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WATER SUPPLY NEEDS AND SOURCES ASSESSMENT
ALTERNATIVE WATER SUPPLY STRATEGIES INVESTIGATION
A TOOL FOR ASSESSING THE FEASIBILITY OF AQUIFER STORAGE RECOVERY

by

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EXECUTIVE SUMMARY

The public water supply within the St. Johns River Water Management District (SJRWMD) is generally provided by high-quality ground water. Reliability, minimal cost and treatment requirements, and supply stability are several characteristics of SJRWMD's ground water resources that make potable ground water the water supply source of choice. However, increasing ground water usage without incurring unacceptable environmental impacts is unlikely. Therefore, SJRWMD has initiated an investigation of the feasibility of alternative water supply strategies.

OVERVIEW

Whether the supply is ground water or surface water, temporal variation in supply and demand is a key issue that had been traditionally addressed by tank and/or reservoir storage facilities or increased treatment level. In recent years, aquifer storage recovery (ASR) has been developed as an alternate means of water storage. ASR is defined as storing water in a suitable aquifer through a well during times when water is available, and recovering the water from the same well during times when it is needed. When the water supply exceeds the demand, a ground water well serves as a recharge well. Water is recovered later from the same well during peak demand. Knowledge of ASR applications, related technical issues, and regulatory constraints provides a decision tool for assessing ASR feasibility at a particular site.

In addition to this conventional storage, ASR is a management tool in utility planning and consumptive use regulation. As a utility planning tool, ASR provides the potential to store large volumes of water, which may be a strategic method of delaying or eliminating treatment plant expansion. The ASR system may also reduce land requirements for treatment facilities; the ASR storage facility does not require land area as do tanks or surface reservoirs.

PROJECT OBJECTIVE

With the potential benefit of this technology as an alternate storage method and as a water management tool, it is valuable to have guidelines to determine the feasibility of ASR in a particular area. Therefore, this technical memorandum (TM) has provided a tool to assist the SJRWMD and utilities in determining whether ASR would be a feasible alternative in solving a utility's water supply needs.

The primary objective of ASR application for this report is to store water for potable and agricultural use in the study area. It must be determined from the technical, economic, and regulatory perspective whether ASR can replace traditional surface reservoirs and tanks.

Before ASR or any storage option can be evaluated, a storage need must be identified. The storage need for a utility is the difference in supply and demand during a specified period caused by a variation in flow rate, quality, or both. It is a maximum volume required to meet demand for the period in which demand exceeds supply. The existence of a storage need defines a possible application for ASR.

There are many potential potable supply and agricultural applications for ASR in the SJRWMD. The applications fit into the following three basic supply/storage scenarios, which incorporate storage as part of the solution to a potable or agricultural water supply problem:

1. Potable water source (treated or untreated ground water or treated surface water for storage and recovery)
2. Raw water source for potable supply (untreated surface water for storage, then recovered and treated to potable standards)
3. Raw water source for agricultural supply (untreated surface water for storage and recovery).

Although each scenario is technically feasible, untreated raw water ASR implementation would be difficult under current regulation. However, progress is being made to incorporate the different applications into the existing regulations.

ASR Process

Operation of ASR consists of injecting water to be stored into an aquifer for later removal. As water is stored in an aquifer or storage zone of lower quality, a buffer zone appears between the native water and the stored water. As an increased water volume is stored in the aquifer, the buffer zone will start to move away from the well. When the recovery cycle begins, the water removed is the water closest to the well that has nearly the same quality as the previously treated water. One recharge-and-recovery phase is called an operation cycle. The volume of water stored verses the volume of water removed is referred to as the recovery efficiency. This efficiency may start low and greatly improve in successive test cycles, depending on the stored water volume, and eventually approach 100 percent.

Evaluating Feasibility

The typical procedure for implementing an ASR system includes three general phases. The first phase is the preliminary feasibility assessment and conceptual design. In this phase, initial information is gathered to assess whether ASR should be considered as a storage option. After ASR is determined desirable, hydrogeological, financial, and regulatory issues are investigated to determine whether ASR can be feasible for the specific water supplier. The second phase includes the initial field investigation and permitting for a test ASR well. Detailed information is then collected from this well and the final feasibility of an ASR system is assessed. After the well is complete, several tests are performed to define the applicability of the ASR system and determine the proper expansion needed to meet the particular water supplier's needs. The third phase includes the expansion of the ASR system to match the demand on the utility. The general use of this document and screening tool is to aid in the first two phases of the ASR implementation procedure.

Feasibility Screening Tool

The screening tool, which is provided as the backbone of this document, is divided into the following three areas:

- Technical feasibility factors—provides the majority of the screening tool in two subsections: facility planning factors, which determines the need for ASR over other storage options; and hydrogeologic, design and operational factors, which aids in determining whether ASR will satisfy the specific needs of the utility.
- Cost factors—provides approximate costs for ASR systems for specific flow rates compared to other options related to storage or expansion.
- Regulatory factors—provides the existing regulations that govern the ASR concept.

The screening tool incorporates a score report which is provided for the four sections (designated Part A, B, C, and D on the report sheets). The scoring sheet will be used to record the respective ranking scores for each subsection or utility information important to ASR.

ASR is becoming an integral part of water supply and resource management throughout Florida. As population increases, so does the demand on ground water as the main source of water supply. Thus, more emphasis will be placed on alternate water sources (surface and reuse water) to offset the ground water withdrawal. ASR practicability extends to other areas of resource management, such as general aquifer recharge with surface water to augment distant future water supplies, wetland management, drainage control, and others.

INTRODUCTION

Public water supply within the St. Johns River Water Management District (SJRWMD) is generally provided by high-quality ground water. Several characteristics of SJRWMD's ground water resources make potable ground water the water supply source of choice. First, ground water is inherently reliable—an important attribute for public water supply. Second, treatment requirements and cost are often minimal because of the generally good-quality raw ground water. Third, if the resource is developed and managed properly, the quality of the raw ground water remains stable.

To date, high-quality, reliable, and inexpensive public ground water supplies have been developed within the SJRWMD. However, it is unlikely that all additional future public water supply needs can be met by increasing the use of ground water resources without incurring unacceptable environmental impact. Therefore, the SJRWMD has initiated an investigation of the feasibility of alternative water supply strategies.

PROJECT BACKGROUND

The SJRWMD previously evaluated the potential impact of increased ground water withdrawal through the year 2010 (Vergara, 1994). Based on this evaluation, the SJRWMD identified areas where water supply problems are now critical or will become critical. An increase in ground water withdrawal could adversely impact area water resources, including impacts on natural systems, ground water quality, and existing legal users.

The SJRWMD is investigating the technical, environmental, and economic feasibility of alternative water supply strategies as a means of preventing the existing and/or projected adverse impact. The SJRWMD-sponsored program includes investigations conducted by several consultants, including CH2M HILL, and by SJRWMD staff.

Figure 1 illustrates the water supply options being considered for the SJRWMD. Major options include increased supply, demand reduction, and increased system storage to better manage existing supplies. For any area of critical concern, increased supply options could include developing one or more of the following potential water supply sources:

