIS IS A STANDARD LEGEND SHEET THEREFORE, SOME SYMBOLS OR ABBREVIATIONS MAY APPEAR ON THIS SHEET AND MAY NOT BE UTILIZED ON THIS PROJECT

ORIGINALLY SIGNED AND SEALED BY ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL) ON 12/20/11

WATERWORKS

GENERAL
ABBREVIATIONS

DECEMBER 2011
G-003

DISCIPLINE

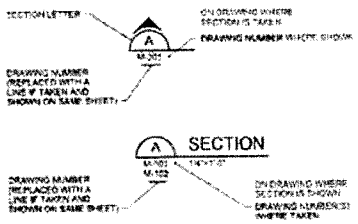
LETTER	DISCIPLINE
G	GENERAL
D	DEMOLITION
C	CIVIL YARD
A	ARCHITECTURAL
S	STRUCTURAL
M	MECHANICAL
H	HEATING, VENTILATION AND COOLING
P	PLUMBING
E	ELECTRICAL
N	INSTRUMENTATION

DRAWING NUMBERING

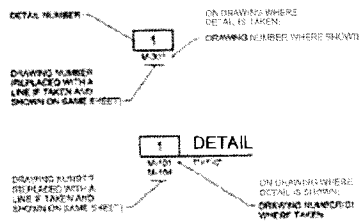
DRAWING SERIES	DESCRIPTION
000	GENERAL / OVERALL
100	PLANS
200	SECTIONS
300	DETAILS
400	ELEVATIONS
500	SCHEDULES

DRAWING NUMBER

SECTION



DETAIL



STANDARD VALVE AND OPERATOR

UNIQUE VALVE AND OPERATOR

EQUIPMENT DESIGNATION

LINE TYPE APPEARANCE

BLACK	MAIN DISCIPLINE
LIGHT OR MEDIUM GRAY OR SCREENED	EXISTING OR OFF DISCIPLINE
DARK GRAY	NEW OFF DISCIPLINE

GENERAL SYMBOLOGY

	STRUCTURE OR EQUIPMENT TO BE REMOVED OR DEMOLISHED
XXXX	LINE OF REMOVAL OR DEMOLITION

PROCESS FLOW STREAM IDENTIFIERS

PIPING SYSTEM ABBREVIATION	PIPING SYSTEM DESCRIPTION	PIPING MATERIAL
BW	BACKWASH	DIP
DR	DRAIN	CCP
GW	GROUND WATER	DIP
OF	OVERFLOW	DIP
SHC OR NaOCl	SODIUM HYPOCHLORITE	LDPE
RECI	RECYCLED WATER	CCP
PW	POTABLE WATER	DIP
V	VENT	GALV

EQUIPMENT TYPE IDENTIFIERS

ABBREVIATION	DESCRIPTION
AMV	ADSORPTION MEDIA VESSEL
APV	AIR PRESSURE VALVE
BAV	BALL VALVE
BFV	BUTTERFLY VALVE
CKV	CHECK VALVE
F	FILTER
FE	FLOW ELEMENT
GAV	GATE VALVE
IQ	INJECTION QUILL
LE	LEVEL ELEMENT
RD	RUPTURE DISK
RP	RECYCLE PUMP
T	TANK

ORIGINALLY SIGNED AND SEALED BY

ARIZONA REGISTERED PROFESSIONAL ENGINEER (OFFICE)

REVIEWED BY LRP 47962 ON 12/21/11

WATERWORKS

GENERAL

STANDARD DESIGNATIONS

DECEMBER 2011

G-004

RELEASE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF AECOM AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF AECOM. © 2011 AECOM

PIPE AND FITTING SYMBOLS

DOUBLE LINE	SINGLE LINE	
		EXISTING PIPE (SCREENED)
		NEW PIPE
		EXISTING PIPE TO BE ABANDONED
		EXISTING PIPE TO BE REMOVED
		BALL JOINT
		FLANGE COUPLING ADAPTER
		FLEXIBLE COUPLING
		FLEXIBLE COUPLING WITH THRUST TIES
		DISMANTLING JOINT
		STEEL BELLOWS EXPANSION JOINT
		ELASTOMER BELLOWS EXPANSION JOINT
		ELBOW - 90 DEGREE
		ELBOW UP - 90 DEGREE
		ELBOW DOWN - 90 DEGREE
		ELBOW - 45 DEGREE
		ELBOW UP - 45 DEGREE
		ELBOW DOWN - 45 DEGREE
		TAP
		TEE UP
		TEE DOWN
		CROSS
		LATERAL
		LATERAL UP
		LATERAL DOWN
		REDUCER - CONCENTRIC

PIPE AND FITTING SYMBOLS

DOUBLE LINE	SINGLE LINE	
		REDUCER - ECCENTRIC
		UNION
		BLIND FLANGE
		PLUG
		CAP

VALVE SYMBOLS

DOUBLE LINE	SINGLE LINE	
		GATE
		KNIFE GATE
		BUTTERFLY
		GLOBE
		BALL
		V-PORT BALL
		PLUG OR COCK
		SEAT PORT ECCENTRIC PLUG (PEC) REQUIRED SEAT LOCATION
FP	FP	FULL PORT PLUG
		REFLUX
		DIAPHRAGM
		FULL PORT PLUG
		SWING CHECK
		DOUBLE DISC OR SILENT CHECK
		BALL CHECK
	HP	HOSE VALVE
	X	NON-FREEZE HOSE VALVE SEE NUMBER IN SPECIFICATIONS
	X	NON-FREEZE HOSE VALVE WITH HOSE RACK SEE NUMBER IN SPECIFICATIONS
	SA	SAMPLE
		MUD
		PRESSURE RELIEF
		AIR AND OR VACUUM RELEASE
	REGULATED SIDE	PRESSURE CONTROL
		MULTI PORT VALVE ARROWS INDICATE FLOW PATTERN. SEAT PORTS ARE APPLIED BY INDICATED FLOW PATTERN. BALL VALVE SHOWN. FOR OTHER VALVE TYPES, APPROPRIATE VALVE SYMBOL SHOWN
		FIRE HYDRANT
		CATHODIC PROTECTION TEST STATION
		CATHODIC PROTECTION ANODE

FLOW METERS

DOUBLE LINE	SINGLE LINE	
		MAGMETER
		PROPELLER METER
		INSERTION METER

PUMPS

- MIXING
- DIAPHRAGM
- CENTRIFUGAL
- PERISTALTIC

MIXERS

- STATIC MIXER

ACTUATORS

- P — PNEUMATIC
- M — MOTORIZED
- S — SOLENOID

MISCELLANEOUS PIPING SYMBOLS

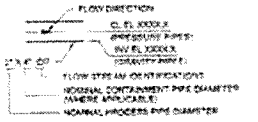
- STRAINER
- SIGHT GLASS
- FLEXIBLE (ELASTOMER) PIPE CONNECTION
- GAUGE WITH COCK
- THERMOMETER
- ECCENTRIC
- GALVANIC ANODE
- AIR SET XX – SUPPLY PRESSURE / PSIG
- TYPICAL INSTRUMENT SYMBOL (SEE I&C LEGEND)
- DRAIN
- DOUBLE CONTAINMENT PIPE
- RUPTURE DISK

INSTRUMENTATION SYMBOLS

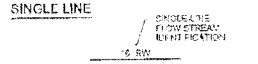
SYMBOL	DESCRIPTION
PS	PRESSURE SWITCH
PSH	PRESSURE SWITCH HIGH
PI	PRESSURE INDICATOR
LSL	LOW LEVEL SWITCH
LSLL	LEVEL SWITCH LOW LOW
LSH	LEVEL SWITCH HIGH
LSHH	LEVEL SWITCH HIGH HIGH
DPI	DIFFERENTIAL PRESSURE INDICATOR
FS	FLOW SWITCH
FM	FLOW METER

PIPING DESIGNATION

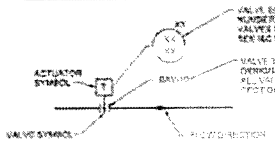
DOUBLE LINE



SINGLE LINE



VALVE DESIGNATIONS



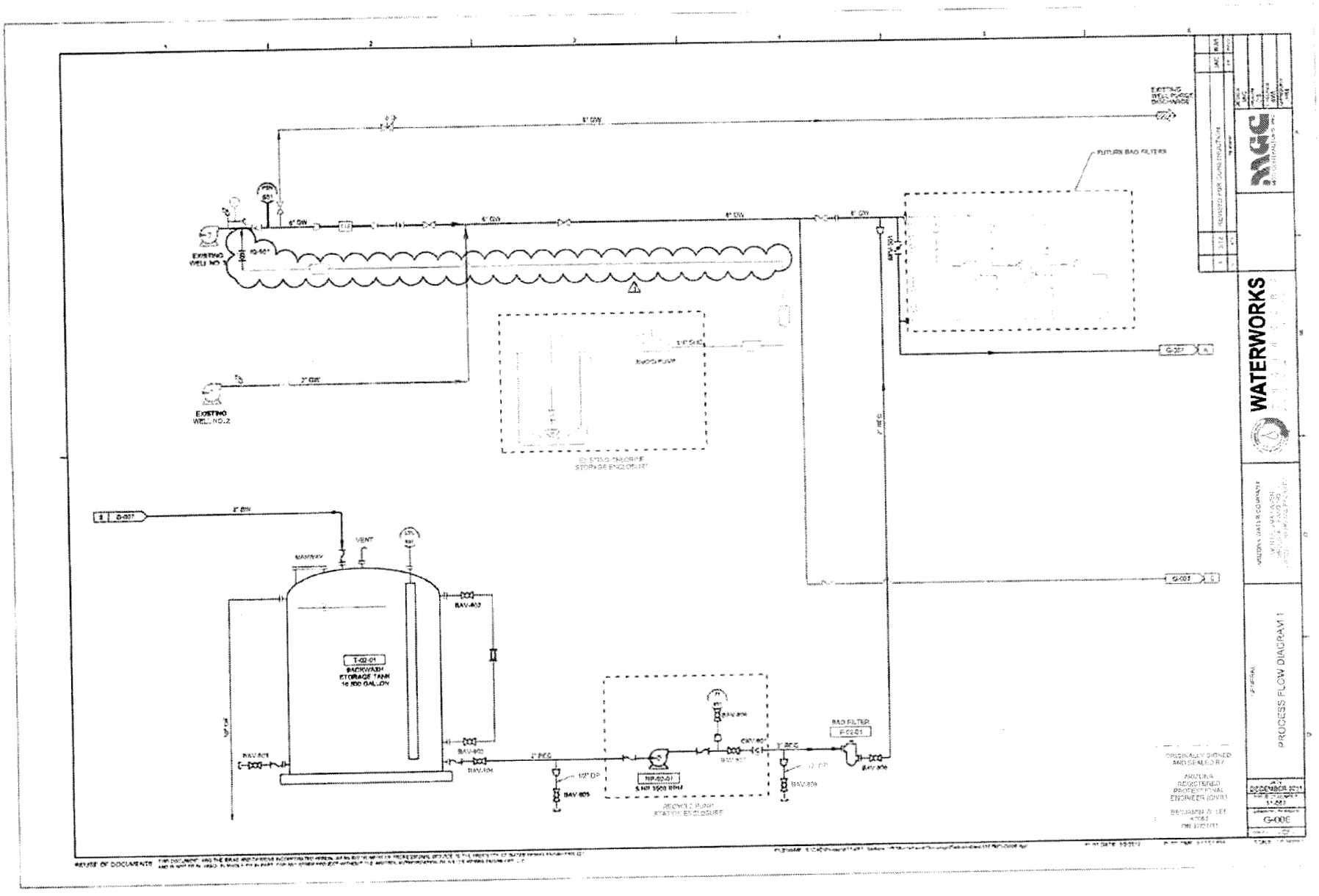
NOTES
1. ELECTRIC VALVE SHOWN, MANUAL VALVE SIMILAR

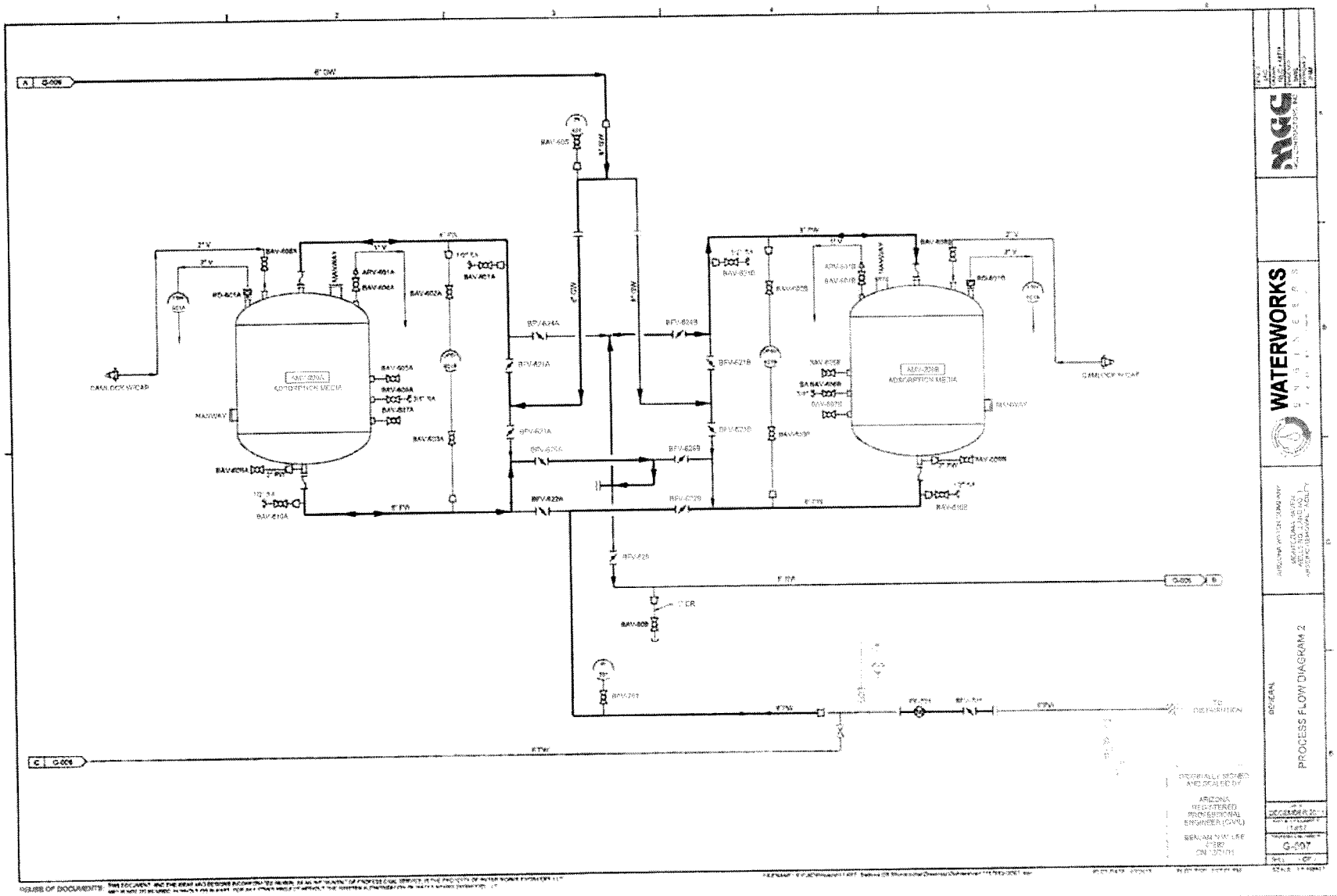
NOTES
1. EARLY FLANGED END CONNECTIONS ARE SHOWN HERE FOR DOUBLE LINE FITTINGS. FITTINGS WITH OTHER END MATERIALS ARE SHOWN SPECIFICALLY ON THE CONSTRUCTION DRAWINGS. ALSO SEE PIPING SPECIFICATIONS AND THE PIPING SCHEDULE.
2. SYMBOLS SHOWN HERE FOR SINGLE LINE FITTINGS ARE GENERIC ONLY. REFER TO PIPING SPECIFICATIONS FOR SPECIFIC END CONNECTIONS FOR SINGLE LINE PIPE AND FITTINGS.

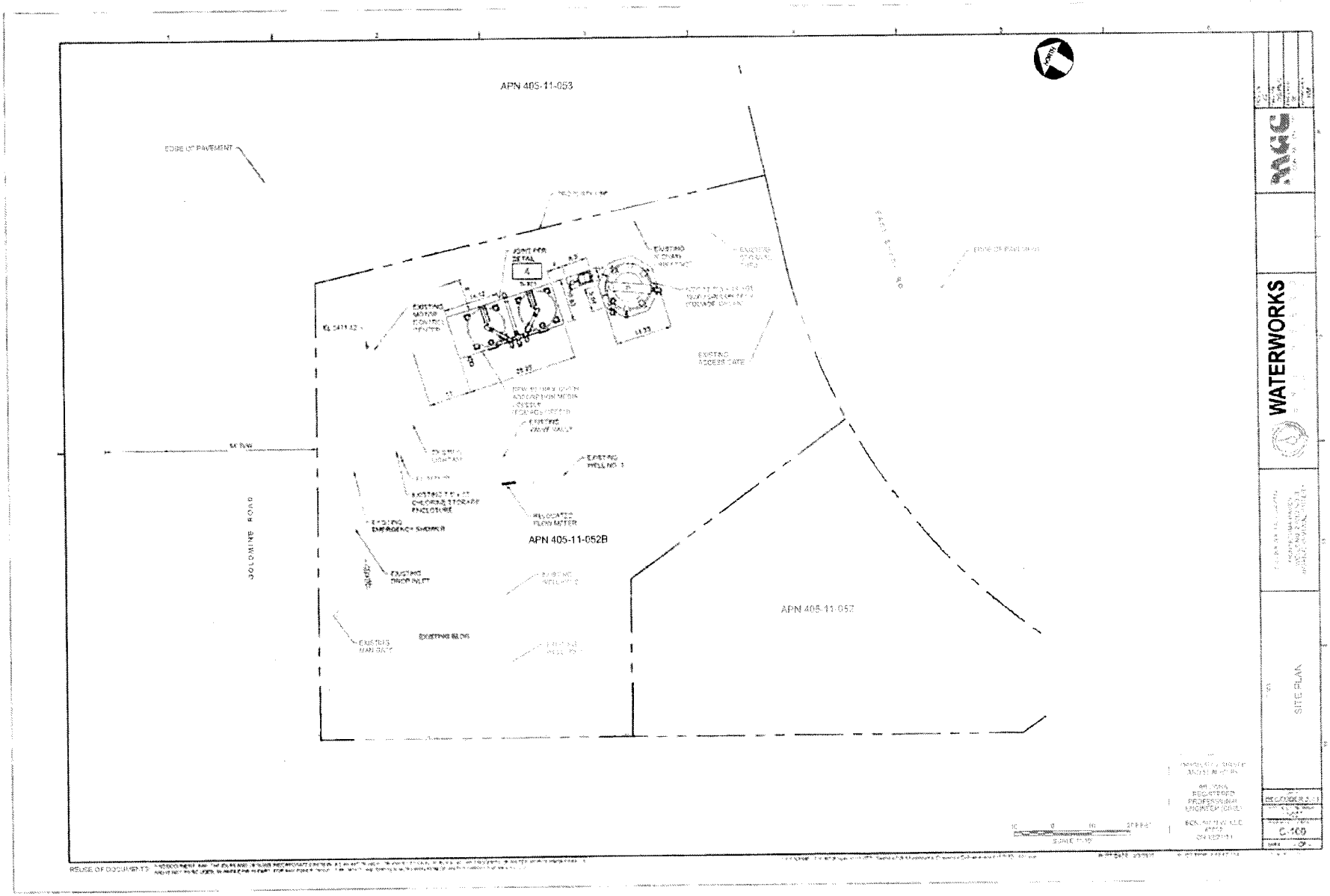
ORIGINALLY SIGNED AND SEALED BY
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
BENJAMIN W. LEE
6 PAGES
ON 12/21/11

DECEMBER 2011
11-05-
G-005

REUSE OF DOCUMENTS


EXISTING WELL NO.1
EXISTING WELL NO.2
8" DIW
FUTURE BAG FILTER
EXISTING CHLORINE STORAGE ENCLOSURE
BACKWASH STORAGE TANK 10,000 GALLON
VENT
MANWAY
BAV-802
BAV-803
BAV-804
BAV-805
BAV-806
BAV-807
BAV-808
BAV-809
BAV-810
BAG FILTER
F-02-01
RECYCLE PUMP STATION ENCLOSURE
ORIGINALLY SIGNED AND SEALED BY
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
WATERWORKS
PROCESS FLOW DIAGRAM 1
G-00E


WATERWORKS
PROCESS FLOW DIAGRAM 2
G-007
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
BENJAMIN MILLER
CERT
ON 123101
ISSUED FOR CONSTRUCTION
DECEMBER 2021
ADJUSTMENT NO. 1
ADJUSTMENT NO. 2
ADJUSTMENT NO. 3
ADJUSTMENT NO. 4
ADJUSTMENT NO. 5
ADJUSTMENT NO. 6
ADJUSTMENT NO. 7
ADJUSTMENT NO. 8
ADJUSTMENT NO. 9
ADJUSTMENT NO. 10
ADJUSTMENT NO. 11
ADJUSTMENT NO. 12
ADJUSTMENT NO. 13
ADJUSTMENT NO. 14
ADJUSTMENT NO. 15
ADJUSTMENT NO. 16
ADJUSTMENT NO. 17
ADJUSTMENT NO. 18
ADJUSTMENT NO. 19
ADJUSTMENT NO. 20
ADJUSTMENT NO. 21
ADJUSTMENT NO. 22
ADJUSTMENT NO. 23
ADJUSTMENT NO. 24
ADJUSTMENT NO. 25
ADJUSTMENT NO. 26
ADJUSTMENT NO. 27
ADJUSTMENT NO. 28
ADJUSTMENT NO. 29
ADJUSTMENT NO. 30
ADJUSTMENT NO. 31
ADJUSTMENT NO. 32
ADJUSTMENT NO. 33
ADJUSTMENT NO. 34
ADJUSTMENT NO. 35
ADJUSTMENT NO. 36
ADJUSTMENT NO. 37
ADJUSTMENT NO. 38
ADJUSTMENT NO. 39
ADJUSTMENT NO. 40
ADJUSTMENT NO. 41
ADJUSTMENT NO. 42
ADJUSTMENT NO. 43
ADJUSTMENT NO. 44
ADJUSTMENT NO. 45
ADJUSTMENT NO. 46
ADJUSTMENT NO. 47
ADJUSTMENT NO. 48
ADJUSTMENT NO. 49
ADJUSTMENT NO. 50
ADJUSTMENT NO. 51
ADJUSTMENT NO. 52
ADJUSTMENT NO. 53
ADJUSTMENT NO. 54
ADJUSTMENT NO. 55
ADJUSTMENT NO. 56
ADJUSTMENT NO. 57
ADJUSTMENT NO. 58
ADJUSTMENT NO. 59
ADJUSTMENT NO. 60
ADJUSTMENT NO. 61
ADJUSTMENT NO. 62
ADJUSTMENT NO. 63
ADJUSTMENT NO. 64
ADJUSTMENT NO. 65
ADJUSTMENT NO. 66
ADJUSTMENT NO. 67
ADJUSTMENT NO. 68
ADJUSTMENT NO. 69
ADJUSTMENT NO. 70
ADJUSTMENT NO. 71
ADJUSTMENT NO. 72
ADJUSTMENT NO. 73
ADJUSTMENT NO. 74
ADJUSTMENT NO. 75
ADJUSTMENT NO. 76
ADJUSTMENT NO. 77
ADJUSTMENT NO. 78
ADJUSTMENT NO. 79
ADJUSTMENT NO. 80
ADJUSTMENT NO. 81
ADJUSTMENT NO. 82
ADJUSTMENT NO. 83
ADJUSTMENT NO. 84
ADJUSTMENT NO. 85
ADJUSTMENT NO. 86
ADJUSTMENT NO. 87
ADJUSTMENT NO. 88
ADJUSTMENT NO. 89
ADJUSTMENT NO. 90
ADJUSTMENT NO. 91
ADJUSTMENT NO. 92
ADJUSTMENT NO. 93
ADJUSTMENT NO. 94
ADJUSTMENT NO. 95
ADJUSTMENT NO. 96
ADJUSTMENT NO. 97
ADJUSTMENT NO. 98
ADJUSTMENT NO. 99
ADJUSTMENT NO. 100
ADJUSTMENT NO. 101
ADJUSTMENT NO. 102
ADJUSTMENT NO. 103
ADJUSTMENT NO. 104
ADJUSTMENT NO. 105
ADJUSTMENT NO. 106
ADJUSTMENT NO. 107
ADJUSTMENT NO. 108
ADJUSTMENT NO. 109
ADJUSTMENT NO. 110
ADJUSTMENT NO. 111
ADJUSTMENT NO. 112
ADJUSTMENT NO. 113
ADJUSTMENT NO. 114
ADJUSTMENT NO. 115
ADJUSTMENT NO. 116
ADJUSTMENT NO. 117
ADJUSTMENT NO. 118
ADJUSTMENT NO. 119
ADJUSTMENT NO. 120
ADJUSTMENT NO. 121
ADJUSTMENT NO. 122
ADJUSTMENT NO. 123
ADJUSTMENT NO. 124
ADJUSTMENT NO. 125
ADJUSTMENT NO. 126
ADJUSTMENT NO. 127
ADJUSTMENT NO. 128
ADJUSTMENT NO. 129
ADJUSTMENT NO. 130
ADJUSTMENT NO. 131
ADJUSTMENT NO. 132
ADJUSTMENT NO. 133
ADJUSTMENT NO. 134
ADJUSTMENT NO. 135
ADJUSTMENT NO. 136
ADJUSTMENT NO. 137
ADJUSTMENT NO. 138
ADJUSTMENT NO. 139
ADJUSTMENT NO. 140
ADJUSTMENT NO. 141
ADJUSTMENT NO. 142
ADJUSTMENT NO. 143
ADJUSTMENT NO. 144
ADJUSTMENT NO. 145
ADJUSTMENT NO. 146
ADJUSTMENT NO. 147
ADJUSTMENT NO. 148
ADJUSTMENT NO. 149
ADJUSTMENT NO. 150
ADJUSTMENT NO. 151
ADJUSTMENT NO. 152
ADJUSTMENT NO. 153
ADJUSTMENT NO. 154
ADJUSTMENT NO. 155
ADJUSTMENT NO. 156
ADJUSTMENT NO. 157
ADJUSTMENT NO. 158
ADJUSTMENT NO. 159
ADJUSTMENT NO. 160
ADJUSTMENT NO. 161
ADJUSTMENT NO. 162
ADJUSTMENT NO. 163
ADJUSTMENT NO. 164
ADJUSTMENT NO. 165
ADJUSTMENT NO. 166
ADJUSTMENT NO. 167
ADJUSTMENT NO. 168
ADJUSTMENT NO. 169
ADJUSTMENT NO. 170
ADJUSTMENT NO. 171
ADJUSTMENT NO. 172
ADJUSTMENT NO. 173
ADJUSTMENT NO. 174
ADJUSTMENT NO. 175
ADJUSTMENT NO. 176
ADJUSTMENT NO. 177
ADJUSTMENT NO. 178
ADJUSTMENT NO. 179
ADJUSTMENT NO. 180
ADJUSTMENT NO. 181
ADJUSTMENT NO. 182
ADJUSTMENT NO. 183
ADJUSTMENT NO. 184
ADJUSTMENT NO. 185
ADJUSTMENT NO. 186
ADJUSTMENT NO. 187
ADJUSTMENT NO. 188
ADJUSTMENT NO. 189
ADJUSTMENT NO. 190
ADJUSTMENT NO. 191
ADJUSTMENT NO. 192
ADJUSTMENT NO. 193
ADJUSTMENT NO. 194
ADJUSTMENT NO. 195
ADJUSTMENT NO. 196
ADJUSTMENT NO. 197
ADJUSTMENT NO. 198
ADJUSTMENT NO. 199
ADJUSTMENT NO. 200
ADJUSTMENT NO. 201
ADJUSTMENT NO. 202
ADJUSTMENT NO. 203
ADJUSTMENT NO. 204
ADJUSTMENT NO. 205
ADJUSTMENT NO. 206
ADJUSTMENT NO. 207
ADJUSTMENT NO. 208
ADJUSTMENT NO. 209
ADJUSTMENT NO. 210
ADJUSTMENT NO. 211
ADJUSTMENT NO. 212
ADJUSTMENT NO. 213
ADJUSTMENT NO. 214
ADJUSTMENT NO. 215
ADJUSTMENT NO. 216
ADJUSTMENT NO. 217
ADJUSTMENT NO. 218
ADJUSTMENT NO. 219
ADJUSTMENT NO. 220
ADJUSTMENT NO. 221
ADJUSTMENT NO. 222
ADJUSTMENT NO. 223
ADJUSTMENT NO. 224
ADJUSTMENT NO. 225
ADJUSTMENT NO. 226
ADJUSTMENT NO. 227
ADJUSTMENT NO. 228
ADJUSTMENT NO. 229
ADJUSTMENT NO. 230
ADJUSTMENT NO. 231
ADJUSTMENT NO. 232
ADJUSTMENT NO. 233
ADJUSTMENT NO. 234
ADJUSTMENT NO. 235
ADJUSTMENT NO. 236
ADJUSTMENT NO. 237
ADJUSTMENT NO. 238
ADJUSTMENT NO. 239
ADJUSTMENT NO. 240
ADJUSTMENT NO. 241
ADJUSTMENT NO. 242
ADJUSTMENT NO. 243
ADJUSTMENT NO. 244
ADJUSTMENT NO. 245
ADJUSTMENT NO. 246
ADJUSTMENT NO. 247
ADJUSTMENT NO. 248
ADJUSTMENT NO. 249
ADJUSTMENT NO. 250
ADJUSTMENT NO. 251
ADJUSTMENT NO. 252
ADJUSTMENT NO. 253
ADJUSTMENT NO. 254
ADJUSTMENT NO. 255
ADJUSTMENT NO. 256
ADJUSTMENT NO. 257
ADJUSTMENT NO. 258
ADJUSTMENT NO. 259
ADJUSTMENT NO. 260
ADJUSTMENT NO. 261
ADJUSTMENT NO. 262
ADJUSTMENT NO. 263
ADJUSTMENT NO. 264
ADJUSTMENT NO. 265
ADJUSTMENT NO. 266
ADJUSTMENT NO. 267
ADJUSTMENT NO. 268
ADJUSTMENT NO. 269
ADJUSTMENT NO. 270
ADJUSTMENT NO. 271
ADJUSTMENT NO. 272
ADJUSTMENT NO. 273
ADJUSTMENT NO. 274
ADJUSTMENT NO. 275
ADJUSTMENT NO. 276
ADJUSTMENT NO. 277
ADJUSTMENT NO. 278
ADJUSTMENT NO. 279
ADJUSTMENT NO. 280
ADJUSTMENT NO. 281
ADJUSTMENT NO. 282
ADJUSTMENT NO. 283
ADJUSTMENT NO. 284
ADJUSTMENT NO. 285
ADJUSTMENT NO. 286
ADJUSTMENT NO. 287
ADJUSTMENT NO. 288
ADJUSTMENT NO. 289
ADJUSTMENT NO. 290
ADJUSTMENT NO. 291
ADJUSTMENT NO. 292
ADJUSTMENT NO. 293
ADJUSTMENT NO. 294
ADJUSTMENT NO. 295
ADJUSTMENT NO. 296
ADJUSTMENT NO. 297
ADJUSTMENT NO. 298
ADJUSTMENT NO. 299
ADJUSTMENT NO. 300
ADJUSTMENT NO. 301
ADJUSTMENT NO. 302
ADJUSTMENT NO. 303
ADJUSTMENT NO. 304
ADJUSTMENT NO. 305
ADJUSTMENT NO. 306
ADJUSTMENT NO. 307
ADJUSTMENT NO. 308
ADJUSTMENT NO. 309
ADJUSTMENT NO. 310
ADJUSTMENT NO. 311
ADJUSTMENT NO. 312
ADJUSTMENT NO. 313
ADJUSTMENT NO. 314
ADJUSTMENT NO. 315
ADJUSTMENT NO. 316
ADJUSTMENT NO. 317
ADJUSTMENT NO. 318
ADJUSTMENT NO. 319
ADJUSTMENT NO. 320
ADJUSTMENT NO. 321
ADJUSTMENT NO. 322
ADJUSTMENT NO. 323
ADJUSTMENT NO. 324
ADJUSTMENT NO. 325
ADJUSTMENT NO. 326
ADJUSTMENT NO. 327
ADJUSTMENT NO. 328
ADJUSTMENT NO. 329
ADJUSTMENT NO. 330
ADJUSTMENT NO. 331
ADJUSTMENT NO. 332
ADJUSTMENT NO. 333
ADJUSTMENT NO. 334
ADJUSTMENT NO. 335
ADJUSTMENT NO. 336
ADJUSTMENT NO. 337
ADJUSTMENT NO. 338
ADJUSTMENT NO. 339
ADJUSTMENT NO. 340
ADJUSTMENT NO. 341
ADJUSTMENT NO. 342
ADJUSTMENT NO. 343
ADJUSTMENT NO. 344
ADJUSTMENT NO. 345
ADJUSTMENT NO. 346
ADJUSTMENT NO. 347
ADJUSTMENT NO. 348
ADJUSTMENT NO. 349
ADJUSTMENT NO. 350
ADJUSTMENT NO. 351
ADJUSTMENT NO. 352
ADJUSTMENT NO. 353
ADJUSTMENT NO. 354
ADJUSTMENT NO. 355
ADJUSTMENT NO. 356
ADJUSTMENT NO. 357
ADJUSTMENT NO. 358
ADJUSTMENT NO. 359
ADJUSTMENT NO. 360
ADJUSTMENT NO. 361
ADJUSTMENT NO. 362
ADJUSTMENT NO. 363
ADJUSTMENT NO. 364
ADJUSTMENT NO. 365
ADJUSTMENT NO. 366
ADJUSTMENT NO. 367
ADJUSTMENT NO. 368
ADJUSTMENT NO. 369
ADJUSTMENT NO. 370
ADJUSTMENT NO. 371
ADJUSTMENT NO. 372
ADJUSTMENT NO. 373
ADJUSTMENT NO. 374
ADJUSTMENT NO. 375
ADJUSTMENT NO. 376
ADJUSTMENT NO. 377
ADJUSTMENT NO. 378
ADJUSTMENT NO. 379
ADJUSTMENT NO. 380
ADJUSTMENT NO. 381
ADJUSTMENT NO. 382
ADJUSTMENT NO. 383
ADJUSTMENT NO. 384
ADJUSTMENT NO. 385
ADJUSTMENT NO. 386
ADJUSTMENT NO. 387
ADJUSTMENT NO. 388
ADJUSTMENT NO. 389
ADJUSTMENT NO. 390
ADJUSTMENT NO. 391
ADJUSTMENT NO. 392
ADJUSTMENT NO. 393
ADJUSTMENT NO. 394
ADJUSTMENT NO. 395
ADJUSTMENT NO. 396
ADJUSTMENT NO. 397
ADJUSTMENT NO. 398
ADJUSTMENT NO. 399
ADJUSTMENT NO. 400
ADJUSTMENT NO. 401
ADJUSTMENT NO. 402
ADJUSTMENT NO. 403
ADJUSTMENT NO. 404
ADJUSTMENT NO. 405
ADJUSTMENT NO. 406
ADJUSTMENT NO. 407
ADJUSTMENT NO. 408
ADJUSTMENT NO. 409
ADJUSTMENT NO. 410
ADJUSTMENT NO. 411
ADJUSTMENT NO. 412
ADJUSTMENT NO. 413
ADJUSTMENT NO. 414
ADJUSTMENT NO. 415
ADJUSTMENT NO. 416
ADJUSTMENT NO. 417
ADJUSTMENT NO. 418
ADJUSTMENT NO. 419
ADJUSTMENT NO. 420
ADJUSTMENT NO. 421
ADJUSTMENT NO. 422
ADJUSTMENT NO. 423
ADJUSTMENT NO. 424
ADJUSTMENT NO. 425
ADJUSTMENT NO. 426
ADJUSTMENT NO. 427
ADJUSTMENT NO. 428
ADJUSTMENT NO. 429
ADJUSTMENT NO. 430
ADJUSTMENT NO. 431
ADJUSTMENT NO. 432
ADJUSTMENT NO. 433
ADJUSTMENT NO. 434
ADJUSTMENT NO. 435
ADJUSTMENT NO. 436
ADJUSTMENT NO. 437
ADJUSTMENT NO. 438
ADJUSTMENT NO. 439
ADJUSTMENT NO. 440
ADJUSTMENT NO. 441
ADJUSTMENT NO. 442
ADJUSTMENT NO. 443
ADJUSTMENT NO. 444
ADJUSTMENT NO. 445
ADJUSTMENT NO. 446
ADJUSTMENT NO. 447
ADJUSTMENT NO. 448
ADJUSTMENT NO. 449
ADJUSTMENT NO. 450
ADJUSTMENT NO. 451
ADJUSTMENT NO. 452
ADJUSTMENT NO. 453
ADJUSTMENT NO. 454
ADJUSTMENT NO. 455
ADJUSTMENT NO. 456
ADJUSTMENT NO. 457
ADJUSTMENT NO. 458
ADJUSTMENT NO. 459
ADJUSTMENT NO. 460
ADJUSTMENT NO. 461
ADJUSTMENT NO. 462
ADJUSTMENT NO. 463
ADJUSTMENT NO. 464
ADJUSTMENT NO. 465
ADJUSTMENT NO. 466
ADJUSTMENT NO. 467
ADJUSTMENT NO. 468
ADJUSTMENT NO. 469
ADJUSTMENT NO. 470
ADJUSTMENT NO. 471
ADJUSTMENT NO. 472
ADJUSTMENT NO. 473
ADJUSTMENT NO. 474
ADJUSTMENT NO. 475
ADJUSTMENT NO. 476
ADJUSTMENT NO. 477
ADJUSTMENT NO. 478
ADJUSTMENT NO. 479
ADJUSTMENT NO. 480
ADJUSTMENT NO. 481
ADJUSTMENT NO. 482
ADJUSTMENT NO. 483
ADJUSTMENT NO. 484
ADJUSTMENT NO. 485
ADJUSTMENT NO. 486
ADJUSTMENT NO. 487
ADJUSTMENT NO. 488
ADJUSTMENT NO. 489
ADJUSTMENT NO. 490
ADJUSTMENT NO. 491
ADJUSTMENT NO. 492
ADJUSTMENT NO. 493
ADJUSTMENT NO. 494
ADJUSTMENT NO. 495
ADJUSTMENT NO. 496
ADJUSTMENT NO. 497
ADJUSTMENT NO. 498
ADJUSTMENT NO. 499
ADJUSTMENT NO. 500
ADJUSTMENT NO. 501
ADJUSTMENT NO. 502
ADJUSTMENT NO. 503
ADJUSTMENT NO. 504
ADJUSTMENT NO. 505
ADJUSTMENT NO. 506
ADJUSTMENT NO. 507
ADJUSTMENT NO. 508
ADJUSTMENT NO. 509
ADJUSTMENT NO. 510
ADJUSTMENT NO. 511
ADJUSTMENT NO. 512
ADJUSTMENT NO. 513
ADJUSTMENT NO. 514
ADJUSTMENT NO. 515
ADJUSTMENT NO. 516
ADJUSTMENT NO. 517
ADJUSTMENT NO. 518
ADJUSTMENT NO. 519
ADJUSTMENT NO. 520
ADJUSTMENT NO. 521
ADJUSTMENT NO. 522
ADJUSTMENT NO. 523
ADJUSTMENT NO. 524
ADJUSTMENT NO. 525
ADJUSTMENT NO. 526
ADJUSTMENT NO. 527
ADJUSTMENT NO. 528
ADJUSTMENT NO. 529
ADJUSTMENT NO. 530
ADJUSTMENT NO. 531
ADJUSTMENT NO. 532
ADJUSTMENT NO. 533
ADJUSTMENT NO. 534
ADJUSTMENT NO. 535
ADJUSTMENT NO. 536
ADJUSTMENT NO. 537
ADJUSTMENT NO. 538
ADJUSTMENT NO. 539
ADJUSTMENT NO. 540
ADJUSTMENT NO. 541
ADJUSTMENT NO. 542
ADJUSTMENT NO. 543
ADJUSTMENT NO. 544
ADJUSTMENT NO. 545
ADJUSTMENT NO. 546
ADJUSTMENT NO. 547
ADJUSTMENT NO. 548
ADJUSTMENT NO. 549
ADJUSTMENT NO. 550
ADJUSTMENT NO. 551
ADJUSTMENT NO. 552
ADJUSTMENT NO. 553
ADJUSTMENT NO. 554
ADJUSTMENT NO. 555
ADJUSTMENT NO. 556
ADJUSTMENT NO. 557
ADJUSTMENT NO. 558
ADJUSTMENT NO. 559
ADJUSTMENT NO. 560
ADJUSTMENT NO. 561
ADJUSTMENT NO. 562
ADJUSTMENT NO. 563
ADJUSTMENT NO. 564
ADJUSTMENT NO. 565
ADJUSTMENT NO. 566
ADJUSTMENT NO. 567
ADJUSTMENT NO. 568
ADJUSTMENT NO. 569
ADJUSTMENT NO. 570
ADJUSTMENT NO. 571
ADJUSTMENT NO. 572
ADJUSTMENT NO. 573
ADJUSTMENT NO. 574
ADJUSTMENT NO. 575
ADJUSTMENT NO. 576
ADJUSTMENT NO. 577
ADJUSTMENT NO. 578
ADJUSTMENT NO. 579
ADJUSTMENT NO. 580
ADJUSTMENT NO. 581
ADJUSTMENT NO. 582
ADJUSTMENT NO. 583
ADJUSTMENT NO. 584
ADJUSTMENT NO. 585
ADJUSTMENT NO. 586
ADJUSTMENT NO. 587
ADJUSTMENT NO. 588
ADJUSTMENT NO. 589
ADJUSTMENT NO. 590
ADJUSTMENT NO. 591
ADJUSTMENT NO. 592
ADJUSTMENT NO. 593
ADJUSTMENT NO. 594
ADJUSTMENT NO. 595
ADJUSTMENT NO. 596
ADJUSTMENT NO. 597
ADJUSTMENT NO. 598
ADJUSTMENT NO. 599
ADJUSTMENT NO. 600
ADJUSTMENT NO. 601
ADJUSTMENT NO. 602
ADJUSTMENT NO. 603
ADJUSTMENT NO. 604
ADJUSTMENT NO. 605
ADJUSTMENT NO. 606
ADJUSTMENT NO. 607
ADJUSTMENT NO. 608
ADJUSTMENT NO. 609
ADJUSTMENT NO. 610
ADJUSTMENT NO. 611
ADJUSTMENT NO. 612
ADJUSTMENT NO. 613
ADJUSTMENT NO. 614
ADJUSTMENT NO. 615
ADJUSTMENT NO. 616
ADJUSTMENT NO. 617
ADJUSTMENT NO. 618
ADJUSTMENT NO. 619
ADJUSTMENT NO. 620
ADJUSTMENT NO. 621
ADJUSTMENT NO. 622
ADJUSTMENT NO. 623
ADJUSTMENT NO. 624
ADJUSTMENT NO. 625
ADJUSTMENT NO. 626
ADJUSTMENT NO. 627
ADJUSTMENT NO. 628
ADJUSTMENT NO. 629
ADJUSTMENT NO. 630
ADJUSTMENT NO. 631
ADJUSTMENT NO. 632
ADJUSTMENT NO. 633
ADJUSTMENT NO. 634
ADJUSTMENT NO. 635
ADJUSTMENT NO. 636
ADJUSTMENT NO. 637
ADJUSTMENT NO. 638
ADJUSTMENT NO. 639
ADJUSTMENT NO. 640
ADJUSTMENT NO. 641
ADJUSTMENT NO. 642
ADJUSTMENT NO. 643
ADJUSTMENT NO. 644
ADJUSTMENT NO. 645
ADJUSTMENT NO. 646
ADJUSTMENT NO. 647
ADJUSTMENT NO. 648
ADJUSTMENT NO. 649
ADJUSTMENT NO. 650
ADJUSTMENT NO. 651
ADJUSTMENT NO. 652
ADJUSTMENT NO. 653
ADJUSTMENT NO. 654
ADJUSTMENT NO. 655
ADJUSTMENT NO. 656
ADJUSTMENT NO. 657
ADJUSTMENT NO. 658
ADJUSTMENT NO. 659
ADJUSTMENT NO. 660
ADJUSTMENT NO. 661
ADJUSTMENT NO. 662
ADJUSTMENT NO. 663
ADJUSTMENT NO. 664
ADJUSTMENT NO. 665
ADJUSTMENT NO. 666
ADJUSTMENT NO. 667
ADJUSTMENT NO. 668
ADJUSTMENT NO. 669
ADJUSTMENT NO. 670
ADJUSTMENT NO. 671
ADJUSTMENT NO. 672
ADJUSTMENT NO. 673
ADJUSTMENT NO. 674
ADJUSTMENT NO. 675
ADJUSTMENT NO. 676
ADJUSTMENT NO. 677
ADJUSTMENT NO. 678
ADJUSTMENT NO. 679
ADJUSTMENT NO. 680
ADJUSTMENT NO. 681
ADJUSTMENT NO. 682
ADJUSTMENT NO. 683
ADJUSTMENT NO. 684
ADJUSTMENT NO. 685
ADJUSTMENT NO. 686
ADJUSTMENT NO. 687
ADJUSTMENT NO. 688
ADJUSTMENT NO. 689
ADJUSTMENT NO. 690
ADJUSTMENT NO. 691
ADJUSTMENT NO. 692
ADJUSTMENT NO. 693
ADJUSTMENT NO. 694
ADJUSTMENT NO. 695
ADJUSTMENT NO. 696
ADJUSTMENT NO. 697
ADJUSTMENT NO. 698
ADJUSTMENT NO. 699
ADJUSTMENT NO. 700
ADJUSTMENT NO. 701
ADJUSTMENT NO. 702
ADJUSTMENT NO. 703
ADJUSTMENT NO. 704
ADJUSTMENT NO. 705
ADJUSTMENT NO. 706
ADJUSTMENT NO. 707
ADJUSTMENT NO. 708
ADJUSTMENT NO. 709
ADJUSTMENT NO. 710
ADJUSTMENT NO. 711
ADJUSTMENT NO. 712
ADJUSTMENT NO. 713
ADJUSTMENT NO. 714
ADJUSTMENT NO. 715
ADJUSTMENT NO. 716
ADJUSTMENT NO. 717
ADJUSTMENT NO. 718
ADJUSTMENT NO. 719
ADJUSTMENT NO. 720
ADJUSTMENT NO. 721
ADJUSTMENT NO. 722
ADJUSTMENT NO. 723
ADJUSTMENT NO. 724
ADJUSTMENT NO. 725
ADJUSTMENT NO. 726
ADJUSTMENT NO. 727
ADJUSTMENT NO. 728
ADJUSTMENT NO. 729
ADJUSTMENT NO. 730
ADJUSTMENT NO. 731
ADJUSTMENT NO. 732
ADJUSTMENT NO. 733
ADJUSTMENT NO. 734
ADJUSTMENT NO. 735
ADJUSTMENT NO. 736
ADJUSTMENT NO. 737
ADJUSTMENT NO. 738
ADJUSTMENT NO. 739
ADJUSTMENT NO. 740
ADJUSTMENT NO. 741
ADJUSTMENT NO. 742
ADJUSTMENT NO. 743
ADJUSTMENT NO. 744
ADJUSTMENT NO. 745
ADJUSTMENT NO. 746
ADJUSTMENT NO. 747
ADJUSTMENT NO. 748
ADJUSTMENT NO. 749
ADJUSTMENT NO. 750
ADJUSTMENT NO. 751
ADJUSTMENT NO. 752
ADJUSTMENT NO. 753
ADJUSTMENT NO. 754
ADJUSTMENT NO. 755
ADJUSTMENT NO. 756
ADJUSTMENT NO. 757
ADJUSTMENT NO. 758
ADJUSTMENT NO. 759
ADJUSTMENT NO. 760
ADJUSTMENT NO. 761
ADJUSTMENT NO. 762
ADJUSTMENT NO. 763
ADJUSTMENT NO. 764
ADJUSTMENT NO. 765
ADJUSTMENT NO. 766
ADJUSTMENT NO. 767
ADJUSTMENT NO. 768
ADJUSTMENT NO. 769
ADJUSTMENT NO. 770
ADJUSTMENT NO. 771
ADJUSTMENT NO. 772
ADJUSTMENT NO. 773
ADJUSTMENT NO. 774
ADJUSTMENT NO. 775
ADJUSTMENT NO. 776
ADJUSTMENT NO. 777
ADJUSTMENT NO. 778
ADJUSTMENT NO. 779
ADJUSTMENT NO. 780
ADJUSTMENT NO. 781
ADJUSTMENT NO. 782
ADJUSTMENT NO. 783
ADJUSTMENT NO. 784
ADJUSTMENT NO. 785
ADJUSTMENT NO. 786
ADJUSTMENT NO. 787
ADJUSTMENT NO. 788
ADJUSTMENT NO. 789
ADJUSTMENT NO. 790
ADJUSTMENT NO. 791
ADJUSTMENT NO. 792
ADJUSTMENT NO. 793
ADJUSTMENT NO. 794
ADJUSTMENT NO. 795
ADJUSTMENT NO. 796
ADJUSTMENT NO. 797
ADJUSTMENT NO. 798
ADJUSTMENT NO. 799
ADJUSTMENT NO. 800
ADJUSTMENT NO. 801
ADJUSTMENT NO. 802
ADJUSTMENT NO. 803
ADJUSTMENT NO. 804
ADJUSTMENT NO. 805
ADJUSTMENT NO. 806
ADJUSTMENT NO. 807
ADJUSTMENT NO. 808
ADJUSTMENT NO. 809
ADJUSTMENT NO. 810
ADJUSTMENT NO. 811
ADJUSTMENT NO. 812
ADJUSTMENT NO. 813
ADJUSTMENT NO. 814
ADJUSTMENT NO. 815
ADJUSTMENT NO. 816
ADJUSTMENT NO. 817
ADJUSTMENT NO. 818
ADJUSTMENT NO. 819
ADJUSTMENT NO. 820
ADJUSTMENT NO. 821
ADJUSTMENT NO. 822
ADJUSTMENT NO. 823
ADJUSTMENT NO. 824
ADJUSTMENT NO. 825
ADJUSTMENT NO. 826
ADJUSTMENT NO. 827
ADJUSTMENT NO. 828
ADJUSTMENT NO. 829
ADJUSTMENT NO. 830
ADJUSTMENT NO. 831
ADJUSTMENT NO. 832
ADJUSTMENT NO. 833
ADJUSTMENT NO. 834
ADJUSTMENT NO. 835
ADJUSTMENT NO. 836
ADJUSTMENT NO. 837
ADJUSTMENT NO. 838
ADJUSTMENT NO. 839
ADJUSTMENT NO. 840
ADJUSTMENT NO. 841
ADJUSTMENT NO. 842
ADJUSTMENT NO. 843
ADJUSTMENT NO. 844
ADJUSTMENT NO. 845
ADJUSTMENT NO. 846
ADJUSTMENT NO. 847
ADJUSTMENT NO. 848
ADJUSTMENT NO. 849
ADJUSTMENT NO. 850
ADJUSTMENT NO. 851
ADJUSTMENT NO. 852
ADJUSTMENT NO. 853
ADJUSTMENT NO. 854
ADJUSTMENT NO. 855
ADJUSTMENT NO. 856
ADJUSTMENT NO. 857
ADJUSTMENT NO. 858
ADJUSTMENT NO. 859
ADJUSTMENT NO. 860
ADJUSTMENT NO. 861
ADJUSTMENT NO. 862
ADJUSTMENT NO. 863
ADJUSTMENT NO. 864
ADJUSTMENT NO. 865
ADJUSTMENT NO. 866
ADJUSTMENT NO. 867
ADJUSTMENT NO. 868
ADJUSTMENT NO. 869
ADJUSTMENT NO. 870
ADJUSTMENT NO. 871
ADJUSTMENT NO. 872
ADJUSTMENT NO. 873
ADJUSTMENT NO. 874
ADJUSTMENT NO. 875
ADJUSTMENT NO. 876
ADJUSTMENT NO. 877
ADJUSTMENT NO. 878
ADJUSTMENT NO. 879
ADJUSTMENT NO. 880
ADJUSTMENT NO. 881
ADJUSTMENT NO. 882
ADJUSTMENT NO. 883
ADJUSTMENT NO. 884
ADJUSTMENT NO. 885
ADJUSTMENT NO. 886
ADJUSTMENT NO. 887
ADJUSTMENT NO. 888
ADJUSTMENT NO. 889
ADJUSTMENT NO. 890
ADJUSTMENT NO. 891
ADJUSTMENT NO. 892
ADJUSTMENT NO. 893
ADJUSTMENT NO. 894
ADJUSTMENT NO. 895
ADJUSTMENT NO. 896
ADJUSTMENT NO. 897
ADJUSTMENT NO. 898
ADJUSTMENT NO. 899
ADJUSTMENT NO. 900
ADJUSTMENT NO. 901
ADJUSTMENT NO. 902
ADJUSTMENT NO. 903
ADJUSTMENT NO. 904
ADJUSTMENT NO. 905
ADJUSTMENT NO. 906
ADJUSTMENT NO. 907
ADJUSTMENT NO. 908
ADJUSTMENT NO. 909
ADJUSTMENT NO. 910
ADJUSTMENT NO. 911
ADJUSTMENT NO. 912
ADJUSTMENT NO. 913
ADJUSTMENT NO. 914
ADJUSTMENT NO. 915
ADJUSTMENT NO. 916
ADJUSTMENT NO. 917
ADJUSTMENT NO. 918
ADJUSTMENT NO. 919
ADJUSTMENT NO. 920
ADJUSTMENT NO. 921
ADJUSTMENT NO. 922
ADJUSTMENT NO. 923
ADJUSTMENT NO. 924
ADJUSTMENT NO. 925
ADJUSTMENT NO. 926
ADJUSTMENT NO. 927
ADJUSTMENT NO. 928
ADJUSTMENT NO. 929
ADJUSTMENT NO. 930
ADJUSTMENT NO. 931
ADJUSTMENT NO. 932
ADJUSTMENT NO. 933
ADJUSTMENT NO. 934
ADJUSTMENT NO. 935
ADJUSTMENT NO. 936
ADJUSTMENT NO. 937
ADJUSTMENT NO. 938
ADJUSTMENT NO. 939
ADJUSTMENT NO. 940
ADJUSTMENT NO. 941
ADJUSTMENT NO. 942
ADJUSTMENT NO. 943
ADJUSTMENT NO. 944
ADJUSTMENT NO. 945
ADJUSTMENT NO. 946
ADJUSTMENT NO. 947
ADJUSTMENT NO. 948
ADJUSTMENT NO. 949
ADJUSTMENT NO. 950
ADJUSTMENT NO. 951
ADJUSTMENT NO. 952
ADJUSTMENT NO. 953
ADJUSTMENT NO. 954
ADJUSTMENT NO. 955
ADJUSTMENT NO. 956
ADJUSTMENT NO. 957
ADJUSTMENT NO. 958
ADJUSTMENT NO. 959
ADJUSTMENT NO. 960
ADJUSTMENT NO. 961
ADJUSTMENT NO. 962
ADJUSTMENT NO. 963
ADJUSTMENT NO. 964
ADJUSTMENT NO. 965
ADJUSTMENT NO. 966
ADJUSTMENT NO. 967
ADJUSTMENT NO. 968
ADJUSTMENT NO. 969
ADJUSTMENT NO. 970
ADJUSTMENT NO. 971
ADJUSTMENT NO. 972
ADJUSTMENT NO. 973
ADJUSTMENT NO. 974
ADJUSTMENT NO. 975
ADJUSTMENT NO. 976
ADJUSTMENT NO. 977
ADJUSTMENT NO. 978
ADJUSTMENT NO. 979
ADJUSTMENT NO. 980
ADJUSTMENT NO. 981
ADJUSTMENT NO. 982
ADJUSTMENT NO. 983
ADJUSTMENT NO. 984
ADJUSTMENT NO. 985
ADJUSTMENT NO. 986
ADJUSTMENT NO. 987
ADJUSTMENT NO. 988
ADJUSTMENT NO. 989
ADJUSTMENT NO. 990
ADJUSTMENT NO. 991
ADJUSTMENT NO. 992
ADJUSTMENT NO. 993
ADJUSTMENT NO. 994
ADJUSTMENT NO. 995
ADJUSTMENT NO. 996
ADJUSTMENT NO. 997
ADJUSTMENT NO. 998
ADJUSTMENT NO. 999
ADJUSTMENT NO. 1000


APN 405-11-053
EDGE OF PAVEMENT
EXISTING MOTOR CONTROL CENTER
EXISTING ACCESS GATE
EXISTING CHLORINE STORAGE ENCLOSURE
EXISTING EMERGENCY SHOWER
EXISTING DROP INLET
EXISTING MAN GATE
EXISTING BLDG
APN 405-11-052B
APN 405-11-057
GOLDEN WAY
WATERWORKS
SITE PLAN
C-100

DESIGN CRITERIA:

1. APPLICABLE CODE: 2006 INTERNATIONAL BUILDING CODE (IBC)
2. REFER TO THE SPECIFICATIONS FOR ADDITIONAL AND SPECIFIC STRUCTURE LOADINGS AND REQUIREMENTS

GENERAL INFORMATION:

1. ALL CONSTRUCTION SHALL CONFORM TO THE LATEST EDITION OF THE IBC
2. FOR ABBREVIATIONS NOT LISTED, SEE ASME Y14.38 "ABBREVIATIONS AND ACRONYMS" PUBLICATION AS DISTRIBUTED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
3. **DESIGN DETAILS ARE INTENDED TO BE TYPICAL AND SHALL APPLY TO ALL SIMILAR SITUATIONS OCCURRING THROUGHOUT THE PROJECT, WHETHER OR NOT THEY ARE KEYED IN EACH LOCATION. CONSULT THE ENGINEER FOR REVIEW PRIOR TO CONSTRUCTION**
4. VERIFY ALL OPENING DIMENSIONS IN WALLS, SLABS, AND DECKS WITH THE ARCHITECTURAL, MECHANICAL, HVAC AND ELECTRICAL DRAWINGS
5. **FOR NUMBER, TYPE, SIZE, ARRANGEMENT, AND/OR LOCATION, OF EQUIPMENT PADS SEE ARCHITECTURAL, MECHANICAL, ELECTRICAL, HVAC AND PLUMBING DRAWINGS. COORDINATE WITH EQUIPMENT SUPPLIER PRIOR TO PLACING SLABS, WALLS AND FOUNDATIONS. COORDINATE ALL MECHANICAL, ELECTRICAL, AND HVAC PIPING OR DUCTWORK WITH MECHANICAL, ELECTRICAL AND HVAC DRAWINGS.**
6. NO STRUCTURAL MEMBERS SHALL BE CUT FOR PIPES, DUCTS, ETC. UNLESS SPECIFICALLY DETAILED OR APPROVED IN WRITING BY THE ENGINEER
7. **SPECIAL INSPECTION IS REQUIRED IN ACCORDANCE WITH** IBC SECTION 1704 AND CHAPTER 17 ON THE FOLLOWING PORTIONS OF THE WORKS: CONCRETE PLACEMENT, REINFORCING STEEL PLACEMENT, EMBEDS AND BOLTS INSTALLED IN CONCRETE, BOLTS INSTALLED ADHESIVE ANCHORS

FOUNDATIONS

1. **IN ACCORDANCE WITH THE CITY OF SEDONA THE FOUNDATIONS HAVE BEEN DESIGNED FOR ALLOWABLE BEARING VALUES OF 1,500 PSF.**
2. FOOTINGS SHALL EXTEND 4'-0" INTO STABLE UNDISTURBED NATURAL SOIL.
3. NO BACKFILL SHALL BE PLACED BEHIND WALLS UNTIL THE CONCRETE HAS ATTAINED 100% OF IT'S SPECIFIED COMPRESSIVE STRENGTH.
4. THE CONTRACTOR SHALL PROVIDE THE ENGINEER AT LEAST 72 HOURS NOTICE FOLLOWING EXCAVATION FOR FOUNDATIONS AND PRIOR TO THE PLACEMENT OF FORMWORK, REINFORCING STEEL AND CONCRETE.

EPOXY ANCHORS

1. EPOXY ANCHORS AND EPOXY DOWELS SHALL BE HILTI HIT-RE 500-SD UNLESS NOTED OTHERWISE. INSTALL ANCHORS IN CONFORMANCE WITH THE MANUFACTURER'S REQUIREMENTS AND ICC REPORT ESR-2322
2. SPECIAL INSPECTION IS REQUIRED PER IBC SECTION 1704 AND THE REQUIREMENTS OF THE ICC REPORT
3. THREADED RODS TO BE GALVANIZED ASTM F1554 GRADE 36, BOLTS TO BE ASTM A615
4. **CONTRACTOR SHALL VERIFY MINIMUM EDGE DISTANCE, SPACING AND THICKNESSES ARE IN ACCORDANCE WITH THE MANUFACTURER'S REQUIREMENTS PRIOR TO INSTALLING ANCHORS**
5. WHEN DRILLING HOLES IN EXISTING CONCRETE, USE CARE AND CAUTION TO AVOID CUTTING OR DAMAGING THE EXISTING REINFORCING BARS. MAINTAIN A REASONABLE CLEARANCE **BETWEEN RE-INFORCEMENT AND THE DRILLED-IN ANCHOR.** CORE DRILLED HOLES ARE NOT PERMITTED.
6. **"THE SPECIAL INSPECTOR MUST BE PRESENT" ON THE JOB SITE CONTINUOUSLY DURING AND/OR INSTALLATION TO VERIFY ANCHOR TYPE, ANCHOR DIMENSIONS, HOLE CLEANLINESS, EMBEDMENT DEPTH, CONCRETE TYPE, CONCRETE COMPRESSIVE STRENGTH, DRILL BIT DIAMETER, HOLE DEPTH, EDGE DISTANCE, AND/OR SPACING, CONCRETE TREATMENT, AND ADHESIVE INJECTION.**

CONCRETE:

1. CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH AT 28 DAYS OF f'c=3,000 psi AS SPECIFIED IN SECTION 03300
2. THE CONTRACTOR SHALL SUBMIT THE CONCRETE MIX DESIGNS TO THE ENGINEER FOR **REVIEW PRIOR TO USE**
3. THE CONTRACTOR SHALL NOTIFY THE ENGINEER 48 HOURS PRIOR TO THE PLACEMENT OF CONCRETE
4. HORIZONTAL CONSTRUCTION JOINTS SHALL BE PREPARED TO EXPOSE CLEAN, SOUND, AGGREGATE AGGREGATES OVER THE ENTIRE JOINT INTERFACE
5. PLACEMENT OF PIPES, CONDUITS OR OTHER EMBEDDED ITEMS IN THE CONCRETE SHALL BE IN ACCORDANCE WITH THESE DRAWINGS OR SHALL BE APPROVED BY THE ENGINEER
6. NO ALUMINUM OR ANY OTHER MATERIAL CONTAINING ALUMINUM OR ANY OTHER MATERIAL HARMFUL TO CONCRETE SHALL BE EMBEDDED IN THE CONCRETE
7. ALL DIMENSIONS SHOWN FOR LOCATION OF REINFORCING STEEL, PRE-TIE SIZE OF BAR AND DENOTE MEAN COVERAGE. SLABS ON GRADE SHALL HAVE POINT DOWELS AT MID DEPTH UNLESS NOTED OTHERWISE
8. CONCRETE SHALL BE MIXED, MUNICIPERED IN ACCORDANCE WITH ASTM C94
9. **THE REQUIREMENTS FOR CONCRETE TIMES, PLACING, TESTING AND CURING ARE CONTAINED IN ISC SECTIONS 1905 - 1908**
10. PORTLAND CEMENT SHALL CONFORM TO ASTM C150 TYPE II. AGGREGATE SHALL CONFORM TO ASTM C33
11. CONTINUOUS WATERSTOP AS SPECIFIED SHALL BE INSTALLED IN ALL CONSTRUCTION JOINTS IN WALLS OF WATER HOLDING BASINS, CHANNELS, AND BELOW GRADE STRUCTURES EXCEPT WHERE SPECIFICALLY NOTED OTHERWISE

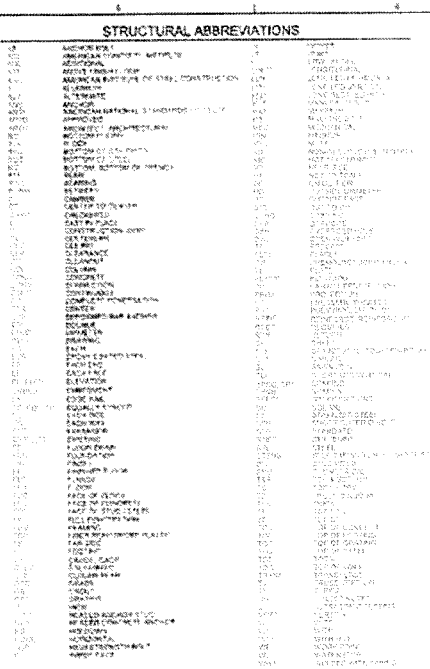
CONCRETE REINFORCING

1. **PROVIDE REINFORCING IN ALL SECTIONS OF CONCRETE AS INDICATED BY THE DETAILS ON THE DRAWINGS OR BY THE SPECIFICATIONS. IF SUCH REINFORCING IS NOT SHOWN IN THE DRAWINGS OR SPECIFICATIONS, MINIMUM REQUIREMENTS SHALL BE MET AS NOTED BELOW.**
2. CLEARANCE FOR REINFORCEMENT BARS: UNLESS SHOWN OTHERWISE, SHALL BE CAST AGAINST EARTH 3", ALL OTHER CONCRETE SURFACES #5 BAR OR SMALLER 1 1/2", #6 BAR OR LARGER 2"
3. **ALL BENDS, UNLESS OTHERWISE SHOWN, SHALL BE TO DEGREE NO. 3 STANDARD HOOKS**
4. **PROVIDE A MINIMUM OF TWO VERTICAL DOWELS AT WALL ENDS, CORNERS AND INTERSECTIONS WITH SIZE TO MATCH TYPICAL VERTICAL REINFORCING STEEL SHOWN.**
5. ALL REINFORCING BE TIED AND LAPS, UNLESS OTHERWISE NOTED, SHALL SATISFY THE FOLLOWING MINIMUM REQUIREMENTS:

CONCRETE DESIGN STRENGTH = 4,000 PSI		GRADE 60 REINF STEEL				
LAP SPLICE LENGTH						
BAR SIZE		#3	#4	#5	#6	#7
SPACING C-C	TOP BAR *	24"	32"	40"	47"	73"
	OTHER BAR	18"	25"	31"	37"	54"

*** TOP BARS SHALL BE DEFINED AS ANY HORIZONTAL BARS PLACED SUCH THAT MORE THAN 12" OF CONCRETE IS CAST IN THE MEMBER BELOW THE BAR. FOR ANY SINGLE POUR, HORIZONTAL WALL BARS ARE CONSIDERED TOP BARS.**

STRUCTURAL ABBREVIATIONS



PREPARED AND SEALED BY
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
JOSHUA A. SOLLIDAY
EXPIRES: 06/30/2015

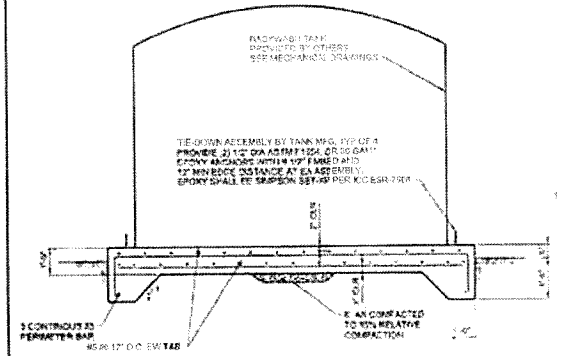
WATERWORKS

ORIGINAL IN COLOR
ARCHITECTURAL / CIVIL / STRUCTURAL / MECHANICAL / ELECTRICAL / PLUMBING / FIRE PROTECTION

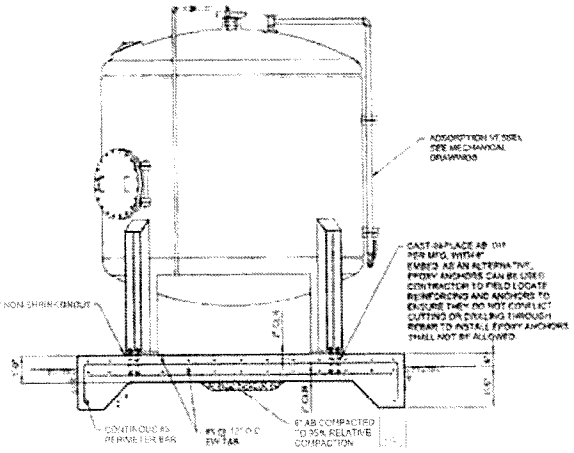
STRUCTURAL
NOTES AND ABBREVIATIONS

DATE: DECEMBER 2014
DRAWN BY: KJM
CHECKED BY: JAS
S-001
SHEET 1 OF 1
SCALE: 1:1

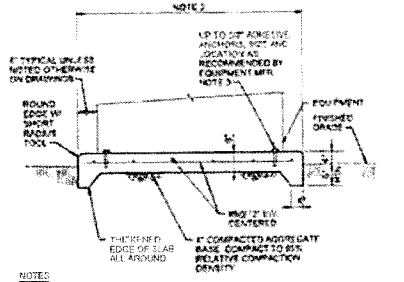
REUSE OF DOCUMENTS: THIS DRAWING AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF SERVICE, IS THE PROPERTY OF WESTERN ENGINEERING, LLC. (WE) AND SHALL NOT BE USED IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WESTERN ENGINEERING, LLC.



1 BACKWASH TANK SLAB



2 ADSORPTION VESSEL SLAB



NOTES

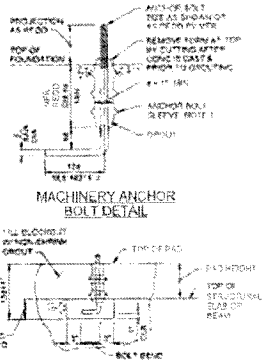
1. SIZE, SIZE, NUMBER, TYPE, LOCATION, AND THREAD PROJECTION OF THE ANCHOR BOLTS SHALL BE DETERMINED BY THE EQUIPMENT MANUFACTURER AND SHALL BE AS APPROVED BY THE ENGINEER. ANCHOR BOLTS SHALL BE HELD IN POSITION WITH A ONE PIECE TEMPLATE MATCHING THE BASE PLATE WHILE PAD IS BEING POURED
2. EQUIPMENT PAD SIZE PER DRAWINGS. WHERE PAD SIZE IS NOT SHOWN, SIZE TO FIT EQUIPMENT
3. IF ANCHOR BOLTS ARE CALLED OUT FOR ON DRAWINGS, PROVIDE ANCHOR BOLTS PER DTL TH S SHEET IN LIEU OF ADHESIVE ANCHORS
4. ANCHOR BOLT LOCATIONS SHALL BE WITHIN 4 INCH OF THE FINAL LOCATION RECOMMENDED FOR EQUIPMENT. IN CASE OF EQUIPMENT PAD SHALL BE REMOVED AND RE-CONSTRUCTED
5. EQUIPMENT BASES SHALL BE INSTALLED LEVEL, UNLESS SPECIFIED OTHERWISE

3 TYPICAL EQUIPMENT SLAB

NOTES

1. CONCRETE SAME DAY AS POUR AS SOON AS SPALLING MAY NOT OCCUR
2. CONTRACTOR SHALL USE STRING LINE OR OTHER POSITIVE MEANS TO PLACE REINFORCING AND LOCATE SAWCUT
3. BREAK REBAR AND ADD SPLICE BARS SIMILAR AT FOUR SIDES

4 SLAB ON GRADE JOINT-TYPE A



NOTES

1. ANCHOR BOLT SLEEVE BY THE ANCHOR BOLT SUPPLY COMPANY SPECIFICATION, OR APPROVED EQUAL
2. AS WHERE MANUFACTURER VERIFIES NO BOLT PULLOUT AT DISTANCE REQUIRED

ANCHOR BOLT DETAILS

ORIGINALLY SIGNED AND SEALED BY

KRISTOPHER RUSSELL DIPIETRO
REGISTERED PROFESSIONAL ENGINEER (CHEM)

JEREMY A. FELLOWS
21695
IN 10/31/17

WATERWORKS

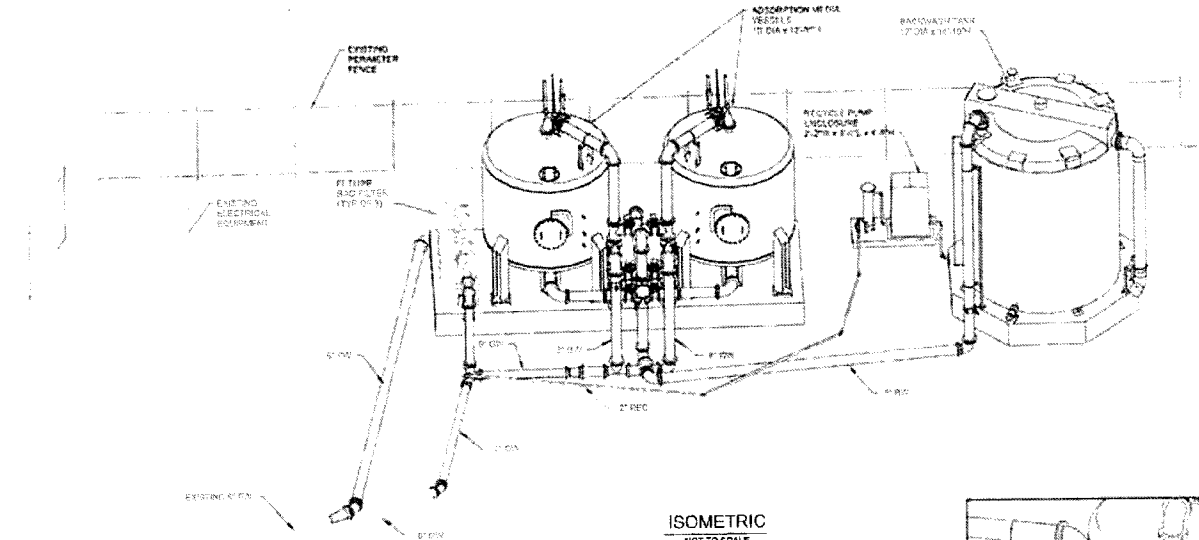
STRUCTURAL

DETAILS

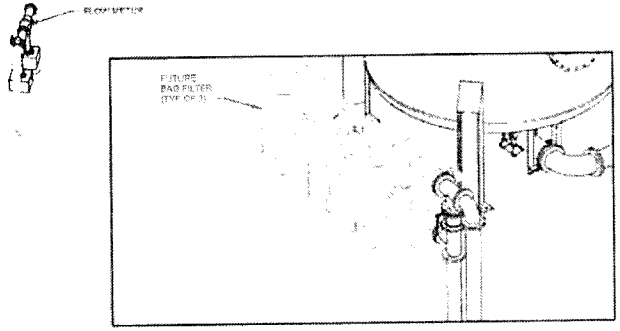
OCTOBER 2017

S-30

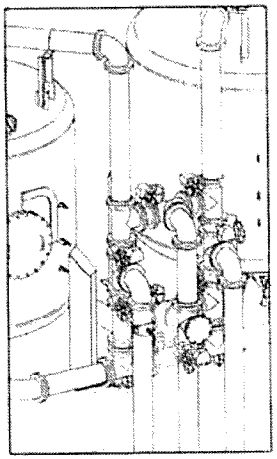
REUSE OF DOCUMENTS



ISOMETRIC
NOT TO SCALE



BAG FILTER
ISOMETRIC
NOT TO SCALE

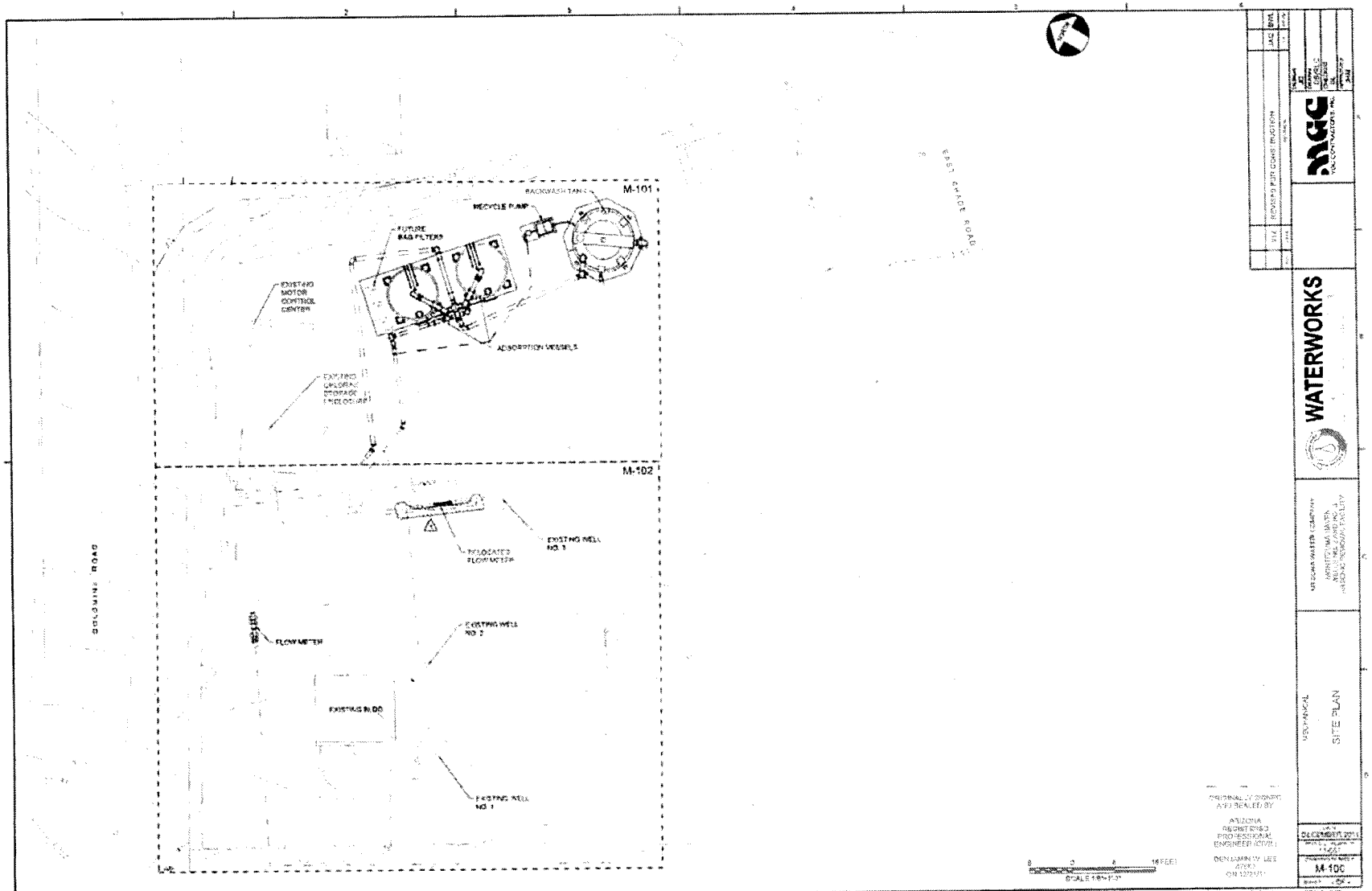


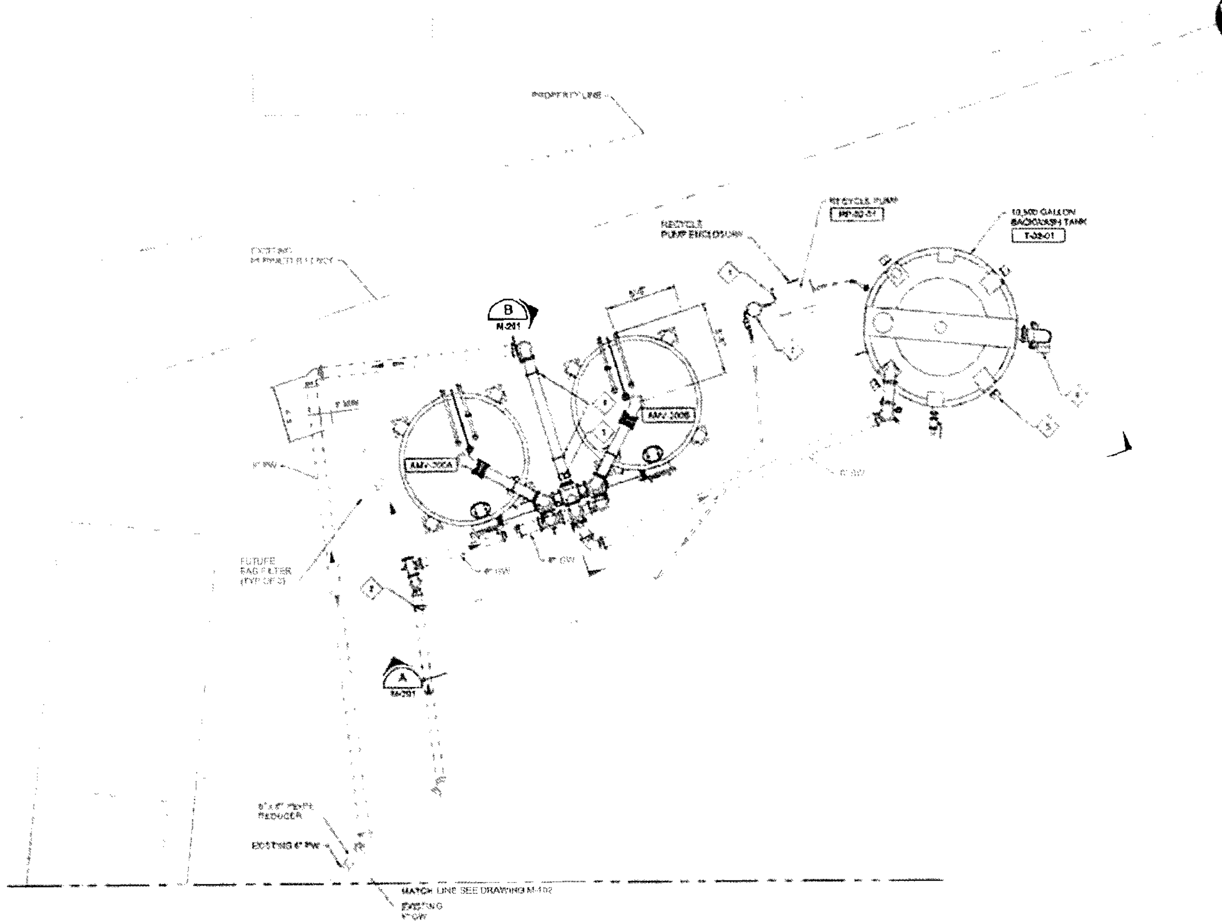
VALVE TREE
ISOMETRIC
NOT TO SCALE

WATERWORKS

ISOMETRIC

M-001


M-101
M-102
RECYCLE PUMP
FUTURE
EXISTING
MOTOR
CONTROL
CENTER
ADSORPTION VESSELS
EXISTING
CHLORINE
STORAGE
EXISTING WELL
NO. 3
RELOCATED
FLOW METER
EXISTING WELL
NO. 2
FLOW METER
EXISTING WELL
NO. 1
GOLDWING ROAD
EAST CHASE ROAD
0
2
4
8 FEET
SCALE: 1/8"=1'-0"
WATERWORKS
SITE PLAN
M-100



NOTES

1. PIPE SUPPORTS PER DETAIL 8 ON M-301
2. SERVICE SADDLE CONNECTIONS PER DETAIL 4 ON M-301
3. PRESSURE GAUGE MOUNTING PER DETAIL 5 ON M-301
4. PIPE SUPPORT PER DETAIL 12 ON M-302
5. INSTALL PER MANUFACTURER'S INSTRUCTIONS
6. INSTALL STAINLESS STEEL MESH
7. INSTALL BAG FILTER, MODEL OR EQUAL, WITH FLANGED INLET/OUTLET, BAG SIZE

ORIGINALLY SIGNED AND SEALED BY

ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)

BENJAMIN W. LEE

MGC CONTRACTORS, INC.

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY

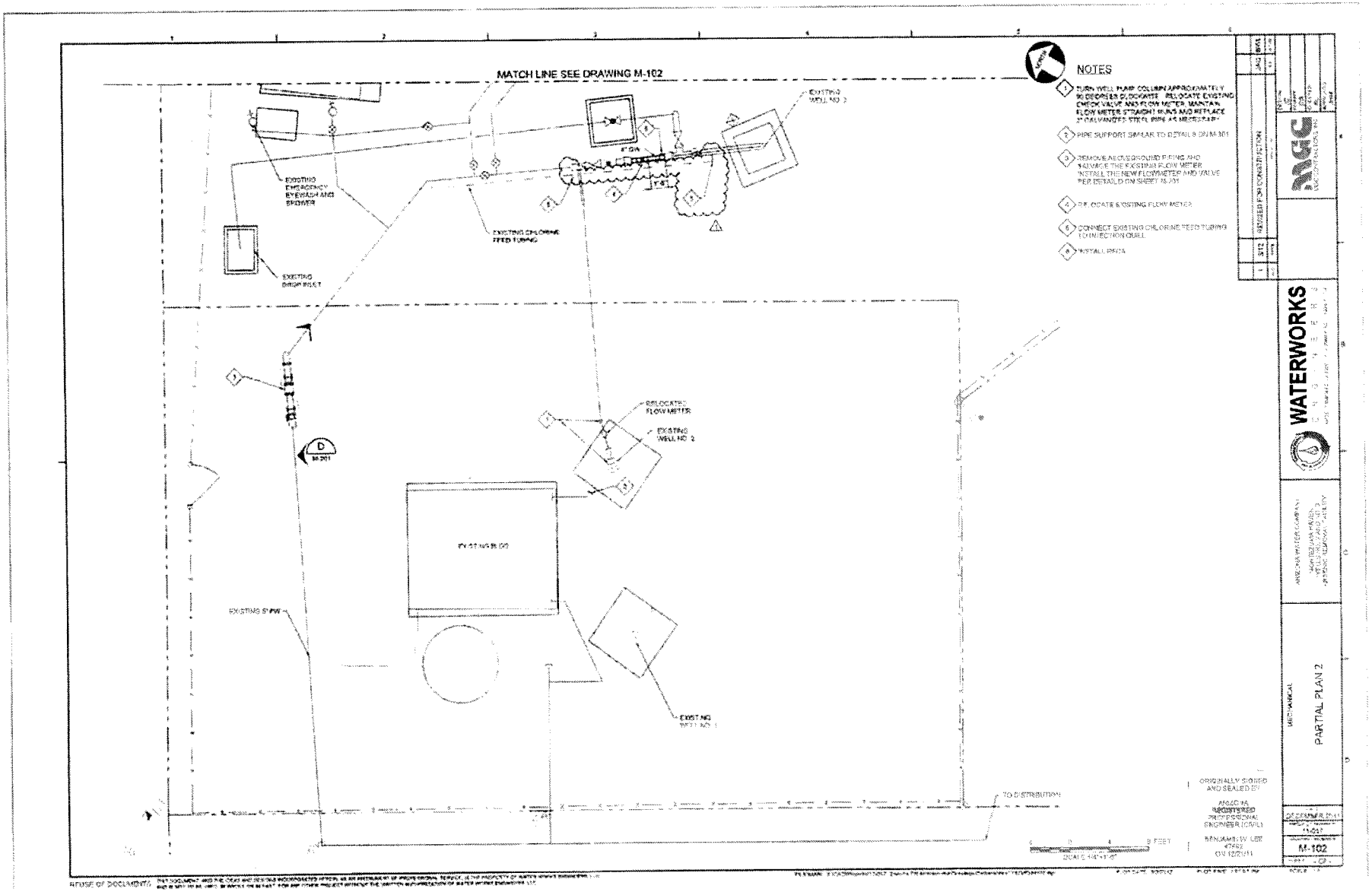
WELLS NO. 2 AND NO. 3 ARSENIC REMOVAL FACILITY

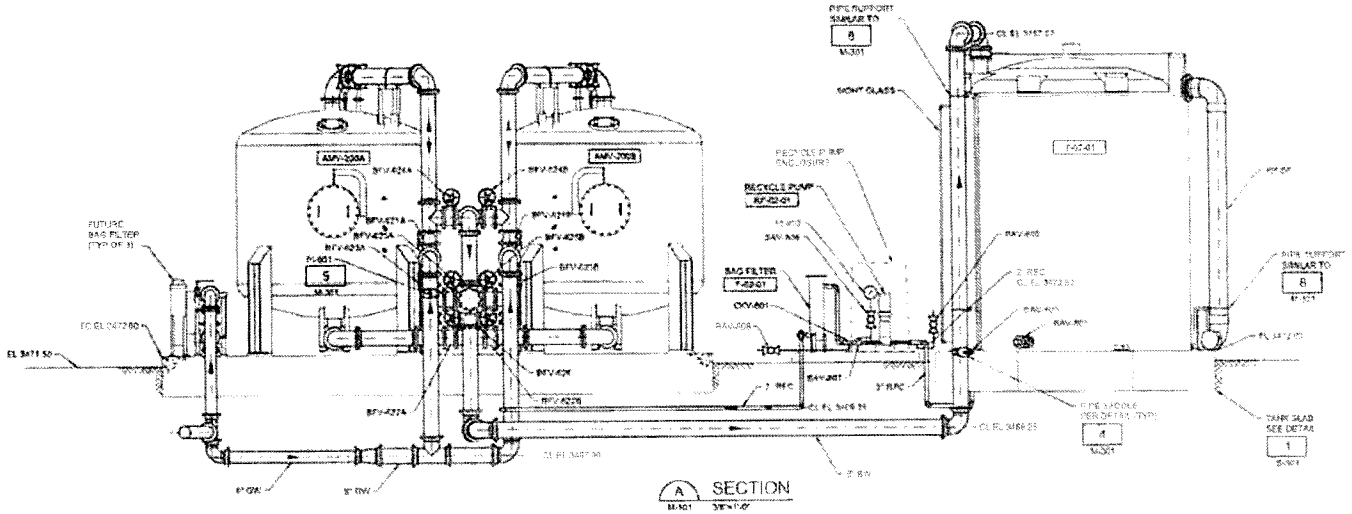
MECHANICAL

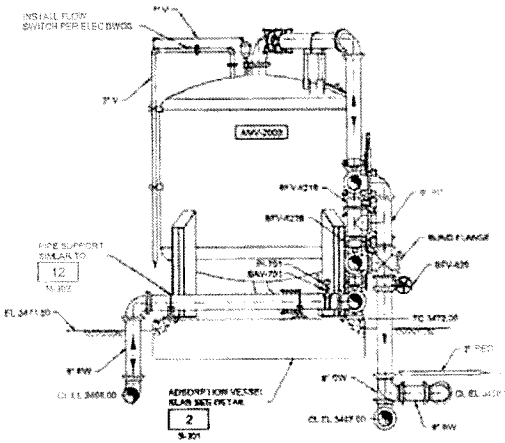
PARTIAL PLAN 1

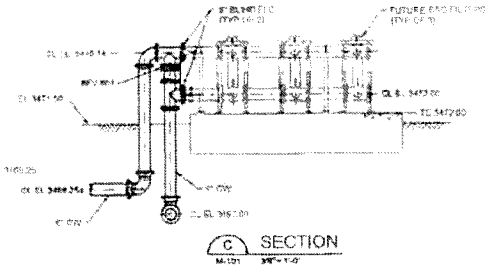
M-101

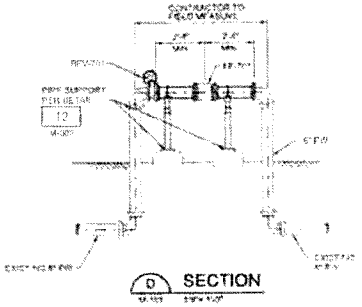
REUSE OF DOCUMENTS


MATCH LINE SEE DRAWING M-102
NOTES
1 TURN WELL PUMP COLUMN APPROXIMATELY 90 DEGREES CLOCKWISE. RELOCATE EXISTING CHECK VALVE AND FLOW METER. MAINTAIN FLOW METER STRAIGHT RUNS AND REPLACE 8" GALVANIZED STEEL PIPE AS NECESSARY
2 PIPE SUPPORT SIMILAR TO DETAIL 8 ON M-301
3 REMOVE ABOVEGROUND PIPING AND SALVAGE THE EXISTING FLOW METER. INSTALL THE NEW FLOWMETER AND VALVE PER DETAILD ON SHEET M-301
4 RELOCATE EXISTING FLOW METER
5 CONNECT EXISTING CHLORINE FEED TUBING TO INJECTION QUILL
6 INSTALL PIPE
EXISTING EMERGENCY EYEWASH AND SHOWER
EXISTING CHLORINE FEED TUBING
EXISTING BRIDGE INLET
RELOCATED FLOW METER
EXISTING WELL NO. 2
EXISTING SHOW
EXISTING WELL NO. 1
TO DISTRIBUTION
WATERWORKS
PARTIAL PLAN 2
M-102





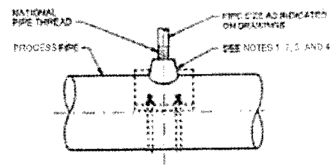




WATERWORKS

SECTIONS

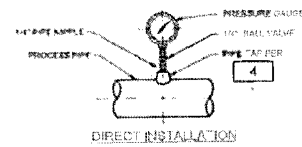
M-201



PIPE TAPS

NOTES:
1. FOR STEEL, GALVANIZED STEEL, AND PVC 2 1/2" AND SMALLER USE A BUSHING IN A TEE.
2. FOR DUCTILE IRON, ALL SIZES USE SERVICE SADDLE.
3. FOR NEW STEEL AND STAINLESS STEEL PIPES 3" AND LARGER, AND PRESSURE VESSELS, USE THRED-O-LET AS SHOWN.
4. FOR EXISTING PVC, STEEL AND STAINLESS STEEL PIPES 3" AND LARGER, USE SERVICE SADDLE.

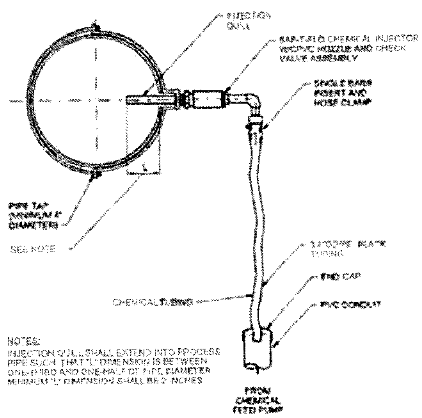
4 PIPE TAPS
M-TYP NTS



DIRECT INSTALLATION

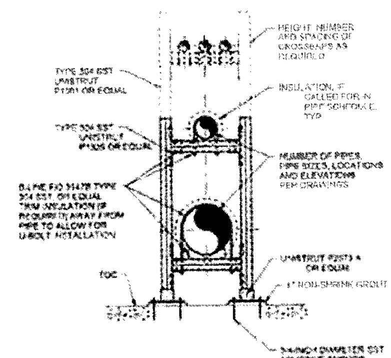
NOTES:
UNLESS NOTED OTHERWISE ON THE DRAWINGS
1. USE DIRECT INSTALLATION FOR POTABLE WATER, RAW WATER, RECLAIMED WATER PROCESS PIPES AND AIR PIPING.
2. USE DIAPHRAGM SEAL INSTALLATION FOR SEWAGE, SLUDGE, CHEMICAL AND ALL PROCESS PIPES THAT ARE NOT WATER OR AIR.
3. ALL PIPE NIPPLES TO BE TYPE 304 STAINLESS STEEL.

5 PRESSURE GAUGE MOUNTING
M-TYP NTS



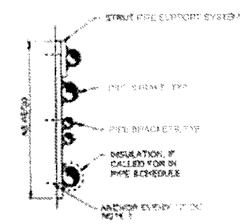
NOTES:
INJECTION QUILL SHALL EXTEND INTO PROCESS PIPE SUCH THAT "L" DIMENSION IS BETWEEN ONE-THIRD AND ONE-HALF OF PIPE DIAMETER. MINIMUM "L" DIMENSION SHALL BE 2 INCHES.

7 CHEMICAL INJECTION POINT
M-TYP NTS

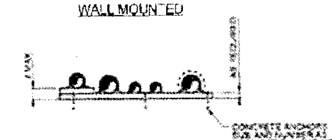


8 FIXED PIPE SUPPORT RACK
M-TYP NTS

NOTE:
USE NEOPRENE SLEEVE ON COPPER AND PVC PIPING AT STRAPS AND BRACKETS



WALL MOUNTED



FLOOR MOUNTED

NOTE:
1. ATTACH TO WALL WITH SST ANCHORS. 3/8" DIAMETER MIN. COORDINATED WITH WALL CONSTRUCTION.

9 PIPE SUPPORTS
M-TYP NTS

ORIGINALLY SIGNED AND SEALED BY
ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)
BENJAMIN W. LEE
47962
DECEMBER 2017

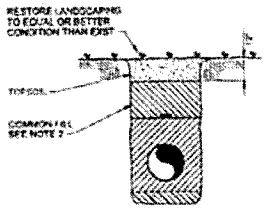
WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
MONTEZUMA WATER WELLS NO. 2 AND NO. 3
ARSENIC REMOVAL FACILITY

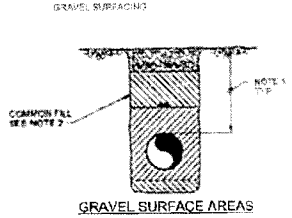
TYPICAL DETAILS I

DECEMBER 2017
M-301

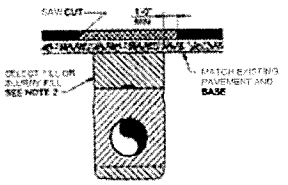
REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS LLC.



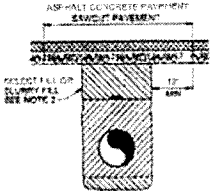
LANDSCAPE AREAS



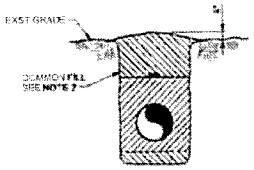
GRAVEL SURFACE AREAS



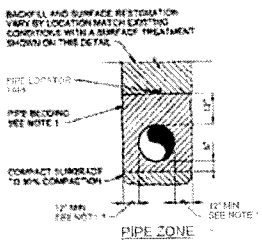
EXISTING PAVED AREA



NEW PAVED AREA



UN-SURFACED AREAS WITHOUT LANDSCAPING



PIPE ZONE

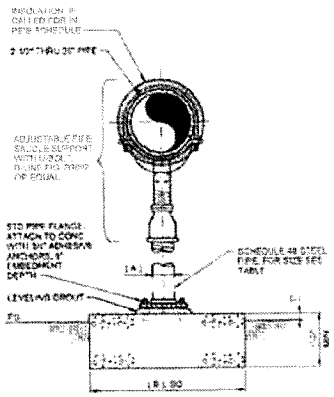
(TYPICAL ALL SECTIONS)

NOTES:

1. PIPE BEDDING SHALL BE GRANULAR BEDDING FOR ALL DUCTILE IRON OR STEEL PIPE AND SAND FOR ALL OTHER PIPE. COMPACT TO 90% RELATIVE COMPACTION. ALTERNATIVELY, SLURRY FILL MAY BE USED FOR PIPE BEDDING. IF SLURRY FILL IS USED, TAKE PRECAUTIONS TO PREVENT PIPE FLOATING. ALSO, IF SLURRY FILL IS USED, TRENCH WIDTH CAN BE NARROWED TO 6-INCHES OUTSIDE OF PIPE WALL ON EACH SIDE.
2. COMPACT ALL TRENCH BACK FILL (COMMON FILL AND SELECT FILL) TO 95% COMPACTION MORE THAN 2 FEET BELOW GRADE; 90% COMPACTION LESS THAN 2 FEET BELOW GRADE.
3. UNLESS NOTIFIED OTHERWISE, PROVIDE MINIMUM 3-FEET OF COVER OVER ALL BURIED PIPELINES.

11 TYPICAL TRENCH SECTIONS

M-TYP NTS



ADJUSTABLE HEIGHT SADDLE PIPE SUPPORT

12

M-TYP NTS

DIMENSION TABLE		
PIPE SIZE		
2-1/2"	2-1/2"	2'-0"
3"	3-1/2"	2'-0"
4"	4"	2'-0"
6"	6"	2'-0"
8"	8"	2'-0"
10"	10"	2'-0"
12"	12"	2'-0"
14"	14"	2'-0"
16"	16"	2'-0"
18"	18"	2'-0"
20"	20"	2'-0"
24"	24"	2'-0"
30"	30"	2'-0"
36"	36"	2'-0"

ORIGINALLY SIGNED AND SEALED BY

ARIZONA REGISTERED PROFESSIONAL ENGINEER (CIVIL)

BENJAMIN W. LEE

(DATE)

ON 12/2/2011

MCG

WATERWORKS

MECHANICAL

TYPICAL DETAILS 2

DECEMBER 2011

M-302

SHEET OF

REUSE OF DOCUMENTS

ELECTRICAL SPECIFICATIONS AND GENERAL NOTES

1. PERFORM ALL WORK IN ACCORDANCE WITH THE CURRENTLY ADOPTED ISSUE OF THE NATIONAL ELECTRICAL CODE (NEC), STATE AND LOCAL REGULATIONS, AND OTHER ORDINANCES HAVING JURISDICTION.
2. CONTRACTOR SHALL COORDINATE WITH THE ELECTRIC UTILITY COMPANY TO DETERMINE THE REQUIREMENTS TO PROVIDE THE ELECTRIC SERVICE FOR THE FACILITY.
3. PROVIDE ALL LABOR, MATERIALS AND EQUIPMENT AS SHOWN AND AS REQUIRED FOR THE COMPLETION OF THE WORK.
4. THE LAYOUT OF THE CONTRACT DRAWINGS IS DIAGRAMMATIC. IT IS NOT THE INTENT OF THESE PLANS AND/OR SPECIFICATIONS TO SHOW EVERY DETAIL OF CONSTRUCTION. THE CONTRACTOR SHALL FURNISH AND INSTALL ALL ITEMS FOR A COMPLETE ELECTRICAL SYSTEM AND PROVIDE ALL REQUIREMENTS NECESSARY FOR EQUIPMENT TO BE PLACED IN PROPER WORKING ORDER.
5. CONTRACTOR SHALL VISIT THE JOBSITE PRIOR TO SUBMITTING THEIR BID TO VERIFY ALL EXISTING CONDITIONS, LOCATIONS, DIMENSIONS AND QUANTITIES AS SHOWN AND/OR AS SPECIFIED.
6. EQUIPMENT, MATERIAL, AND WORKMANSHIP SHALL BE GUARANTEED FREE FROM DEFECTS FOR ONE YEAR FROM THE DATE OF ACCEPTANCE.
7. WORK SHALL BE PERFORMED BY A LICENSED COMMERCIAL CONTRACTOR IN A FIRST-CLASS WORKMANLIKE MANNER AND ALL SYSTEMS SHALL BE TESTED IN THE PRESENCE OF THE OWNER TO DEMONSTRATE THAT EQUIPMENT IS WORKING PROPERLY. DEFECTS SHALL BE CORRECTED AT NO COST TO THE OWNER. EQUIPMENT REQUIRING ADJUSTMENTS OR CALIBRATIONS FOR PROPER OPERATION SHALL BE SET BY THE CONTRACTOR AS NECESSARY, SPECIFIED OR DIRECTED BY THE OWNER.
8. ELECTRICAL EQUIPMENT, DEVICES AND MATERIAL SHALL BE NEW, UL LISTED FOR THE INTENDED USE. ALL ELECTRICAL PANELS SHALL BE ASSEMBLED BY A UL 508 CERTIFIED FACILITY AND SHALL BE SO LABELED.
9. ELECTRICAL CONTRACTOR SHALL COORDINATE WITH OTHER TRADES TO DETERMINE ELECTRICAL REQUIREMENTS, SPACES AND ADEQUATE CLEARANCES WITH RESPECT TO OTHER EQUIPMENT IN THE FACILITY, AND PROVIDE ANY RACEWAY, WIRING, OR CONNECTIONS REQUIRED FOR PROPER OPERATION.
10. WIRING DEVICES SHALL BE NEMA WD-1 HEAVY DUTY INDUSTRIAL GRADE HUBBELL, LEVITON OR EQUAL. RECEPTACLES SHALL HAVE NYLON OR POLYCARBONATE FACES AND BE LABELED MEETING FEDERAL SPECIFICATIONS. UNLESS NOTED OTHERWISE, RECEPTACLES SHALL BE 120V, 15A DUPLEX AND SHALL BE GROUND FAULT TYPE. SWITCHES SHALL BE 20A 120V RATED WITH METAL WEATHERPROOF [illegible] SWITCH COVER, HUBBELL CIPTCR OR EQUAL.
11. CONDUCTORS SHALL BE STRANDED COPPER WIRE (LIGHTING AND RECEPTACLE CIRCUITS MAY BE SOLID). ALL CONDUCTOR INSULATION SHALL BE TYPE THHN/THWN OR XHHW OR XHHW-2. IDENTIFY EACH CONDUCTOR AT EACH TERMINATION POINT WITH HEAT SHRINK OR PLASTIC SLEEVE TYPE WIRE MARKER PERMANENTLY MACHINE IMPRINTED WITH A UNIQUE COMBINATION OF NUMBERS AND LETTERS.
12. EQUIPMENT LUGS, CONNECTORS AND TERMINATIONS, INCLUDED IN PANELS, SWITCHES, STARTERS, CONTACTORS AND CIRCUIT BREAKERS SHALL BE SUITABLE FOR USE WITH CONDUCTORS OPERATING AT 75 DEGREES C.
13. ALL CONDUCTORS SHALL BE IN APPROVED RACEWAY. RACEWAYS FOR THE FOLLOWING:
    GALVANIZED RIGID STEEL (GRS): WHERE CONDUIT BENDS UPWARD FROM UNDERGROUND TO ABOVE GROUND, USE GRS ELBOW WITH AN APPROVED PVC TO GRS COUPLER. GRS CONDUIT SHALL EXTEND A MINIMUM OF 24" BELOW GRADE. USE GRS IN ALL AREAS WHERE CONDUIT MAY BE EXPOSED TO PHYSICAL DAMAGE. USE THREADED STEEL FITTINGS. THREADS OF CONDUIT INSTALLED OUTDOORS SHALL BE COATED WITH ZINC RICH PAINT PRIOR TO MAKING UP. PROTECT UNDERGROUND METAL CONDUIT WITH HALF LAPPED 10 MIL "SCOTCHWRAP" 50 TAPE OR EQUAL.

    INTERMEDIATE METAL CONDUIT (IMC) MAY BE USED IN SIZES 1-1/2" AND LARGER IN LIEU OF RIGID STEEL. FITTINGS AND INSTALLATION SHALL BE AS FOR RIGID STEEL.

    POLYVINYL CHLORIDE (PVC) SCHEDULE 40 SHALL BE USED BELOW FINISHED GRADE. INSTALL 24 INCHES MINIMUM BELOW FINISHED GRADE SURROUNDED BY 3 INCHES OF SAND OR SELECTED FILL FREE OF ORGANIC MATTER, STICKS, GRAVEL, ROCKS OR OTHER SHARP OBJECTS. EXCEPT THAT UNDER CONCRETE SLABS NO MINIMUM DEPTH IS REQUIRED.

    LIQUIDTIGHT FLEXIBLE METAL CONDUIT: USE TO CONNECT TO EQUIPMENT INSTALLED OUTDOORS (36 INCHES MAX LENGTH). USE STEEL FITTINGS. USE COMPRESSION TYPE CONNECTORS.
14. FITTINGS, BOXES, AND SUPPORTS SHALL BE PROVIDED AS REQUIRED TO PROVIDE A COMPLETE SYSTEM. FS AND FD BOXES SHALL BE GALVANIZED CAST IRON. LARGER BOXES SHALL BE NEMA 3R PAINTED STEEL. USE WATERTIGHT THREADED HUBS FOR ALL CONDUIT CONNECTIONS TO THE TOPS OR SIDES OF ENCLOSURES THAT DO NOT HAVE INTEGRAL THREADED HUBS.
15. PROVIDE PULL BOXES FOR UNDERGROUND ELECTRICAL CONDUITS SUCH THAT NO SINGLE CONDUIT RUN HAS BENDS IN EXCESS OF 360 DEGREES. PULL BOXES SHALL BE PRECAST CONCRETE WITH H-20 HIGHWAY RATING. WARNING TAPES WHICH SAY "WARNING-BURIED ELECTRICAL" SHALL BE PLACED IN TRENCHES ABOVE ALL UNDERGROUND ELECTRIC CONDUITS. WARNING TAPE SHALL BE METALLIC TRACEABLE TYPE.
16. FUSES SHALL BE TIME DELAY, CLASS RK-1, BUSS LPS-RK_SP, OR EQUAL. FUSES FOR MOTOR CONTROL CIRCUITS SHALL BE TIME DELAY, BUSS FNW OR EQUAL. FUSES FOR CONTROL TRANSFORMER PRIMARY SHALL BE TIME DELAY, CLASS CC, BUSS FNQ-R OR EQUAL.
17. DISCONNECT SWITCHES SHALL BE FUSED, 3 POLE WITH CLASS R FUSE CLIPS AND VOLTAGE RATING AS REQUIRED UNLESS OTHERWISE SHOWN. OUTDOOR UNITS SHALL BE WEATHERPROOF. UNITS SHALL BE HEAVY DUTY HORSEPOWER RATED, AND HAVE MEANS FOR PAD LOCKING IN THE OPEN POSITION. SWITCHES SHALL BE SQUARE D, GE OR EATON/CUTLER HAMMER.
18. DISCONNECT SWITCHES, STARTERS, PANELS AND CONTROLLERS SHALL BE LABELED WITH ENGRAVED PLASTIC LAMINATE NAMEPLATES ATTACHED WITH SCREWS.
19. PROVIDE EQUIPMENT GROUNDING CONDUCTOR IN ALL CONDUITS. SIZE WIRE PER NEC, UNLESS OTHERWISE SHOWN ON THE DRAWINGS.
20. INSULATE ALL ABOVE GRADE PIPING AND TUBING 1" AND SMALLER WITH 3/8" THICK CLOSED CELL POLYETHYLENE FOAM PIPE INSULATION OF THE APPROPRIATE SIZE TO PROVIDE FREEZE PROTECTION.
21. ALL REQUIRED SYSTEM SHUTDOWNS SHALL BE COORDINATED WITH THE OWNER AT LEAST FOUR DAYS IN ADVANCE OF THE SHUTDOWN.
22. REFER TO ARIZONA WATER COMPANY STANDARD ELECTRICAL SPECIFICATIONS FOR ADDITIONAL REQUIREMENTS. IN CASE OF CONFLICT, AWC SPECIFICATIONS TAKE PRECEDENCE OVER THESE SPECIFICATIONS.

IDENTIFIER SYMBOLS

- INSTRUMENT DEVICE IDENTIFIER
- INSTRUMENT LOOP NUMBER
- AUX PANEL IDENTIFIER
- INSTRUMENT FUNCTION IDENTIFIER

HAND SWITCH FUNCTIONS

HOA – HAND–OFF–AUTO
OCA – OPEN–CLOSE–AUTO
OO – OFF–ON
1,2 – DEVICE SELECT
OCS – OPEN–CLOSE–STOP
MA – MANUAL–AUTO
SFT–BYP – SOFT–BYPASS

EXAMPLES: HS HOA; HS 1,2

PUSHBUTTON (MOMENTARY CONTACT)

EXAMPLES: HMS

SINGLE LINE AND CONDUIT DIAGRAM SYMBOLS

- TRANSFORMER
- UTILITY COMPANY METER
- SINGLE PHASE AMMETER WITH 3 PHASE SELECTOR SWITCH AND 3 CURRENT TRANSFORMERS
- SINGLE PHASE TRANSFORMER RATED VOLTMETER WITH PHASE TO PHASE SELECTOR SWITCH (A-B, B-C, C-A) AND 2 SINGLE PHASE POTENTIAL TRANSFORMERS
- JUNCTION BOX OF SAME MATERIAL AS CONDUIT SYSTEM
- WP — SUBSCRIPT INDICATES WEATHER PROOF DEVICE
- XP — SUBSCRIPT INDICATES EXPLOSION PROOF DEVICE
- DOUBLE THROW SAFETY SWITCH RATING AND POLES PER DRAWINGS
- SYSTEM GROUND PER DRAWINGS
- COMBINATION TYPE MOTOR STARTER DISCONNECT
- 30/3 — DISCONNECT SWITCH RATING AND POLES PER DRAWINGS
- MOTOR WITH HP RATING
- MOTOR WITH INTEGRAL COMBINATION MOTOR STARTER
- FUSE
- CIRCUIT BREAKER
- 30A SIMPLEX RECEPTACLE 3 POLE 4 WIRE GROUNDING
- DUPLEX RECEPTACLE G-D – HUBBELL #GF 5262
- THERMOSTAT
- PHOTOCELL
- FACP — FIRE ALARM CONTROL PANEL
- SMOKE DETECTOR
- FIRE ALARM MANUAL PULL STATION
- FIRE ALARM HORN AND STROBE
- LIGHT SWITCH TOGGLE TYPE. 3 DENOTES 3 WAY. EX DENOTES EXPLOSIONPROOF. WP DENOTES WEATHERPROOF
- CONDUIT IDENTIFIER
- ABOVE GROUND CONDUIT
- UNDER GROUND CONDUIT

SCHEMATIC DIAGRAM SYMBOLS

- NORMALLY CLOSED CONTACT
- NORMALLY OPEN CONTACT
- RELAY COIL
- 2 WAY SOLENOID VALVE FAIL TO CLOSE
- 3 WAY SOLENOID VALVE FAIL TO EXHAUST
- OFF, ON — 2 POSITION MAINTAINED SELECTOR SWITCH
- NORMALLY OPEN MOMENTARY CONTACT PUSHBUTTON
- NORMALLY CLOSED MOMENTARY CONTACT PUSHBUTTON
- 3 POSITION MAINTAINED SELECTOR SWITCH (HAND–OFF–AUTO)
- PILOT LIGHT COLOR PER DRAWINGS
- PUSH TO TEST PILOT LIGHT COLOR PER DRAWINGS (GREEN INDICATED HERE)
- FUSE
- CIRCUIT BREAKER
- THERMAL OVERLOAD SWITCH
- NORMALLY OPEN PRESSURE SWITCH
- NORMALLY CLOSED PRESSURE SWITCH
- NORMALLY OPEN FLOW SWITCH
- NORMALLY CLOSED FLOW SWITCH
- NORMALLY OPEN TEMPERATURE SWITCH
- NORMALLY CLOSED TEMPERATURE SWITCH
- NORMALLY OPEN LEVEL SWITCH
- NORMALLY CLOSED LEVEL SWITCH
- HORN
- RESISTOR
- DIODE
- CONTROL PANEL TERMINAL BLOCK
- TERMINAL BLOCK
- NORMALLY OPEN TIME DELAY CONTACT
- NORMALLY CLOSED TIME DELAY CONTACT
- ● TERMINAL IN CONTROL CABINET

LEGEND

CR-100 — MATCHES COIL LOCATION
NC CONTACT LOCATION
TERMINAL BLOCK
NO CONTACT LOCATION
LINE NUMBER

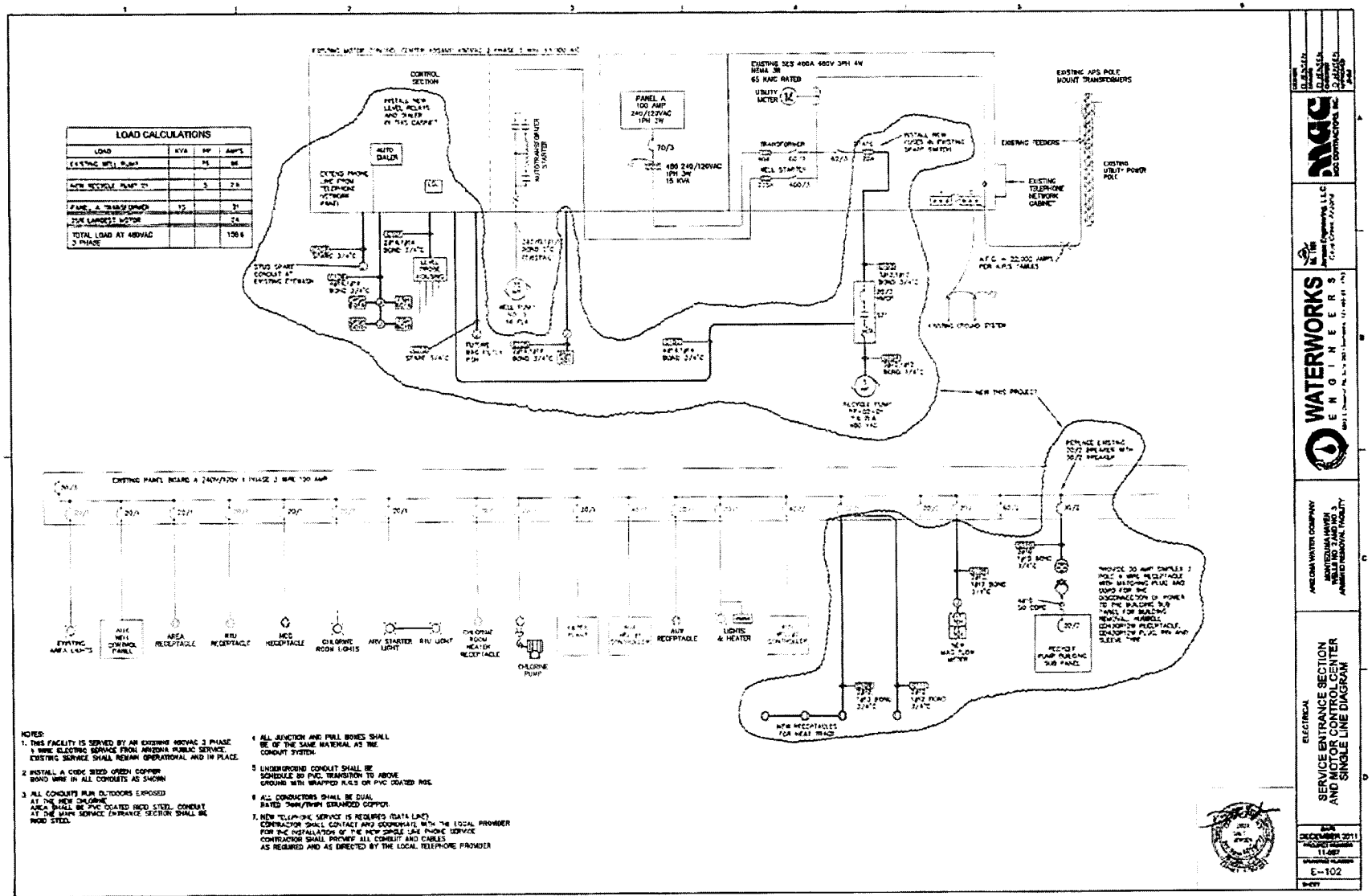
INSTRUMENT & DEVICE LETTERING TABLE

IDENTIFICATION LETTERS

	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
C	CONDUCTIVITY			CONTROL	
D	DENSITY (MASS)	DIFFERENTIAL			
E	VOLTAGE		SENSOR (PRIMARY ELEMENT)		
F	FLOW RATE	RATIO (FRACTION)			
G	GAGING		GLASS OF VIEWING DEVICE		
H	HAND				HIGH
I	CURRENT (ELECTRICAL)		INDICATE		
J	POWER	SCAN			
K	TIME OR TIME SCHEDULE	TIME RATE OF CHANGE		CONTROL STATION	
L	LEVEL		LIGHT		LOW
M	MOTOR	MOMENTARY			MIDDLE OR INTERMEDIATE
N	USER'S CHOICE		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
O	USER'S CHOICE		ORIFICE, RESTRICTION		
P	PRESSURE OR VACUUM		POINT (TEST CONNECTION)		
Q	QUANTITY	INTEGRATE OR TOTALIZE			
R	RADIATION		RECORD		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V	VIBRATION			VALVE, DAMPER, LOUVER	
W	WEIGHT OR FORCE		WELL		
X	UNCLASSIFIED		UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED
Y	EVENT, STATE OR PRESENCE			RELAY, COMPUTE, CONVERT	
Z	POSITION OR DIMENSION			DRIVER, ACTUATOR, UNCLASSIFIED FINAL CONTROL ELEMENT	

REUSE OF DOCUMENTS: THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS LLC AND IS NOT TO BE USED IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

MGC CONTRACTORS INC.
WATERWORKS ENGINEERS
ARIZONA WATER COMPANY
MONTEZUMA HAVEN WELLS NO. 2 AND NO. 3 ARSENIC REMOVAL FACILITY
ELECTRICAL
SPECIFICATIONS AND LEGEND
DECEMBER 2011
11-007
E-101



NOTES:

1. THIS FACILITY IS SERVED BY AN EXISTING 480VAC 3 PHASE 4 WIRE ELECTRIC SERVICE FROM ARIZONA PUBLIC SERVICE. EXISTING SERVICE SHALL REMAIN OPERATIONAL AND IN PLACE.
2. INSTALL A CODE SIZED GREEN COPPER BOND WIRE IN ALL CONDUITS AS SHOWN
3. ALL CONDUITS RUN OUTDOORS EXPOSED AT THE NEW CHLORINE AREA SHALL BE PVC COATED RIGID STEEL CONDUIT AT THE MAIN SERVICE ENTRANCE SECTION SHALL BE RIGID STEEL
4. ALL JUNCTION AND PULL BOXES SHALL BE OF THE SAME MATERIAL AS THE CONDUIT SYSTEM.
5. UNDERGROUND CONDUIT SHALL BE SCHEDULE 80 PVC. TRANSITION TO ABOVE GROUND WITH WRAPPED R.G.S. OR PVC COATED RGS.
6. ALL CONDUCTORS SHALL BE DUAL RATED THWN/THWN STRANDED COPPER
7. NEW TELEPHONE SERVICE IS REQUIRED (DATA LINE) CONTRACTOR SHALL CONTACT AND COORDINATE WITH THE LOCAL PROVIDER FOR THE INSTALLATION OF THE NEW SINGLE LINE PHONE SERVICE CONTRACTOR SHALL PROVIDE ALL CONDUIT AND CABLES AS REQUIRED AND AS DIRECTED BY THE LOCAL TELEPHONE PROVIDER

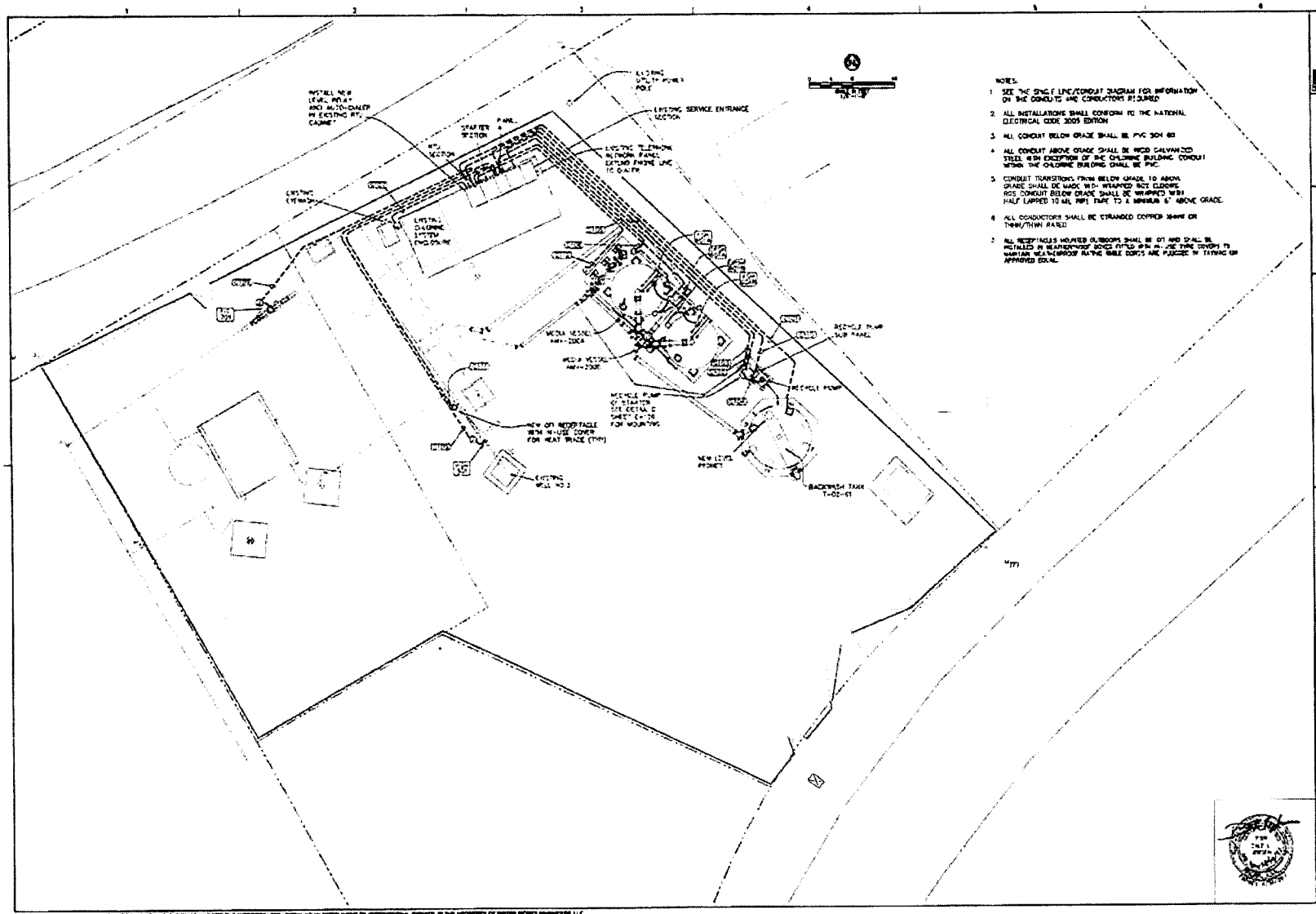
REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS L.L.C. AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
MONTEZUMA HAVEN WELLS NO 2 AND NO 3 ARSENIC REMOVAL FACILITY

ELECTRICAL
SERVICE ENTRANCE SECTION AND MOTOR CONTROL CENTER SINGLE LINE DIAGRAM

DATE: DECEMBER 2011
PROJECT NUMBER: 11.487
DRAWING NUMBER: E-102



WATERWORKS ENGINEERS

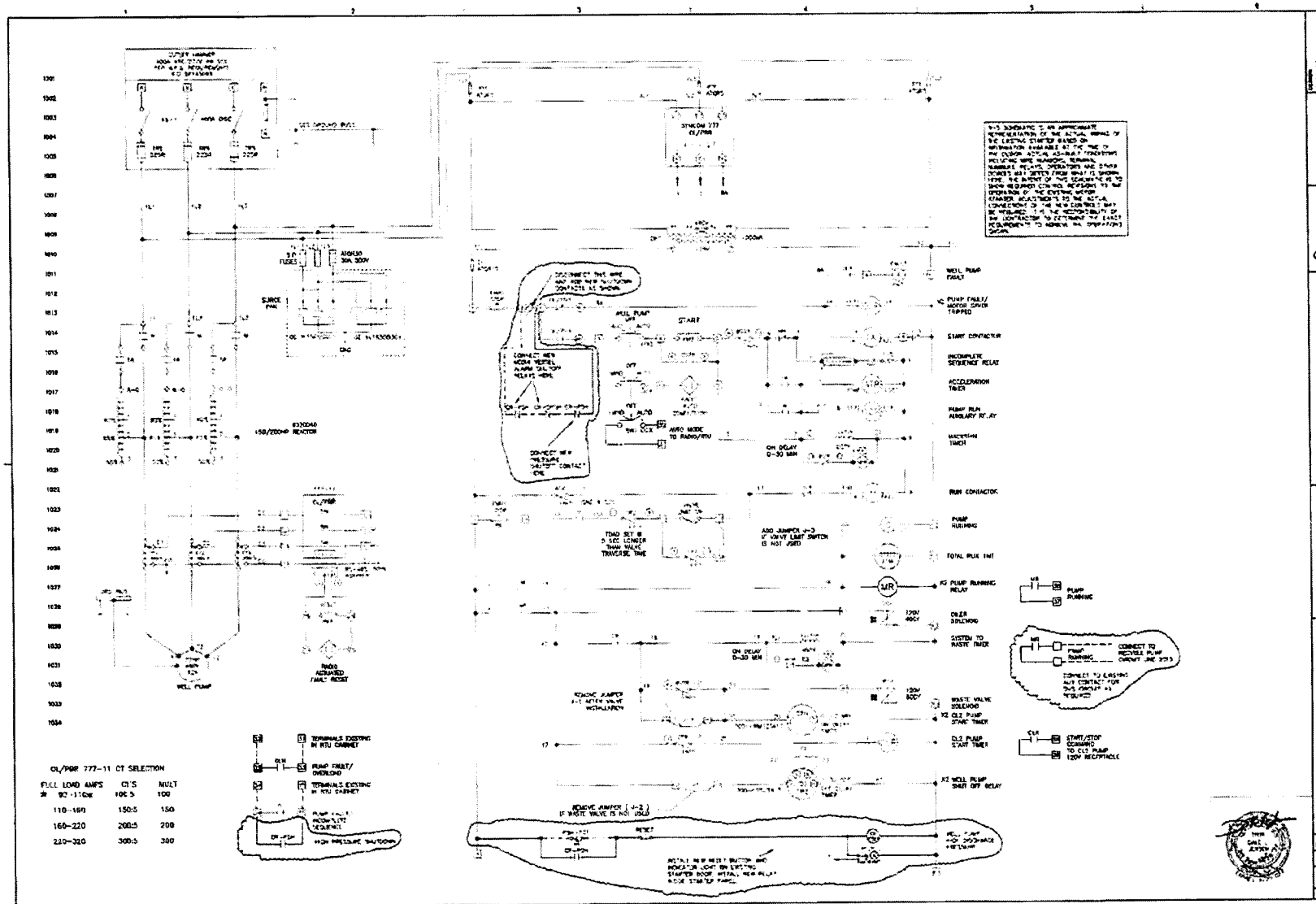
ARIZONA WATER COMPANY
MONTEZUMA HAVEN
WELLS NO 2 AND NO 3
ARSENIC REMOVAL FACILITY

ELECTRICAL
SITE PLAN

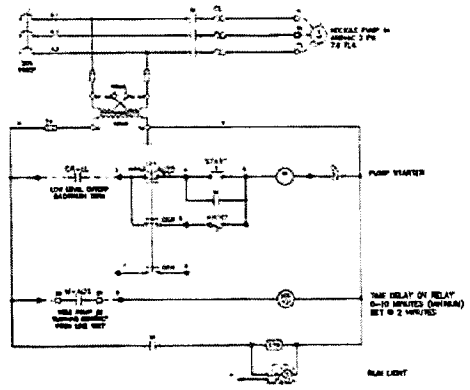
DECEMBER 21, 2011

E-103

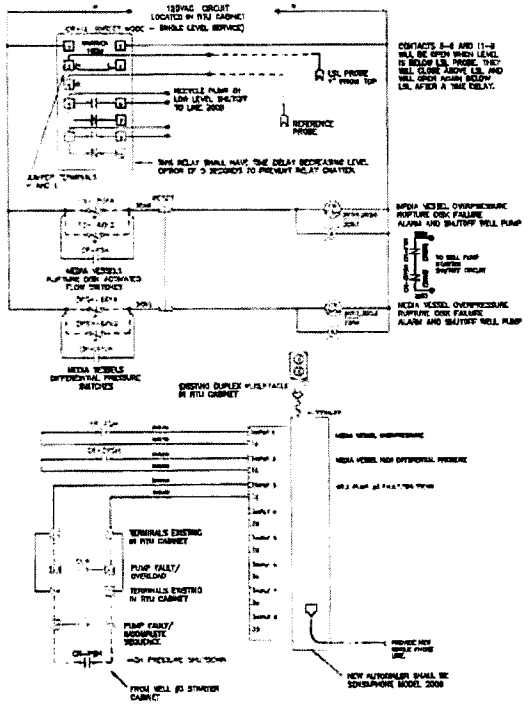
REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC



REUSE OF DOCUMENTS: THIS DRAWING, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, L.L.C. AND IS NOT TO BE USED IN WHOLE OR IN PART FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC.



A RECYCLE PUMP SCHEMATIC



BACKWASH TANK LEVEL & AUTODIALER
B SCHEMATIC

WATERWORKS ENGINEERS

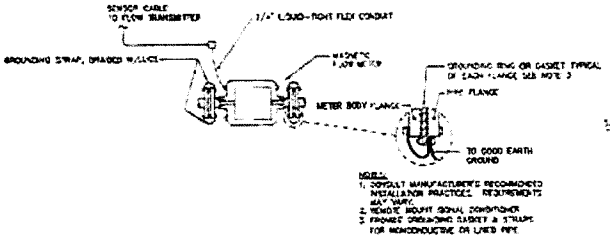
ARIZONA WATER COMPANY
MONTEZUMA HAVEN WELLS NO. 2 AND NO. 4 ARSENIC REMOVAL FACILITY

ELECTRICAL
MISCELLANEOUS SCHEMATIC DIAGRAMS

DECEMBER 2011

E-105

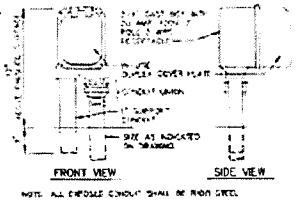
REUSE OF DOCUMENTS: THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC.



MAGNETIC FLOW METER INSTALLATION

A DETAIL

N.T.S

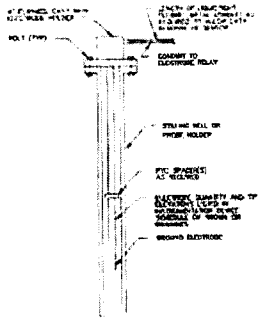


NOTE: ALL CONDUIT SHALL BE RIGID STEEL

TYPICAL WEATHERPROOF RECEPTACLE

B MOUNTING DETAIL

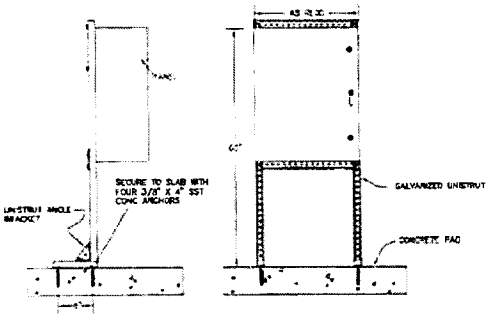
N.T.S



ELECTRODE RELAY TYPE LEVEL SWITCH

C ELECTRODE INSTALLATION DETAIL

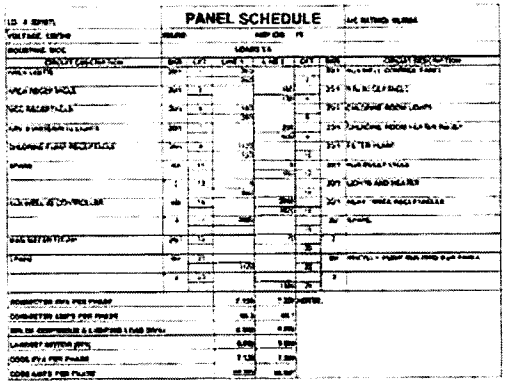
N.T.S



D CONTROL PANEL/STARTER MOUNTING DETAIL

E-103 N.T.S.

PANEL SCHEDULE



PANELBOARD A (EXISTING)

E PANEL SCHEDULE

N.T.S

NOTE: ITEMS SHOWN AS BOLD ARE NEW THIS PROJECT.

REUSE OF DOCUMENTS: THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WILTEY WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WILTEY WORKS ENGINEERS, LLC.

WATERWORKS ENGINEERS

Jensen Engineering, L.L.C. Corpus Christi, Texas

MGC CONSTRUCTION INC.

PECOS WATER COMPANY
MONTEZUMA HAVEN
WATER SYSTEM IMPROVEMENTS
ARSENIC REMOVAL FACILITY

ELECTRICAL
DETAILS

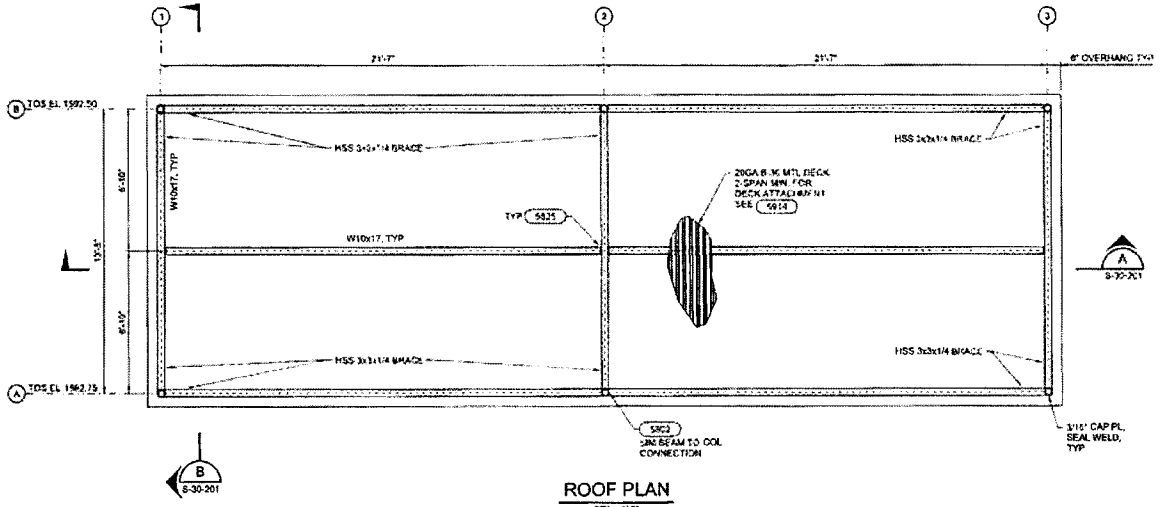
DATE: DECEMBER 2015
PROJECT NUMBER: 13-252
DRAWING NUMBER: E-106
SHEET

Exhibit "J"

Sample Design of Chemical Feed System

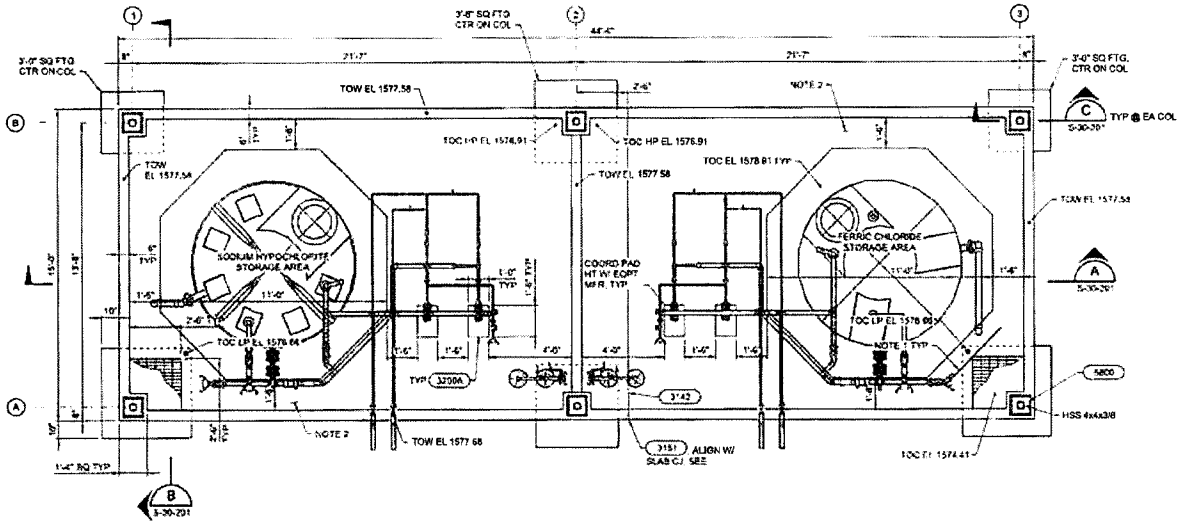
NOTES

1. PROVIDE 15x4'-0" DIAGONAL BAR AT EACH REENTRANT CONCRETE CORNER AT EACH REBAR MAT.
2. APPLY CONCRETE DENSIFIER TO SLAB SURFACE AFTER COMPLETION OF THE SPECIFIED WATER CURE AND INSTALLATION OF CONCRETE CURBS AND PADS.



ROOF PLAN

3/8" = 1'-0"



FOUNDATION PLAN

3/8" = 1'-0"

2 0 2 4 FEET

SCALE 3/8"=1'-0"

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, L.L.C. AND IS NOT TO BE USED IN WHOLE OR IN PART FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

FILENAME: S:\CAD\Projects\13-047 AZ Water Baseline ARS\ CopyOf\working\Drawings\13-047S-30-101.dgn PLOT DATE: 3/11/2014 PLOT TIME: 9:40:51 AM SCALE: 1:2.67887

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

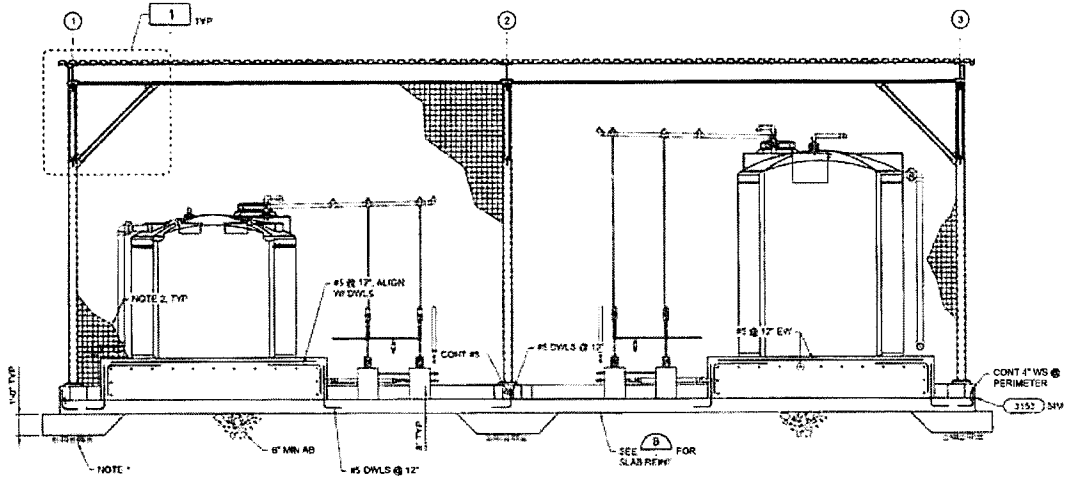
STRUCTURAL

CHEMICAL AREA PLANS

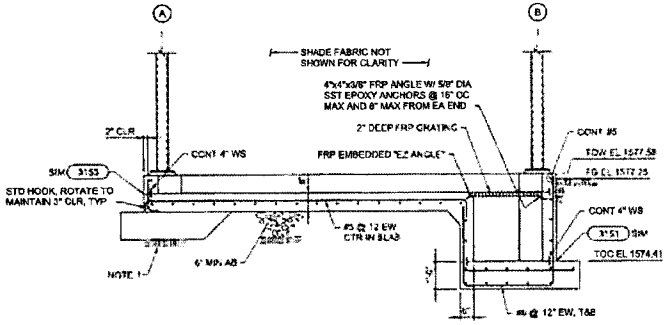
DATE: MARCH 2014
PROJECT NUMBER: 13-047
DRAWING NUMBER: S-30-101
SHEET - OF -

NOTES

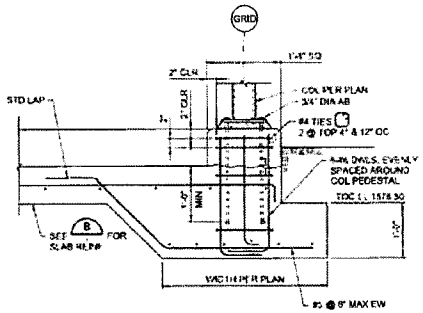
1. OVER-EXCAVATE BELOW ENTIRE STRUCTURE TO A MINIMUM EL 1575.00 EXTEND EXCAVATION HORIZONTALLY FIVE FEET MINIMUM BEYOND STRUCTURE FOOTPRINT. REPLACE W/ SELECT FILL AND AGG BASE
2. INSTALL SHADE FABRIC AROUND STRUCTURE PERIMETER. ATTACH IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS. HARDWARE SHALL INCLUDE SNAP-LINKS AT THE CURTAIN PERIMETER TO ALLOW REMOVAL. PROVIDE A ROLL-UP ASSEMBLY ALONG GRID LINE A. INSTALL INTERMEDIATE SHADE FABRIC SUPPORTS AS REQUIRED FOR FABRIC



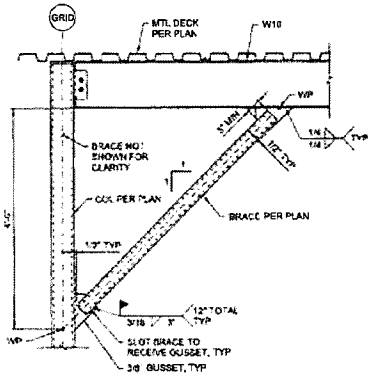
A SECTION
S-30-101 3/8" = 1'-0"



B SECTION
S-30-101 1/2" = 1'-0"



C SECTION
S-30-101 1" = 1'-0"



1 DETAIL
1" = 1'-0"

1 0 1 2 FEET
SCALE 1"=1'-0"
2 0 2 4 FEET
SCALE 1/2"=1'-0"
2 0 2 4 FEET
SCALE 3/8"=1'-0"

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY

DESIGN JAK
DRAWN AA
CHECKED DWG
APPROVED JWM

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

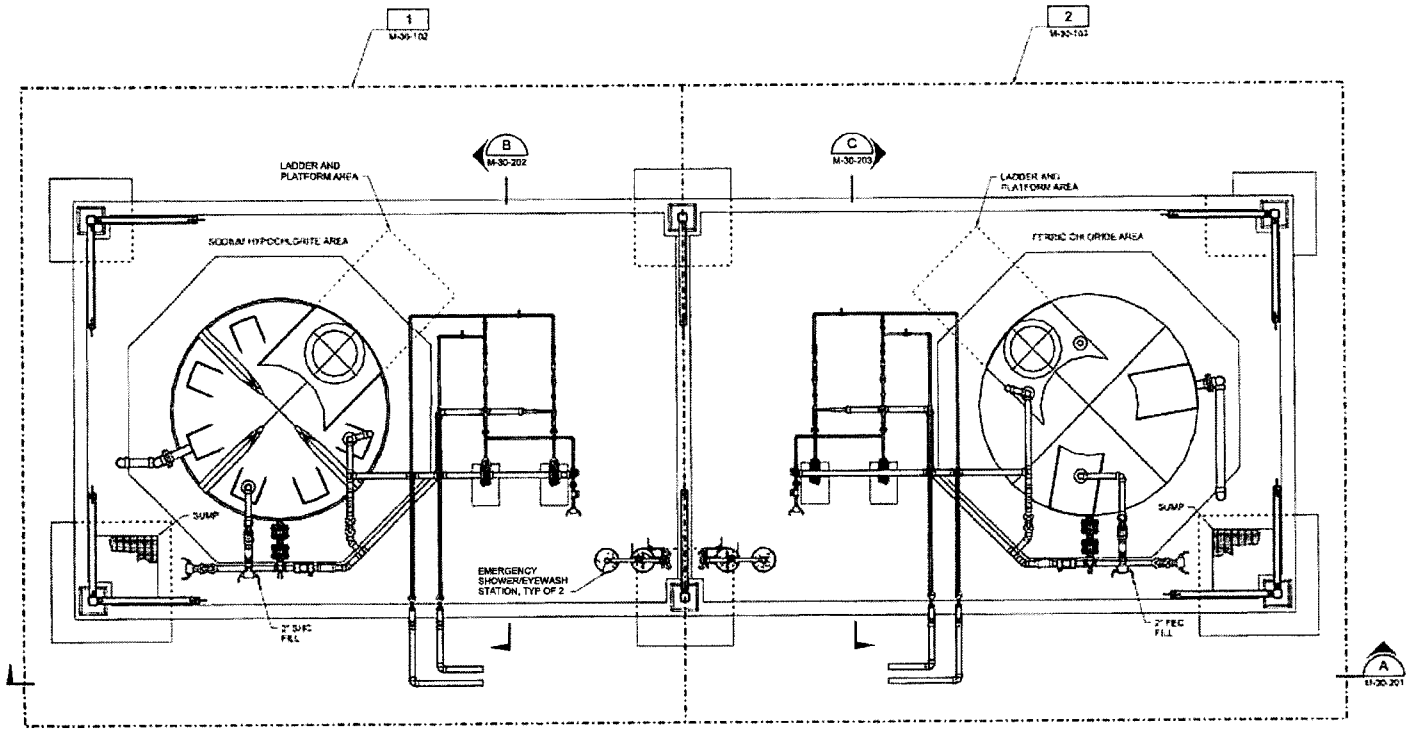
ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

STRUCTURAL
CHEMICAL AREA SECTIONS

DATE MARCH 2014
PROJECT NUMBER 13-047
DRAWING NUMBER S-30-201
SHEET OF
SCALE 1/2 (22x34)

REUSE OF DOCUMENTS: THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATERWORKS ENGINEERS, LLC AND IS NOT TO BE USED IN WHOLE OR IN PART FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATERWORKS ENGINEERS, LLC

TX FNAME: S:\CAD\Projects\13-047 AZ Water Baseline ARF Exp\Drawings\Structural\S-30-201.dgn PLOT DATE: 3/17/2014 PLOT TIME: 8:53:53 AM



PLAN
1/2" = 1'-0"

2 0 2 4 FEET
SCALE 1/2"=1'-0"

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

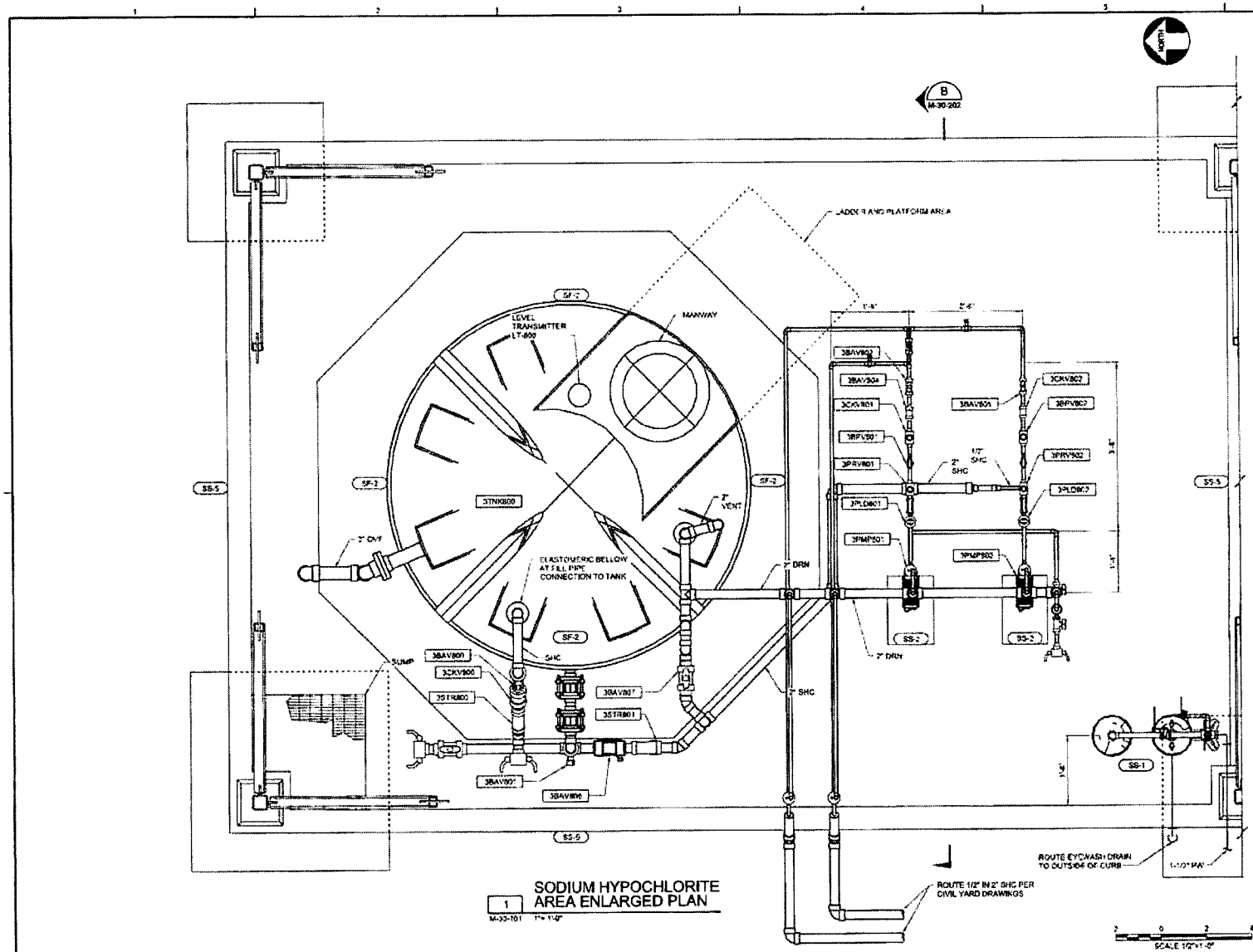
MECHANICAL

CHEMICAL AREA PLAN

DATE
MARCH 2014
PROJECT NUMBER
13-247
DRAWING NUMBER
M-30-101
SHEET - OF -
SCALE 1:2

REUSE OF DOCUMENTS: THIS DOCUMENT AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATERWORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECTS WITHOUT THE WRITTEN AUTHORIZATION OF WATERWORKS ENGINEERS, LLC

FILE NAME: S:\CAD\Projects\13-247 AZ Water Baseline ARF Exp\Drawings\Civil\mechanical\13-247-M-30-101.dgn PLOT DATE: 3/11/2014 PLOT TIME: 11:29:58 AM SCALE: 1:2



1 SODIUM HYPOCHLORITE AREA ENLARGED PLAN
M-30-101 1"= 1'-0"

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
IF NOT ONE INCH THEN SCALE DRAWING ACCORDINGLY

DESIGN AM
DRAWN JWJ
CHECKED
QA/QC
APPROVED ATM

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

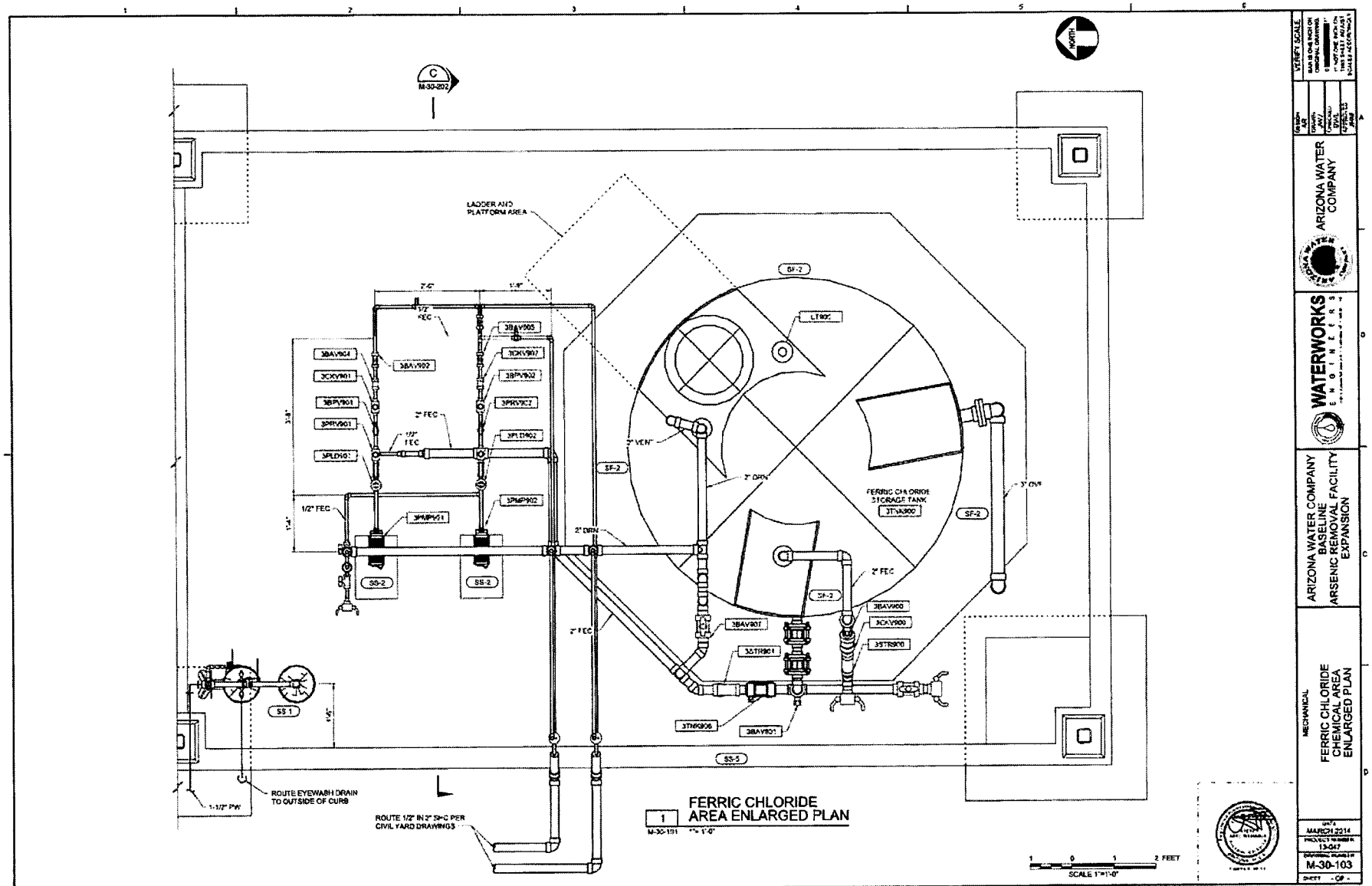
MECHANICAL

SODIUM HYPOCHLORITE CHEMICAL AREA ENLARGED PLAN

DATE MARCH 2014
PROJECT NUMBER 13-067
DRAWING NUMBER M-30-102
SHEET - OF -
SCALE 1:1

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

FILENAME: S:\CAD\Projects\13-067 AZ Water Baseline ARF Exp\Drawings\Submissions\13-067-M-30-102.dgn PLOT DATE: 3/11/2014 PLOT TIME: 11:29:05 AM



VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET ADJUST SCALE ACCORDINGLY

DESIGN	DRAWN	CHECKED	APPROVED
MJB	ANV		

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

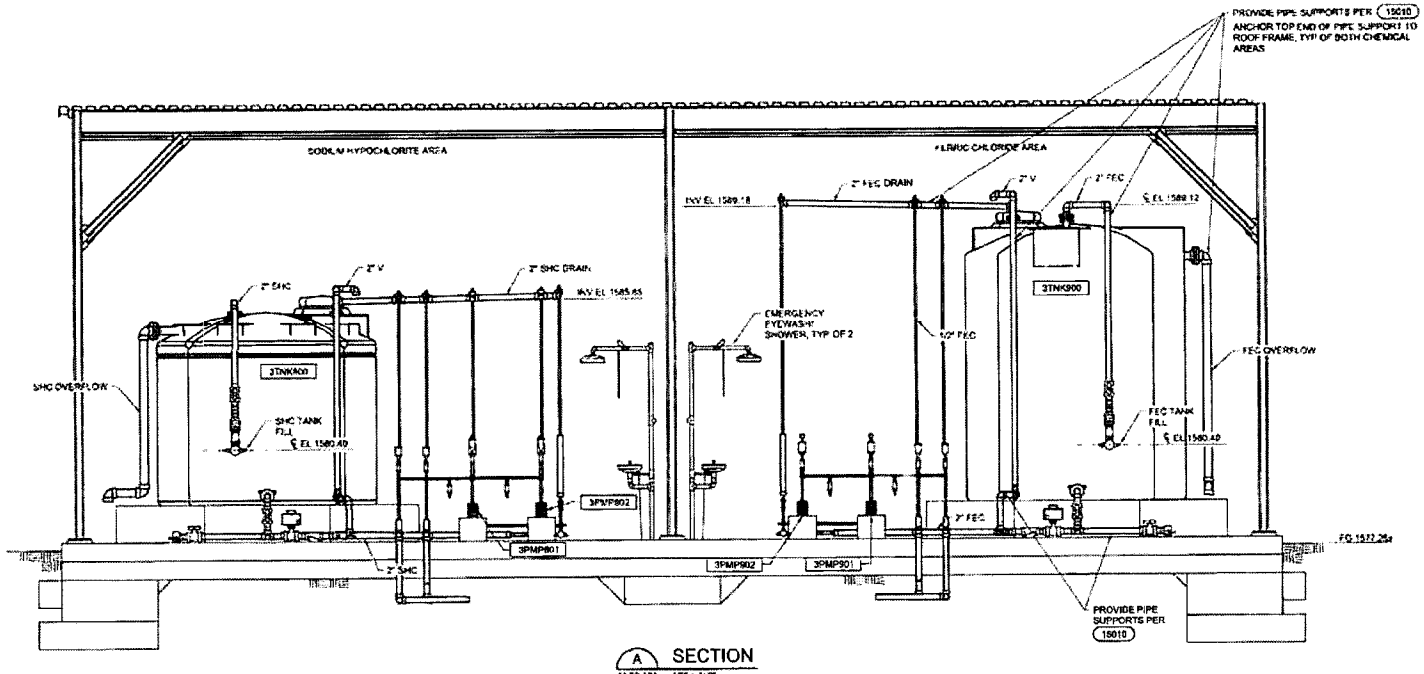
MECHANICAL

FERRIC CHLORIDE CHEMICAL AREA ENLARGED PLAN

DATE: MARCH 2014
PROJECT NUMBER: 13-047
DRAWING NUMBER: M-30-103
SHEET - OF -
SCALE: 1:1

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

FILE NAME: S:\CAD\Projects\13-047 AZ Water Baseline ARF Facility\Drawings\Civil\M-30-103.dgn
PLOT DATE: 3/11/2014
PLOT TIME: 11:29:06 AM



A SECTION
M-30-101 1/2" = 1'-0"

2 0 2 4 FEET
SCALE 1/2"=1'-0"

REUSE OF DOCUMENTS: "THIS DOCUMENT" AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC. AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC.

FILENAME: S:\CAD\Projects\13-047 AZ Water Baseline\ARF Exp\Drawings\Mechanical\13-047D-M-30-201.dgn PLOT DATE: 3/11/2014 PLOT TIME: 11:29:36 AM

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
IF NOT ONE INCH ON THIS SHEET ADJUST SCALES ACCORDINGLY

DESIGN: AJS
DRAWN: JWU
CHECKED: BWK
APPROVED: BWK

ARIZONA WATER COMPANY

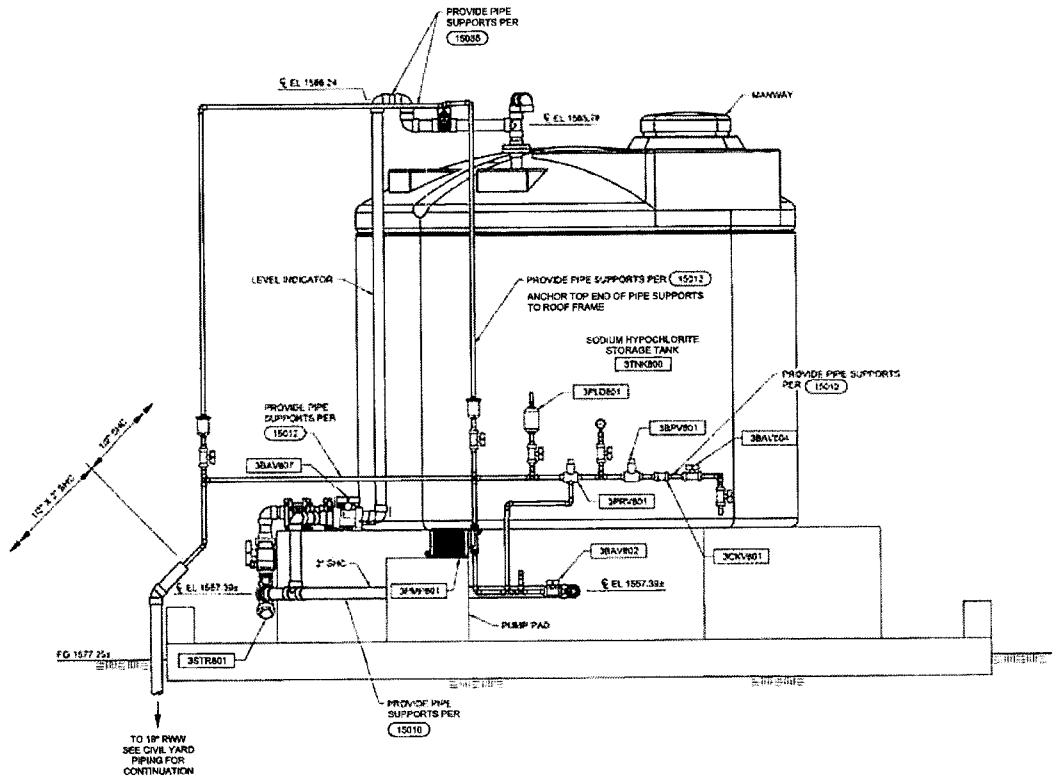
WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE ARSENIC REMOVAL FACILITY EXPANSION

MECHANICAL

CHEMICAL AREA SECTION 1

DATE: MARCH 2014
PROJECT NUMBER: 13-047
DRAWING NUMBER: M-30-201
SHEET: 1 OF 1
SCALE: 1:2



B SECTION
M-30-101 1" = 1'-0"

1 0 1 2 FEET
SCALE 1"=1'-0"

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

FILENAME: S:\CAD\Projects\13-047 AZ Water Baseline ARF\Drawings\Construction\13047SM-M-30-202.dgn PLOT DATE: 3/11/2014 PLOT TIME: 11:26:13 AM SCALE: 1:1

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY

DESIGNED: SM
DRAWN: JW
CHECKED: SM
APPROVED: SM

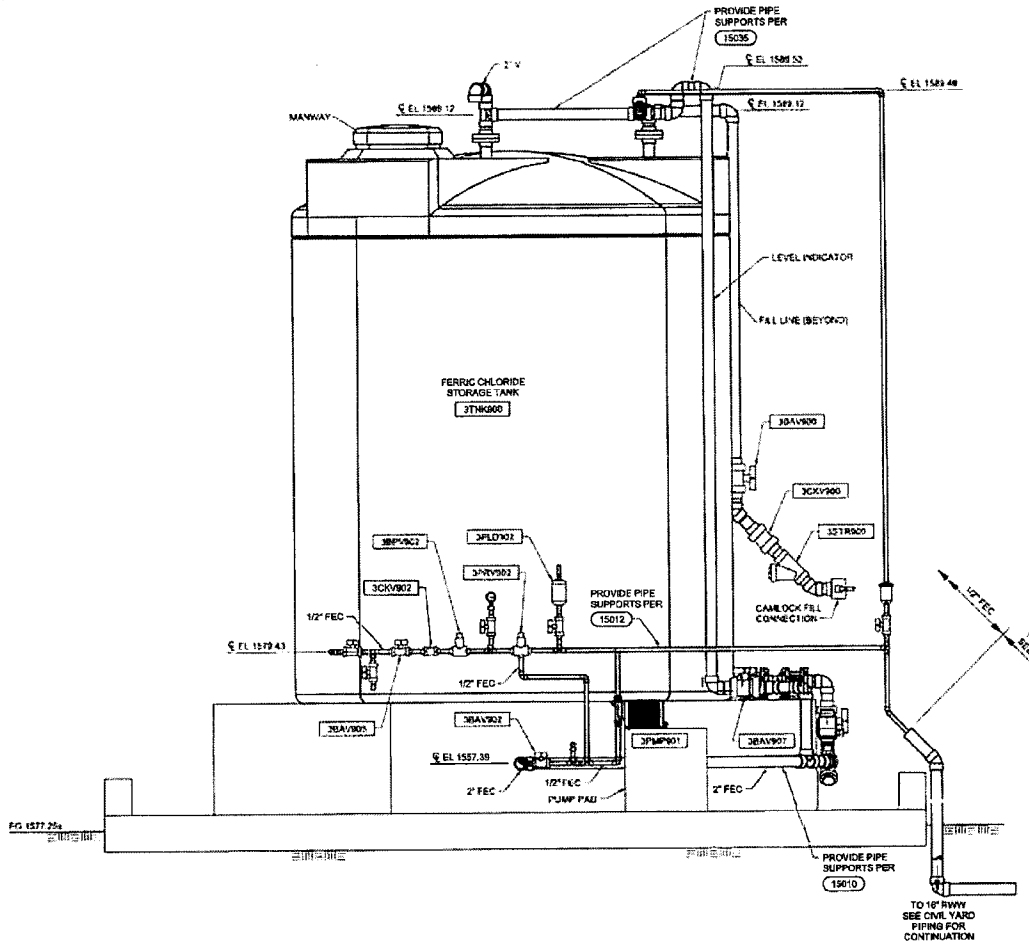
ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY
EXPANSION

MECHANICAL
SODIUM HYPOCHLORITE SECTION

DATE: MARCH 2014
PROJECT NUMBER: 13-047
DRAWING NUMBER: M-30-202
SHEET - OF -



C SECTION
M-30-101 1" = 1'-0"

SCALE 1"=1'-0"
1 0 1 2 FEET

REUSE OF DOCUMENTS: THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF WATER WORKS ENGINEERS, LLC AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF WATER WORKS ENGINEERS, LLC

FILENAME: S:\CAD\Projects\13-047 AZ Water Baseline ARF Expansion\drawings\13-047D-M-30-203.dgn PLOT DATE: 3/11/2014 PLOT TIME: 11:28:14 AM SCALE: 1:1

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH ON THIS SHEET ADJUST SCALE ACCORDINGLY

DESIGN AR
DRAWN JHV
CHECKED BWA
APPROVED JHM

ARIZONA WATER COMPANY

WATERWORKS ENGINEERS

ARIZONA WATER COMPANY
BASELINE
ARSENIC REMOVAL FACILITY EXPANSION

MECHANICAL

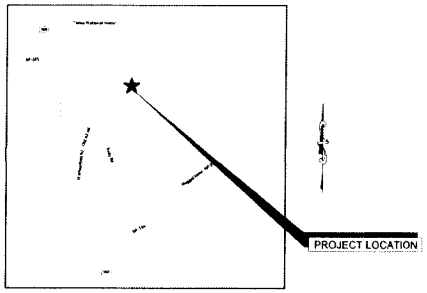
FERRIC CHLORIDE SECTION

DATE MARCH 2014
PROJECT NUMBER 13-047
DRAWING NUMBER M-30-203
SHEET - OF -

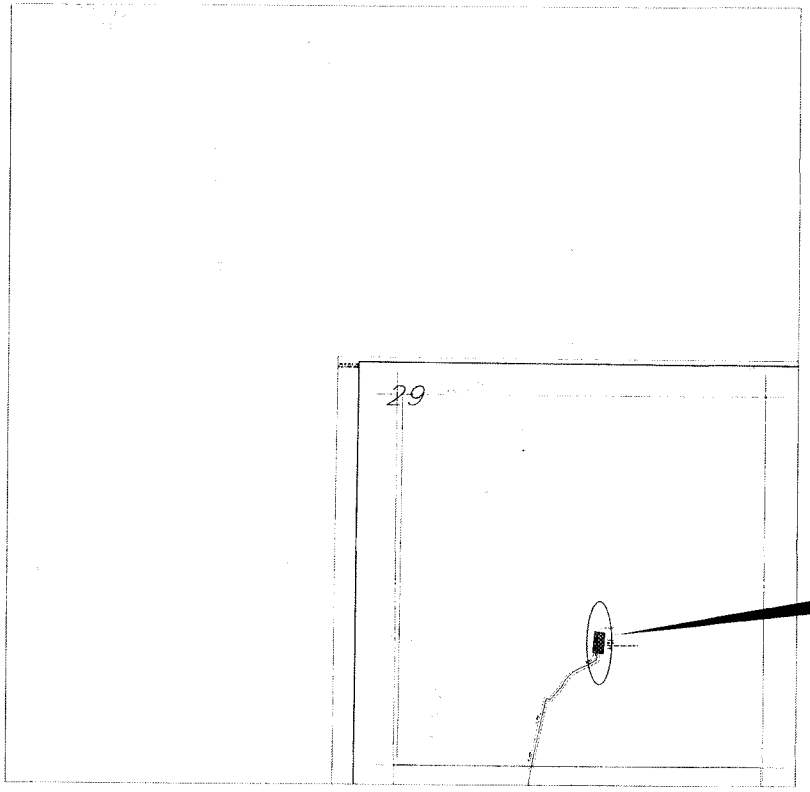
Exhibit "K"

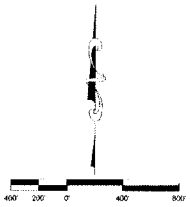
Sample Design of Sodium Hypochlorite Feed System

CONSTRUCT LIQUID CHLORINATION DISINFECTION SYSTEM AT WELL SITE No. 28, NEAR GLOBE, ARIZONA
SE 1/4 SEC. 29, T. 2 N., R. 15 E. OF THE G. & S. R. B. & M.



VICINITY MAP





PROJECT OVERALL

GENERAL NOTES

1. All work and materials shall conform to current County Health Department Standards and Revisions, Arizona Water Company Standard Specifications and Details, and Arizona Department of Health Services Engineering Bulletin No. 10.
2. Permits required will be secured from the appropriate agency (i.e. county permit in county right-of-way).
3. Prior to construction, the appropriate agency shall be notified as required by the permits.
4. All backfill, compaction, and testing shall be per current County, City, State, ADOT, and Arizona Water Company standards and specifications.
5. All water lines 8" and less are to have a minimum cover of 36 inches & all water lines 12" and greater are to have 48" of minimum cover over the top of pipe to finished grade, unless otherwise specified on the construction drawings.
6. All manhole covers, valve boxes, etc. shall be adjusted to finished grade prior to placing of asphaltic concrete surface course by the contractor (where applicable).
7. All water lines shall be pressure and leakage tested in accordance with AWWA C-600 or AWS 613.14.
8. All water lines are to be disinfected per ADEQ Engineering Bulletin No.8 and AWWA C651-92.
9. Air release valves are required at water system high points per Arizona Water Company standard details.
10. Water/sewer separations shall be per current Arizona Water Company standards and ADEQ AAC R18-4-502-C.
11. It shall be the contractor's responsibility to uncover all existing water lines being connected to, and to verify the location, depth and size of pipe before any construction begins.
12. Any construction performed without the knowledge of the inspector or his representative is liable for removal and replacement at the contractor's expense.
13. In accordance with AAC R18-4-213, all materials added after January 1, 1993 which may come in contact with drinking water, shall conform to National Sanitation Foundation Standards 60 and 61.
14. All water services shall be set a minimum of 2 Feet on the customers property and NOT within right of way.
15. Unless otherwise specified on the construction drawings, all water mains are to be installed 5 Feet from the property line inside the right-of-way or easement.
16. Water valves shall be spaced not more than 500 Feet in commercial districts and not more than 800 Feet in other districts. Variations may be required for transmission mains or special applications. Sufficient valving is required where water lines cross streams, railroads and major highways.
17. Maximum Joint Deflection For 6" Mechanical Joint Ductile Iron Pipe Is 7°-7'-0" For 18 Foot Length Pipe. For A Maximum Curve Of 345 Feet.
18. Maximum Joint Deflection For 8", 10" & 12" Push On Joint Ductile Iron Pipe Is 5°-0'-18" For 18 Foot Length Pipe. For A Maximum Curve Of 205 Feet.
19. Maximum Joint Deflection For 8" & 12" Mechanical Joint Ductile Iron Pipe Is 5°-21'-0" For 18 Foot Length Pipe. For A Maximum Curve Of 195 Feet.

ADEQ APPROVAL

FILE No.

DATE

RELEASED TO CONSTRUCTION

APR 18 2014

FRED SCHNEIDER

SITE STATISTICS

APN: 265-17-0180

SITE ADDRESS: 2955 HOBEY ROAD GLOBE, AZ. 85501

OWNER/ENGINEER/DEVELOPER

ARIZONA WATER COMPANY
POST OFFICE BOX 29006
PHOENIX, AZ. 85038-9006
VOICE: (602) 240-5655 FAX: (602) 240-2957
CONTACT: RICHARD HACKER

SHEET INDEX

SHEET No.	DWG. No.	DESCRIPTION	PREPARED BY
1	SS-0199	PROJECT OVERALL	A.W.Co.
2	SS-0199	SITE PLAN	A.W.Co.
3	SS-0199	GENERAL NOTES	A.W.Co.
4	SS-0199	DETAILS	A.W.Co.

The installation shown is to be installed in accordance with the Arizona Water Company Standard Specifications and As-Builts and with the Arizona Department of Environmental Quality.

263-1100
(480)-374E-IT
(480)-374-2001

1-5137

MIAMI

SE 1/4 SEC. 29, T. 2 N., R. 15 E.

0100

1"=40'

1/14/2014

AS SHOWN

JAK

ARIZONA WATER COMPANY
3805 N. BLACK CANYON HWY. POST OFFICE BOX 29006
PHOENIX, ARIZONA 85038-9006
(602) 240-5650

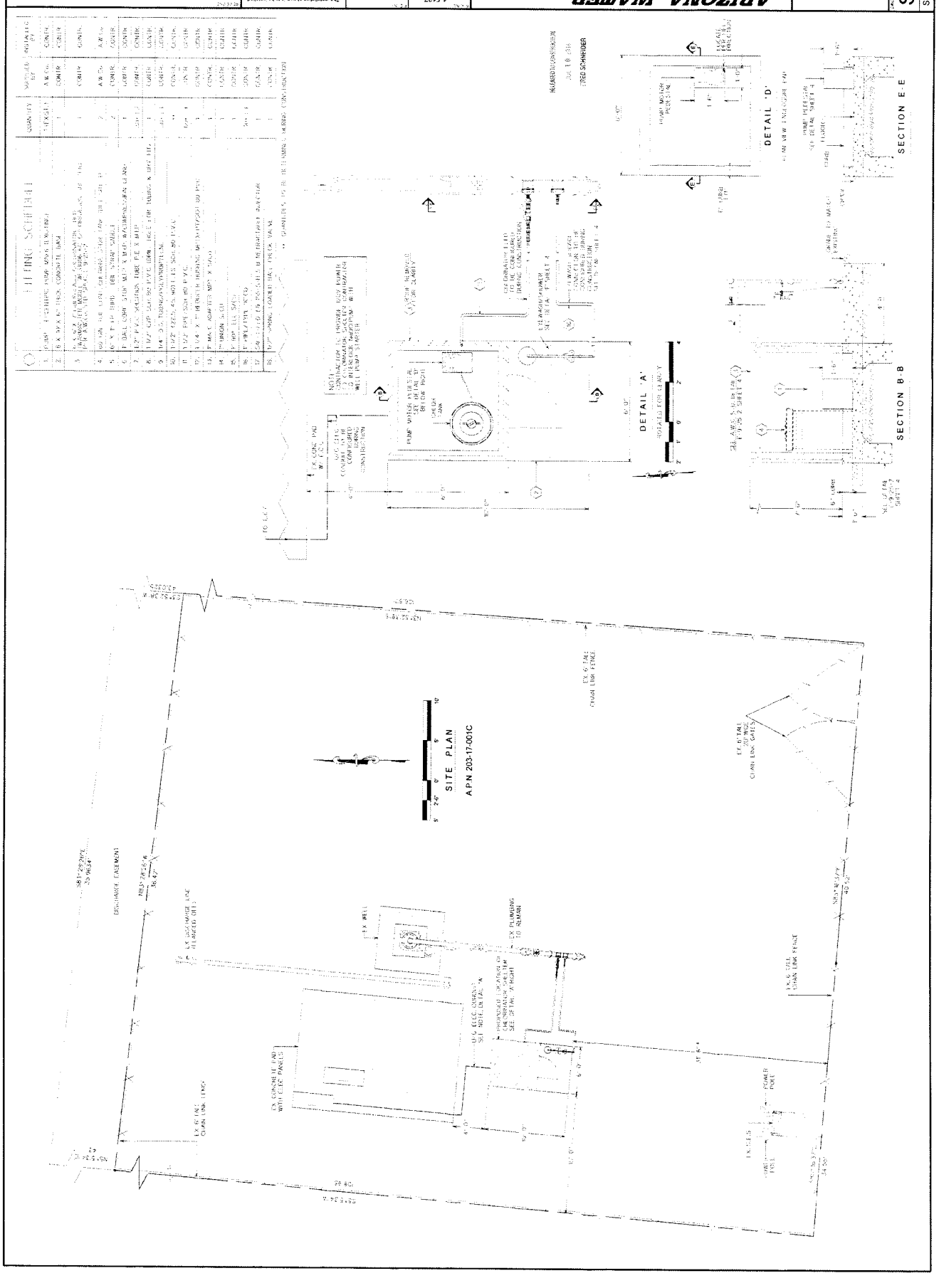
CONSTRUCT LIQUID CHLORINATION DISINFECTION SYSTEM AT WELL SITE No. 28, NEAR GLOBE, ARIZONA

PROJECT OVERALL

53726
RICHARD D HACKER
REGISTERED
ARIZONA U.S.A.

Expires 9-30-2015

DWG. No.
SS-0199
SHEET 1 OF 4


ARIZONA WATER COMPANY
3805 N. BLACK CANYON HWY POST OFFICE BOX 29006
PHOENIX, ARIZONA 85038-3006
(602) 240-6860
CONSTRUCT LIQUID CHLORINATION DISINFECTION SYSTEM
AT WELL SITE No. 28, NEAR GLOBE, ARIZONA
SITE PLAN
MIAMI
SE 1/4 SEC. 28, T. 2 N., R. 15 E.
0100
1/14/2014
AS SHOWN
JAK
1-5137
263-1100
1-800-STAKE IT
SS-0199
SHEET 2 OF 4
Expires 9-30-2015
SECTION E-E
SECTION B-B
DETAIL 'A'
DETAIL 'D'
SITE PLAN
A.P.N. 203-17-001C
EX. 6' TALL CHAIN LINK FENCE
EX. CONCRETE PAD WITH ELEC. PANELS
EX. 6' TALL CHAIN LINK FENCE
EX. WELL
EX. PLUMBING TO REMAIN
EX. 6' TALL CHAIN LINK GATES
EX. POWER POLE
DRAINAGE EASEMENT

E.8.1
CONSTRUCTION SPECIFICATIONS
FOR THE INSTALLATION OF WATER DISTRIBUTION SYSTEMS
DUCTILE IRON

DEFINITIONS

A. Company: The words "Company" or "Arizona Water Company" mean Arizona Water Company, and where applicable, any division of Arizona Water Company, whose principal place of business is located at 3805 North Black Canyon Highway, Phoenix, Arizona 85015-5351 (Post Office Box 29006, Phoenix, Arizona 85038-9006).

B. Company's Authorized Representative: The words "Company's Authorized Representative" mean any officer of the Company, and any of the Company's Engineers, any Division Manager or Superintendent of the Company and/or such other person(s) designated in writing as the "Company's Authorized Representative" by the President or any Vice President of the Company.

C. Contractor: The word "Contractor" means either an individual or other entity employed to do the work as shown on the Construction Drawings and as specified herein.

D. Construction Drawings: The words "Construction Drawings" mean plans prepared by or on behalf of Arizona Water Company.

E. Contract: The word "Contract" means the written document titled "Proposal/Contract" when such document has been signed by an officer or other authorized representative of both the Contractor and the Company.

(1) GENERAL

All work is to be completed in a safe, workmanlike manner and in accordance with these Construction Specifications; any deviation therefrom must be approved in writing by the Company.

Installations must conform with the requirements of all governmental regulating agencies and the cost of conforming to such regulations must be included in the unit bid prices. Examples of such regulations, without attempting to be inclusive, are:

(2) LOCATION MARKING

(3) TRENCH EXCAVATION

(4) MATERIALS TO BE PROVIDED BY CONTRACTOR

(5) INSTALLATION OF MATERIALS

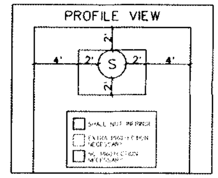
(6) BACKFILL OF WATER MAIN TRENCHES

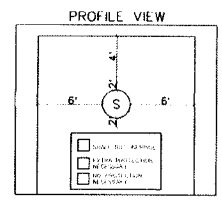
(7) HYDROSTATIC TESTING OF COMPLETED PIPELINES

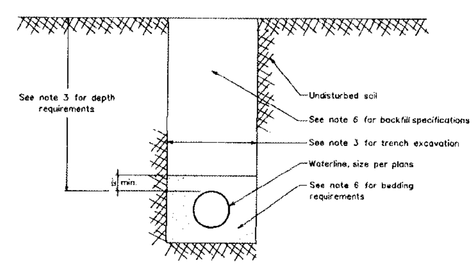
(8) STERILIZATION AND FLUSHING OF COMPLETED WATER PIPELINES

(9) NO OTHER UTILITIES ALLOWED IN OR NEAR WATER PIPELINE TRENCHES

(10) PROTECTION OF WATER MAINS NEAR SEWERS







TYPICAL TRENCH DETAIL
Per MAG Detail 601, 601.4.2, 601.4.6

RELEASED FOR CONSTRUCTION
FRED SCHNEIDER

W.O. NO.	1-5137
SYSTEM	MIAMI
LEGAL DESC.	SE 1/4 SEC. 29, T. 2 N., R. 15 E
	0100
DATE	1/14/2014
SCALE	AS SHOWN
DRAWN BY	JAK
CHECKED BY	MJM

The installation shown is to be installed in accordance with the Arizona Water Company standard specifications on file with the Arizona Department of Environmental Quality

263-1100
1-800-STAKE-IT

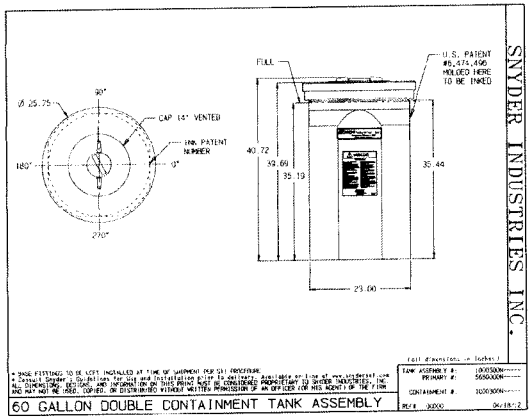
ARIZONA WATER COMPANY
3805 N. BLACK CANYON HWY. POST OFFICE BOX 29006
PHOENIX, ARIZONA 85038-9006
(602) 240-6860

CONSTRUCT LIQUID CHLORINATION DISINFECTION SYSTEM
AT WELL SITE No. 28, NEAR GLOBE, ARIZONA

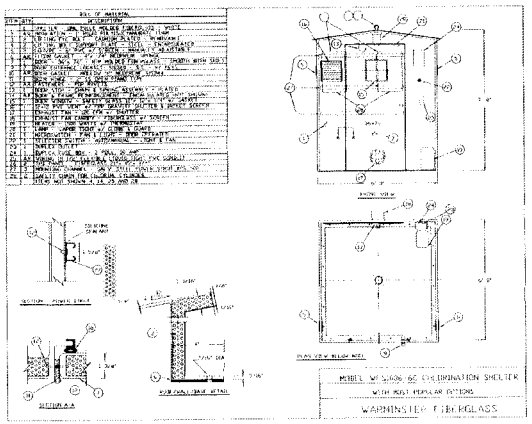
GENERAL NOTES

53726
RICHARD D. HACKER
ARIZONA, U.S.A.
Expires 9-30-2015

SS-0199
SHEET 3 OF 4



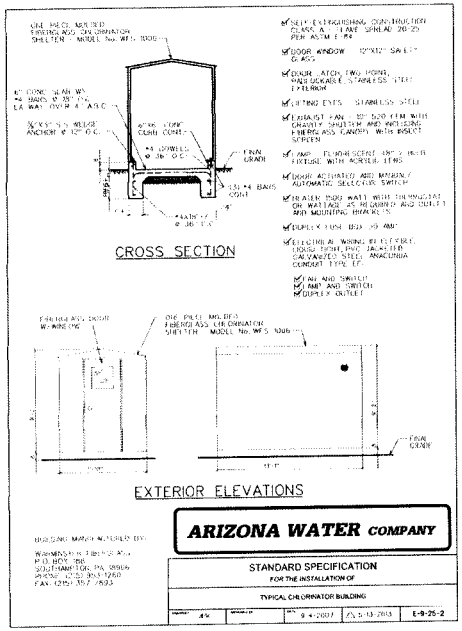
60 GALLON DOUBLE CONTAINMENT TANK ASSEMBLY



MOBEL MS-3636-SC CHLORINATION SHELTER
WITH ROOF POPULAR PITCHING
WARMINSTER FIBERGLASS

	FITTING SCHEDULE	QUANTITY	SUPPLIED BY	INSTALLED BY
1.	PUMP - (ECCENTRIC STEM) MYERS (EXISTING)	1 (EXIST)	A.W.Co.	CONTR.
2.	6'-1 10 x 6" THICK CONCRETE BASE	1	CONTR.	CONTR.
3.	6" x 6" x 3" FIBERGLASS CHLORINATION CELL (CHEMSYSTEM MODEL #FS3000) 6S CHLORINATION SYSTEM PER A.W.Co. STD. SPEC. # 9-20-7	1	CONTR.	CONTR.
4.	60 GAL DBL CONT CHLORINE STOR. TANK (SPT. 4)	2	A.W.Co.	A.W.Co.
5.	6" X 6" P.V.C. TEE - DBL STRAP SADDLE	2	CONTR	CONTR
6.	1" BALL CORP STOP, VERT X M.I.P. W/LOME XCESSION GLAND	1	CONTR.	CONTR.
7.	1/2" P.V.C. SOLUTION TUBE PER X M.I.P.	10'-0"	CONTR.	CONTR.
8.	1-1/2" CAP SCH. 80 P.V.C. (DRILL HOLE FOR TUBING & DRY FIT)	1	CONTR	CONTR
9.	1/4" O.D. TUBING FOR PROPYLENE	50'-0"	CONTR	CONTR
10.	1-1/2" 1/2 S, 45, 90 ELLS SCH. 80 P.V.C.	***	CONTR.	CONTR
11.	1-1/2" PIPE/SCH. 80 P.V.C.	60'-0"	CONTR.	CONTR.
12.	1 1/4" X 1" REDUCER BUSHING MPT/SPT/SCH. 80 PVC	1	CONTR.	CONTR.
13.	1" MALE ADAPTER MPT X S/CU	1	CONTR.	CONTR.
14.	1" UNION S/CU	1	CONTR.	CONTR
15.	1" 90° ELL S/CU	1	CONTR.	CONTR
16.	1" PIPE/TYPE K/CU	20'-0"	CONTR.	CONTR
17.	SAF-T-FLO EH-150-S H D P RETRACTABLE INJECTOR	1	CONTR.	CONTR.
18.	1/2" SPRING LOADED BALL CHECK VALVE	1	CONTR	CONTR.

*** QUANTITIES TO BE DETERMINED DURING CONSTRUCTION



Sodium Hypochlorite Chlorinator Specifications

DESCRIPTION:
The chlorination system shall be a sodium hypochlorite chlorinator as supplied by Chemical Injection Technology Inc.; P.O. Box 4144, Cave Creek, AZ 85331 or its equivalent. The chlorination system shall be completely assembled and ready to install.

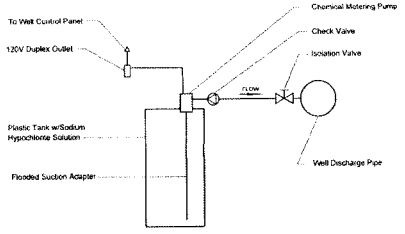
COMPONENTS:
The Chlorination system shall have the following components:
A. Walchem heain chemical metering pump w/ a total solution output control valve
B. Flooded Suction Adapter
C. Plastic tank assembly
D. Reverse flow check valve
E. Manual isolation valve
F. On/off pump control (switched outlet)

ELECTRICAL FIXTURES:
120V,15A,1PH, weatherproof duplex outlet (G.F.I.)

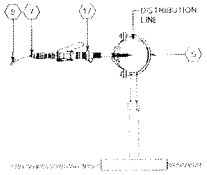
CHLORINATOR DESIGN:
The chlorination facility shall be designed and constructed in accordance with Arizona State Department of Health Engineering Bulletin Number 8 - "Disinfection of Water Systems" Latest Revision

CHLORINATOR EQUIPMENT:
The sodium hypochlorite chlorinator equipment shall conform to NSF Standard 60 and 61.

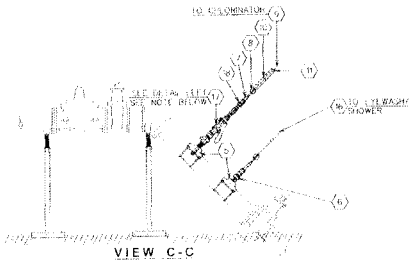
CHLORINATOR OPERATION:
The chlorination facility shall be operated in accordance with Arizona State Department of Health Engineering Bulletin Number 8, "Disinfection of Water Systems", Table 1 latest revision



Chlorinator Schematic

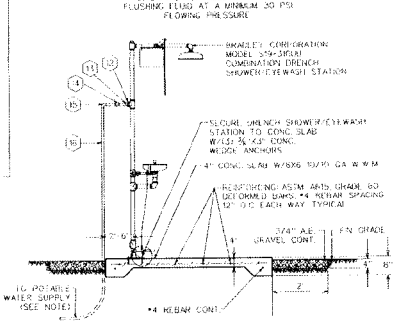


INJECTION POINT DETAIL
NOT TO SCALE

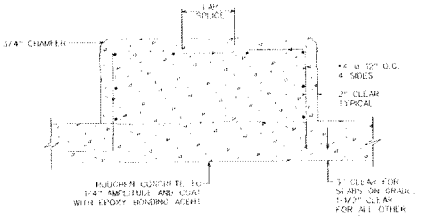


VIEW C-C

NOTE: (1) LENGTH OF 1/2" SOLUTION TUBE TO BE DETERMINED BY FIELD PERSONNEL



DRENCH SHOWER/EYEWASH STATION
DETAIL 'F'



PUMP PEDESTAL DETAIL
NOT TO SCALE

FOUNDATION NOTES

1. FOUNDATION BEAR FOOTING ON UNDISTURBED SOIL OR APPROVED ENGINEERED FILL SOIL PRESSURE 1,500 PSF PER IBC 1804.2, CLASS 4 MATERIAL

2. CONCRETE A.C.I. MANUAL OF CONCRETE PRACTICE, TYPE II CEMENT, MINIMUM 28 DAY STRENGTH OF 2,500 PSI, MAXIMUM SLUMP 5"

3. REINFORCING: ASTM A615, GRADE 60 DEFORMED BARS #4 REBAR SPACING 12" O.C. EACH WAY

CONCRETE COVER TO REINFORCING

A. CONCRETE AGAINST EARTH ..... 3"
B. OTHER ..... 1½"

LAP SPLICES 48 BAR DIAMETERS UNLESS OTHERWISE NOTED.

RELEASED TO CONSTRUCTION
SEP 16 2014
FRED SCHNEIDER

This installation shown is to be installed in accordance with the Arizona Water Company standard specifications on file with the Arizona Corporation Commission.

Arizona Water Company
P.O. Box 29006
Phoenix, AZ 85038-9006
263-1100
1-800-STAKE-IT
(Arizona only)

DRAWING NO.	
REVISIONS	
JOB NO.	1-5137
DESIGNED	MIAMI
T.R.& SEC.	SE 1/4 SEC. 28, T. 2 N., R. 15 E.
M. DEPT.	0100
DATE	1/14/2014
DRAWN BY	JAK
SCALE	AS SHOWN
CHECKED BY	

ARIZONA WATER COMPANY
3805 N. BLACK CANYON HWY. • POST OFFICE BOX 29006
PHOENIX, ARIZONA 85038-9006
(602) 240-6860

CONSTRUCT LIQUID CHLORINATION DISINFECTION SYSTEM AT WELL SITE NO. 28, NEAR GLOBE, ARIZONA

DETAILS

PROJECT TITLE

PROJECT SHEET TITLE

55726
RICHARD D HACKER
REGISTERED PROFESSIONAL ENGINEER
ARIZONA U.S.A.
Expires 9-30-2015

ORIG. No.
SS-0199
SHEET 4 OF 4

Exhibit "L"

20-Year Life Cycle Cost Assumptions

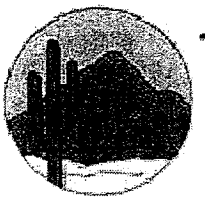
Exhibit "L"

20-Year Life Cycle Cost Analysis Assumptions

1. Interest Rate: 4% per year
2. Capital Cost: Bid Price
3. O&M Costs:
    a. Utilization: 25% (winter) to 50% (summer)
    b. Method of Operation: Partial treatment with bypass
    c. Company Operator Labor Rate: $75/hr (specify expected manhours)
    d. Media Removal/Replacement Cost: Per Exhibit "B" (specify frequency per guarantee)
    e. Power Cost: $0.15/kWh (specify expected power consumption)
    f. Laboratory: $500/month
    g. Vehicles/Fuel: $250/month
    h. Routine Repairs/Parts: $1,000/month
    i. Chemical Costs (specify chemical demand) :
        i. Delivery frequency: Once per month.
        ii. Sodium hypochlorite (12.5%): $1.67/gal (includes tax and delivery)
        iii. Sulfuric acid (91-93%): $2.23/gal (includes tax and delivery)
        iv. Sodium hydroxide: (50% summer/25% winter) $2.59/gal (includes tax and delivery)
        v. Ferric chloride (38-42%): $3.16/gal (includes tax and delivery)
        vi. Chlorine Demand: 1 ppm
        vii. Desired Chlorine Residual: 1 ppm

Exhibit "M"

Arizona Water Company
EI&C Design Guidelines Technical Specification



ARIZONA WATER COMPANY

EI&C DESIGN GUIDELINES

TECHNICAL SPECIFICATIONS

NOVEMBER 2009

Corporate Office
3805 North Black Canyon Hwy • Phoenix, AZ 85015-5351
P.O. Box 29006 • Phoenix, AZ 85038-9006
602.240.6860 (Phone)
602.240.6878 or 602.240.6874 (Fax)

Exhibit "N"

ADEQ Initial Start-Up Monitoring Form

Initial Start-Up Monitoring Form

For Ground Water Systems with Treatment Plants and/or Blending Plans

Please mail completed form and all Field & Lab analyses to:
ADEQ Drinking Water Monitoring and Protection Unit
1110 W. Washington St., Mail Code 5415B-2,

PWS ID Number (5 digits):	AZ04 –	**PWS Name:**			
Contact Person/Title:		**Phone #**		**E-Mail Address:**	
Choose One:	☐ Treatment Plant Only	☐ Treatment Plant & Blending Plan		☐ Blending Plan Only	
Entry Point to the Distribution System (EPDS) #:		**Contaminant:**	☐ Arsenic ☐ Fluoride ☐ Nitrate ☐ Other:		

Samples	MM/DD/YY	Sample Time (24h)	Raw Water Result (mg/L) (Insert well registration numbers below)					Treated Water Result (mg/L)	Finished Blended Water Results (mg/L)	Test Method
			Well # 55-	Well # 55-	Well # 55-	Well # 55-	Well # 55-			
Day 1										☐Field ☐Lab
Day 2										☐Field ☐Lab
Day 3										☐Field ☐Lab
Day 4										☐Field ☐Lab
Day 5										☐Field ☐Lab
Week 2										☐Lab
Week 3										☐Lab
Week 4										☐Lab
Month 2										☐Lab
Month 3										☐Lab

If Water System chooses to take Field Tested Water Samples, any of the following Field Test Kits are acceptable: *ITS Arsenic Quick II Test Kit, Pat No. 481303, ITS Fluoride eXact Xtra Micro Strips, Part No. 486611 or Hach Nitrate Color Disc Test Kit Model NI-14.* All Water Samples from week 2 thru Month 3 must be submitted to a Certified Laboratory for analysis. Hard copies of Certified Lab Results must be provided with this form.

I hereby certify that the information listed above is accurate to the best of my knowledge. Furthermore, unless otherwise directed by the State, I understand that quarterly compliance monitoring shall commence for the above noted contaminant after initial monitoring has been completed. This quarterly routine compliance monitoring frequency shall remain in effect for the life of the treatment plant.

Water System Owner/Representative (Print)	Signature	Date

PRELIMINARY [X]

ACTUAL [ ]

ARIZONA WATER COMPANY
COST ESTIMATE WORKSHEET

DATE PREPARED: 11/3/2014

PREPARED BY: James Wilson

SYSTEM: Pinal Valley

1 OF 1

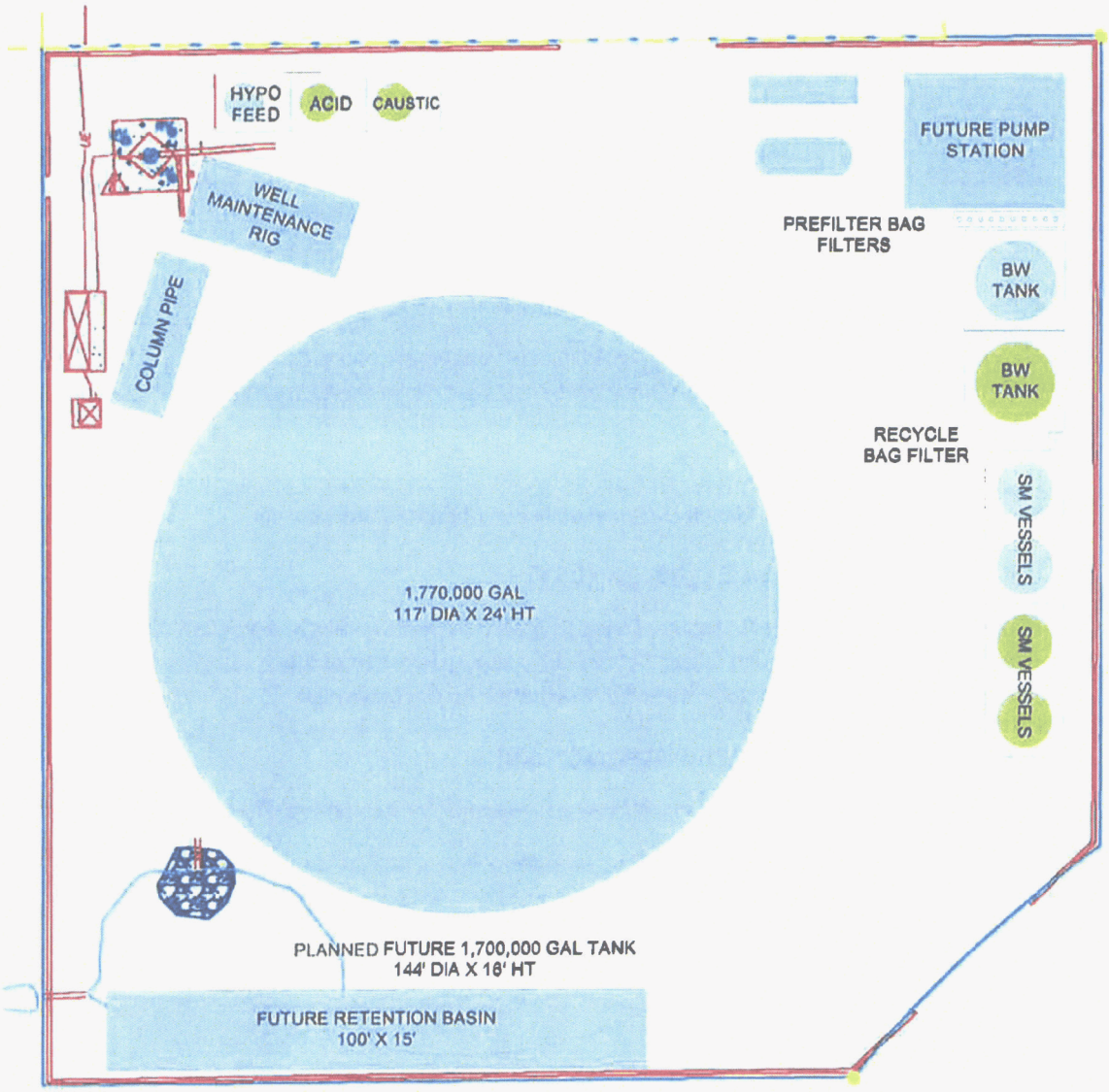
PROJECT LOCATION:

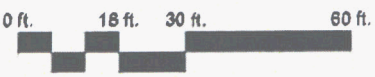
DRAWING NO

PROJECT DESCRIPTION

Design and construct an Arsenic Removal Facility at Coolidge Well No. 13

	DESCRIPTION	PLANT PROP ACCT	QUANTITY	UNIT COST	TOTAL
CONTRACT WORK	Preliminary ARF Design Analysis	332	1	$ 28,000.00	$ 28,000
	ARF Design	332	1	75,000.00	75,000
	Provide and install ARF vessels with median and all related fittings	332	1	350,000.00	350,000
	Provide and install chemical system	332	1	250,000.00	250,000
	Provide and intall onsite piping with all related fittings	332	1	165,000.00	165,000
	Provide and install backwash system with all related fittings	332	1	200,000.00	200,000
	Testing commissioning and training	332	1	75,000.00	75,000
	CA Services	332	1	60,000.00	60,000
	Contracting tax	332	1	75,000.00	75,000
	Performance and Payment bond	332	1	15,000.00	15,000
	SERVICE CONNECTIONS: DOUBLE-LONG	345			
	SERVICE CONNECTIONS: DOUBLE-SHORT	345			
	TAXABLE SERVICE CONNECTIONS COMPLETE: SINGLE-LONG	345			
	TAXABLE SERVICE CONNECTIONS COMPLETE: SINGLE-SHORT	345			
					$ 1,293,000
MATERIALS					
	SERVICE CONNECTIONS: DOUBLE-LONG	345			
	SERVICE CONNECTIONS: DOUBLE-SHORT	345			
	TAXABLE SERVICE CONNECTIONS: SINGLE-LONG	345			
	TAXABLE SERVICE CONNECTIONS: SINGLE-SHORT	345			
	TAXABLE METERS	346			
	METERS	346			
TOTAL MATERIALS					$ -
LABOR	Project management and submittal review	332	120	$ 55.00	$ 6,600
	TESTING FEE	332	1	$ 1,500.00	1,500
	PERMIT FEE	332	1	11,000.00	11,000
	SURVEY FEE	332	1	1,500.00	1,500
	FIELD INSPECTION	332	120	55.00	6,600
	INSTALL SERVICE CONNECTIONS: DOUBLE-LONG	345			
	INSTALL SERVICE CONNECTIONS: DOUBLE-SHORT	345			
	INSTALL **TAXABLE** SERVICE CONNECTIONS: SINGLE-LONG	345			
	INSTALL **TAXABLE** SERVICE CONNECTIONS: SINGLE-SHORT	345			
TOTAL LABOR					$ 27,200
SUBTOTAL - CONTRACT WORK, MATERIALS, AND LABOR					$ 1,320,200
OVERHEAD					158,500
TOTAL	REFUNDABLE PORTION [ ] NON-REFUNDABLE PORTION [ ]			**COST ESTIMATE**	$ 1,478,700





LEGEND

- AWC future planned equipment
- Proposed arsenic treatment equipment
- Future arsenic treatment equipment

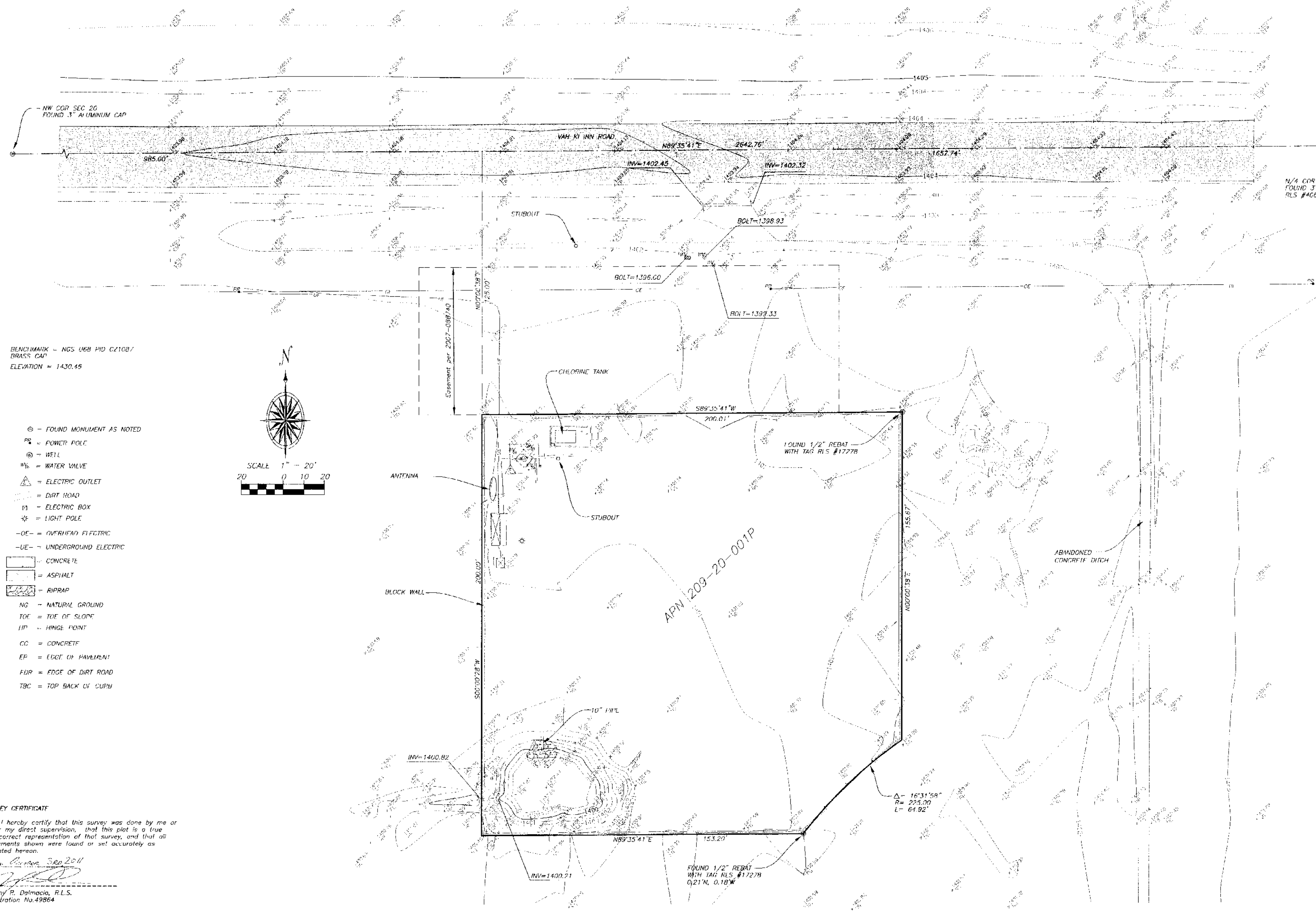
ADSORPTIVE

~~Figure 9 – Alternative 1 SM - Parallel Site Layout~~

COOLIDGE WELL NO. 13
ARSENIC REMOVAL FACILITY ALTERNATIVES EVALUATION
ARIZONA WATER COMPANY

carollo

RECORD OF SURVEY



BENCHMARK – NGS U68 PID CZ1087
BRASS CAP
ELEVATION = 1430.45

- ⊙ – FOUND MONUMENT AS NOTED
- PP = POWER POLE
- ⊛ = WELL
- WV = WATER VALVE
- = ELECTRIC OUTLET
- = DIRT ROAD
- = ELECTRIC BOX
- = LIGHT POLE
- –OE– = OVERHEAD ELECTRIC
- –UE– = UNDERGROUND ELECTRIC
- = CONCRETE
- = ASPHALT
- = RIPRAP
- NG = NATURAL GROUND
- TOE = TOE OF SLOPE
- HP = HINGE POINT
- CC = CONCRETE
- EP = EDGE OF PAVEMENT
- EDR = EDGE OF DIRT ROAD
- TBC = TOP BACK OF CURB

SURVEY CERTIFICATE

I hereby certify that this survey was done by me or under my direct supervision, that this plat is a true and correct representation of that survey, and that all monuments shown were found or set accurately as indicated hereon.

Dated: October 3rd 2011

Jeremy R. Dalmacio, R.L.S.
Registration No.49864

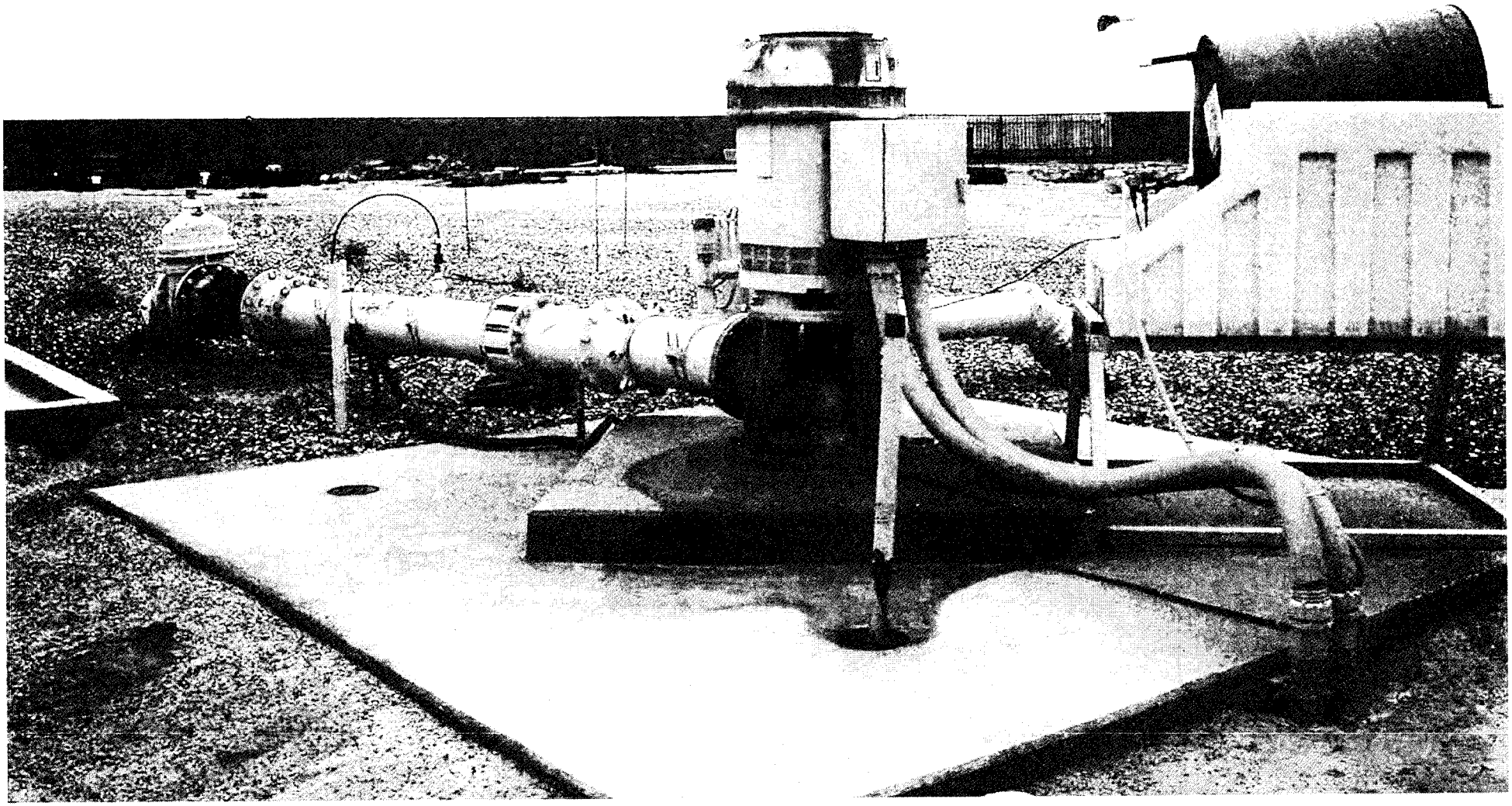
Arizona Water - Coolidge Well #13
TOPOGRAPHIC SURVEY
A PORTION OF THE NW/4 SEC 20
T5S, R8E, G&SRM, PINAL COUNTY, ARIZONA

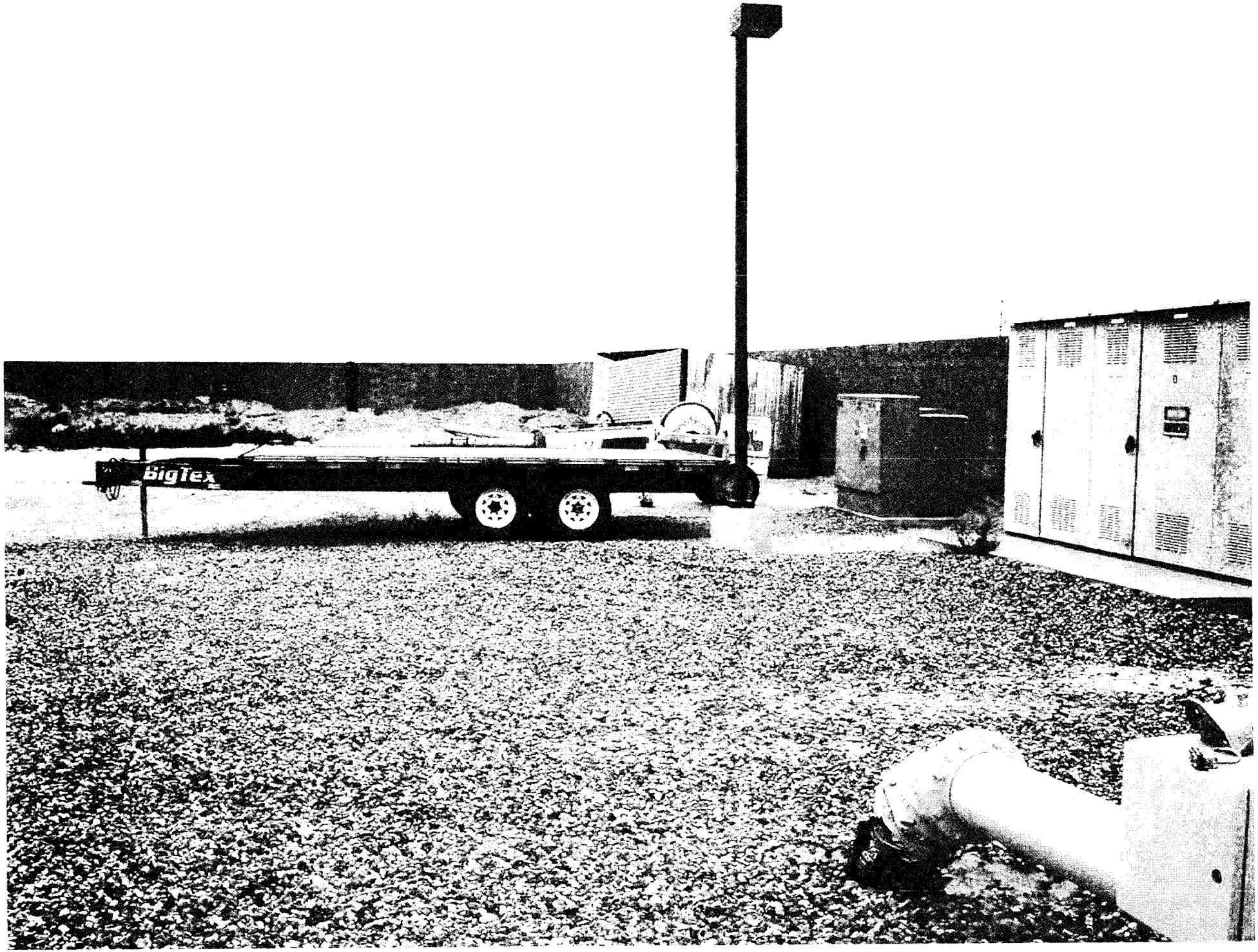
SHEET 1 OF 1

HANSEN
ENGINEERING & SURVEYING

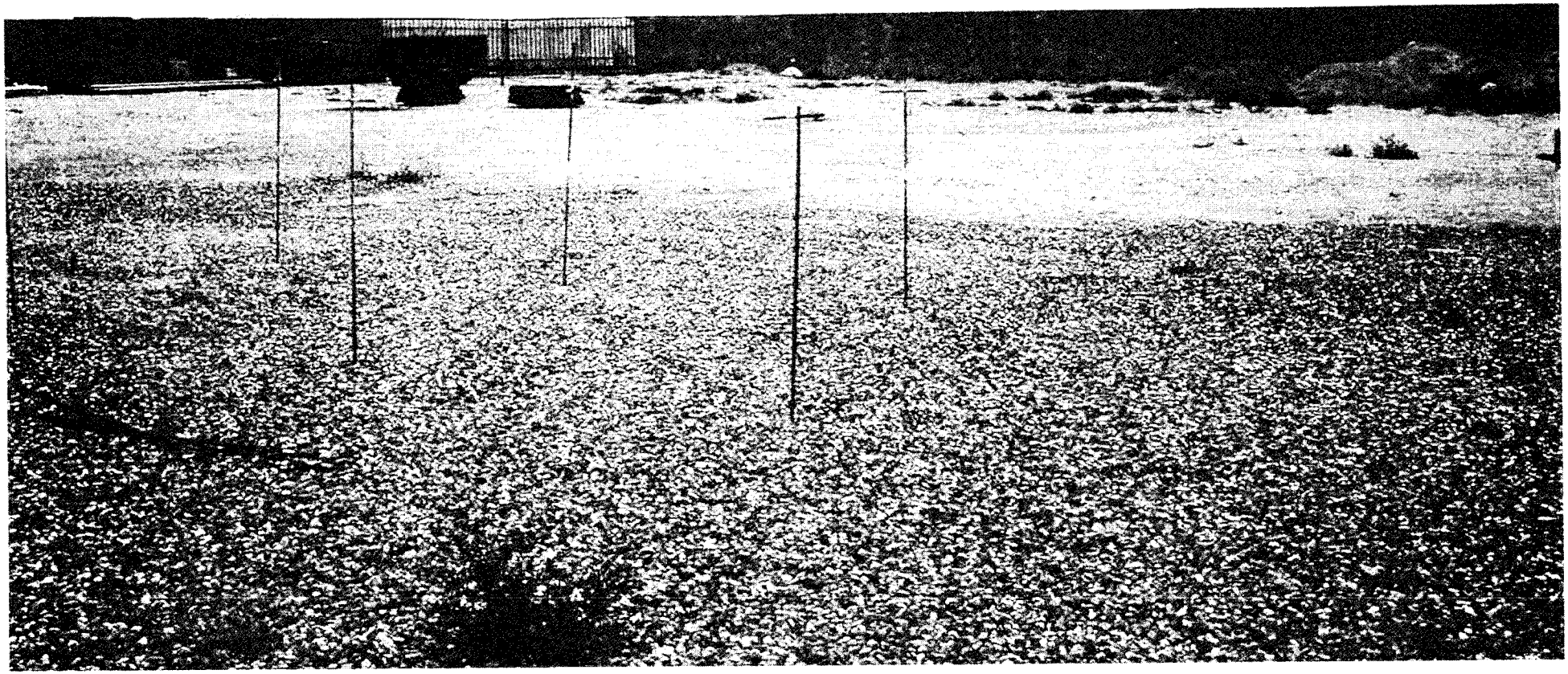
30th ANNIVERSARY 1979 2009

49864
JEREMY R.
DALMACIO

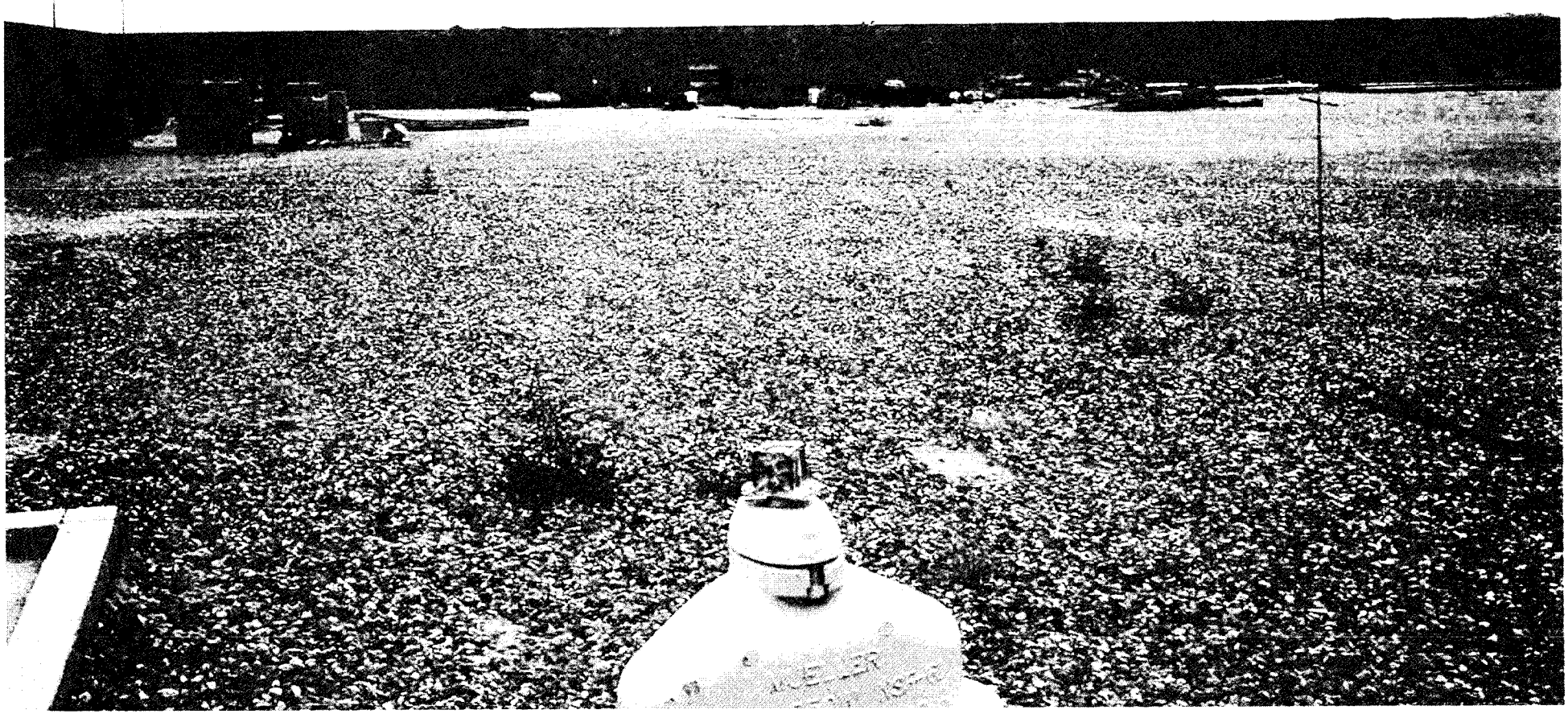


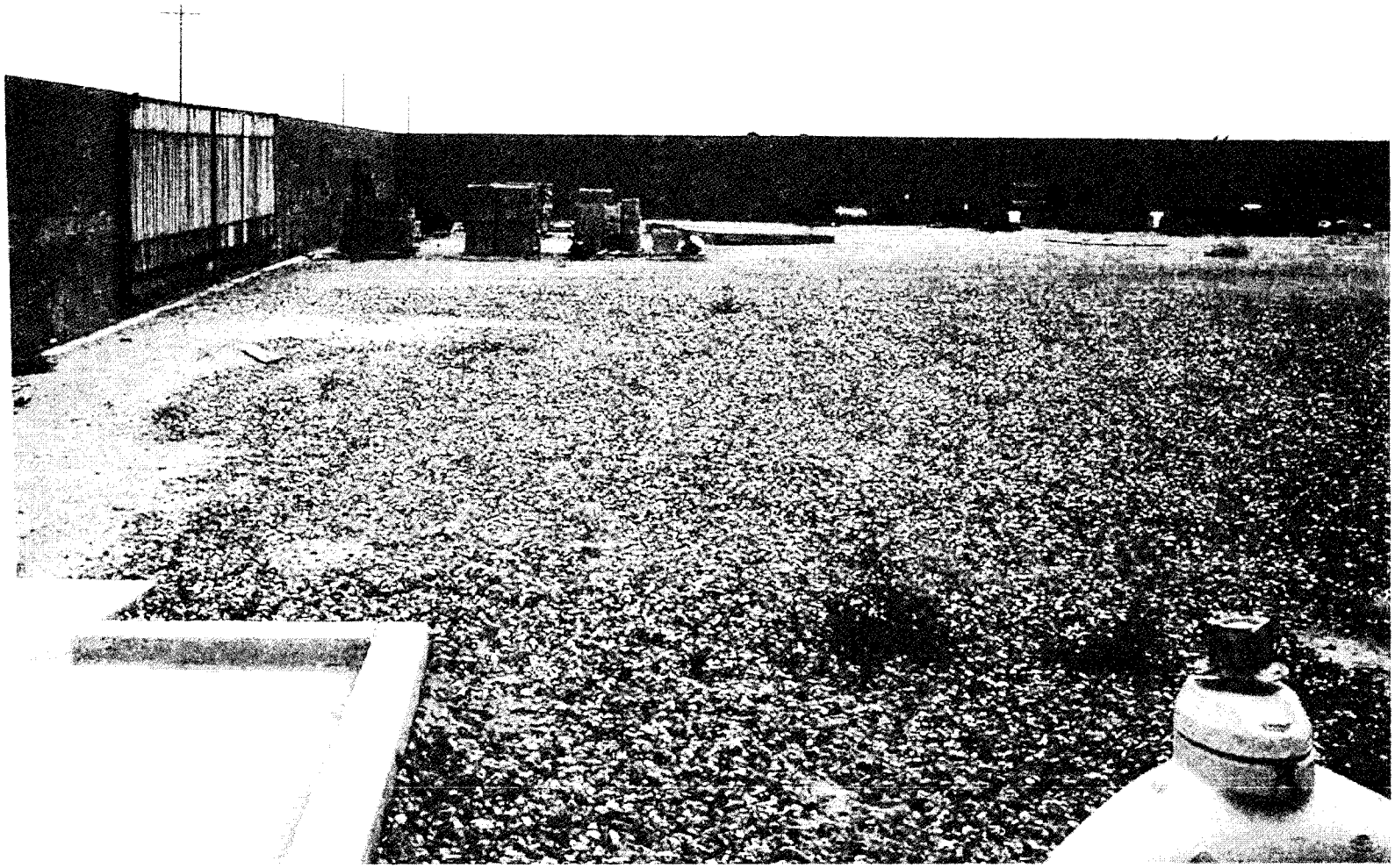
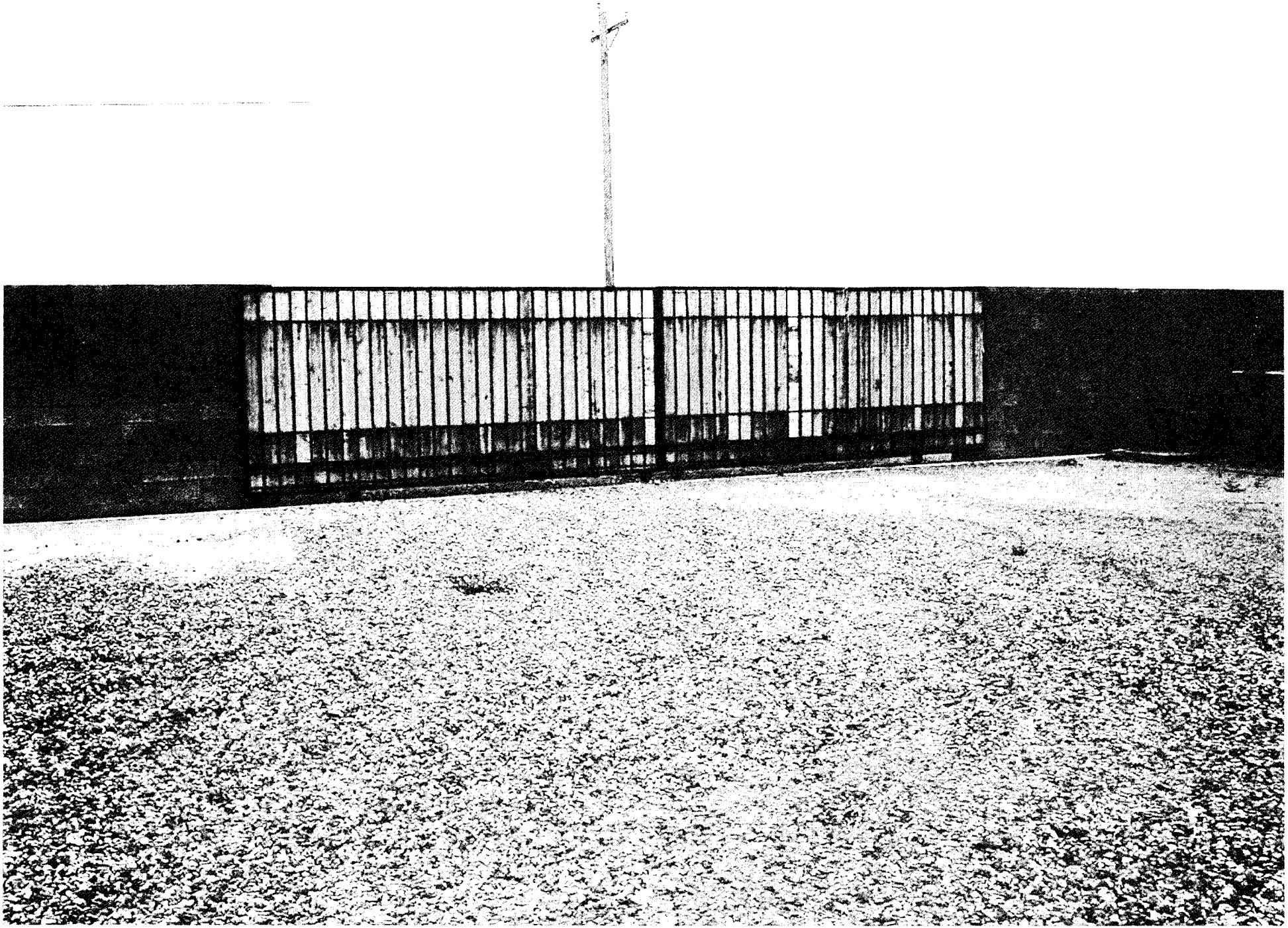
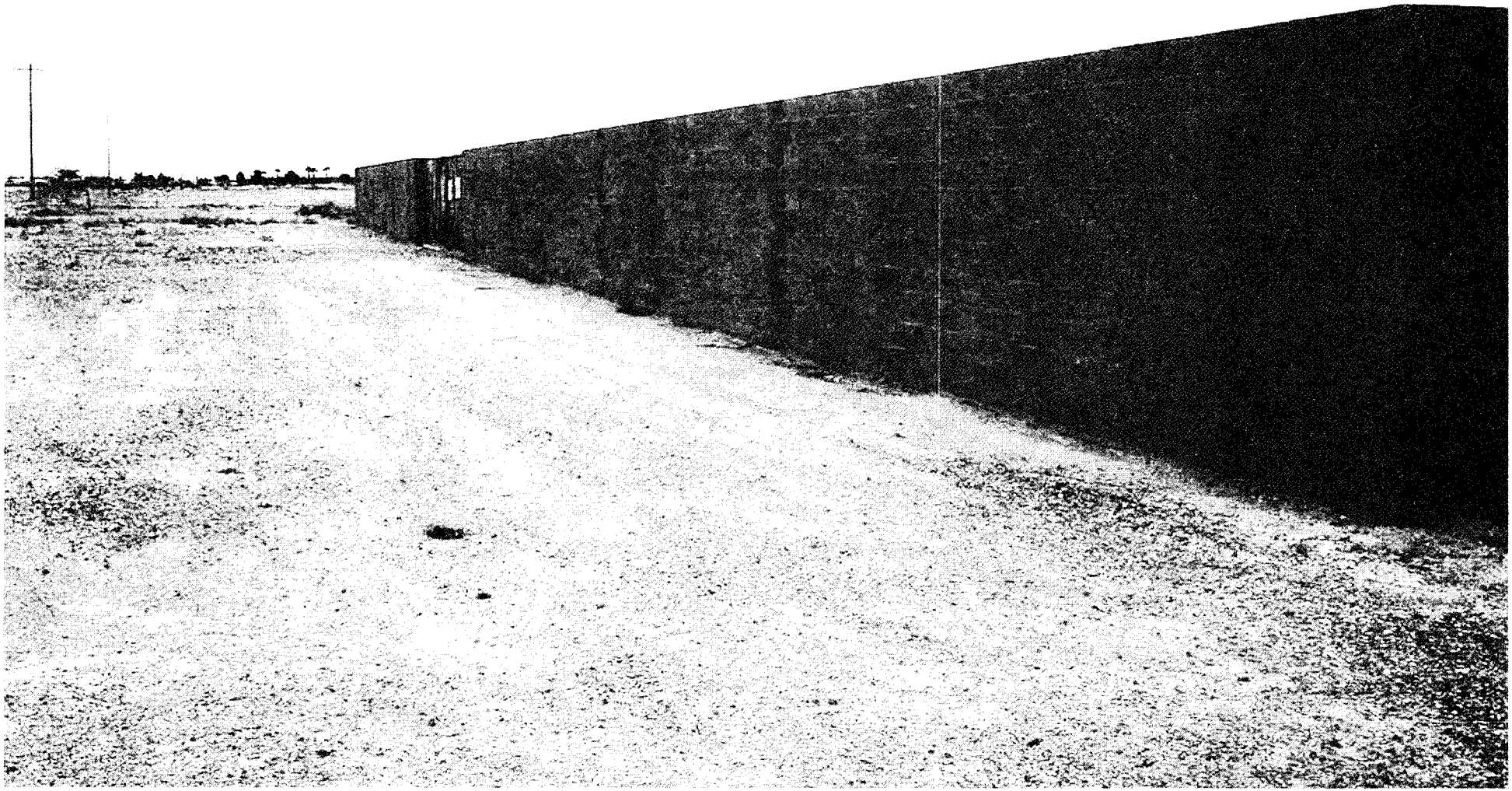
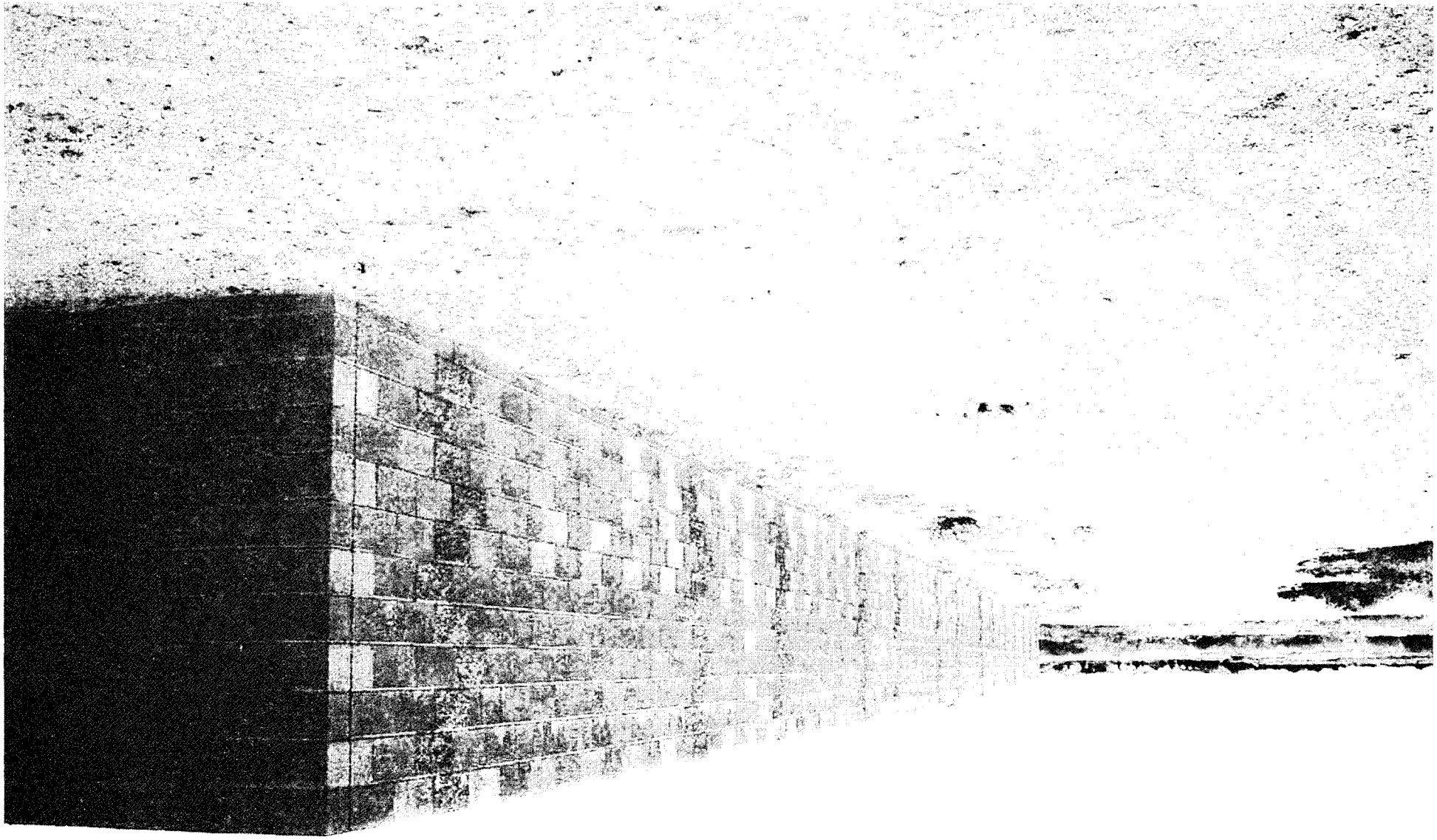

BigTex

BigTex



UNAUTHORIZED
PERSONNEL
KEEP OUT
WARNING
13
ARIZONA
WATER
COMPANY
0
0





SODIUM
HYPOCHLORITE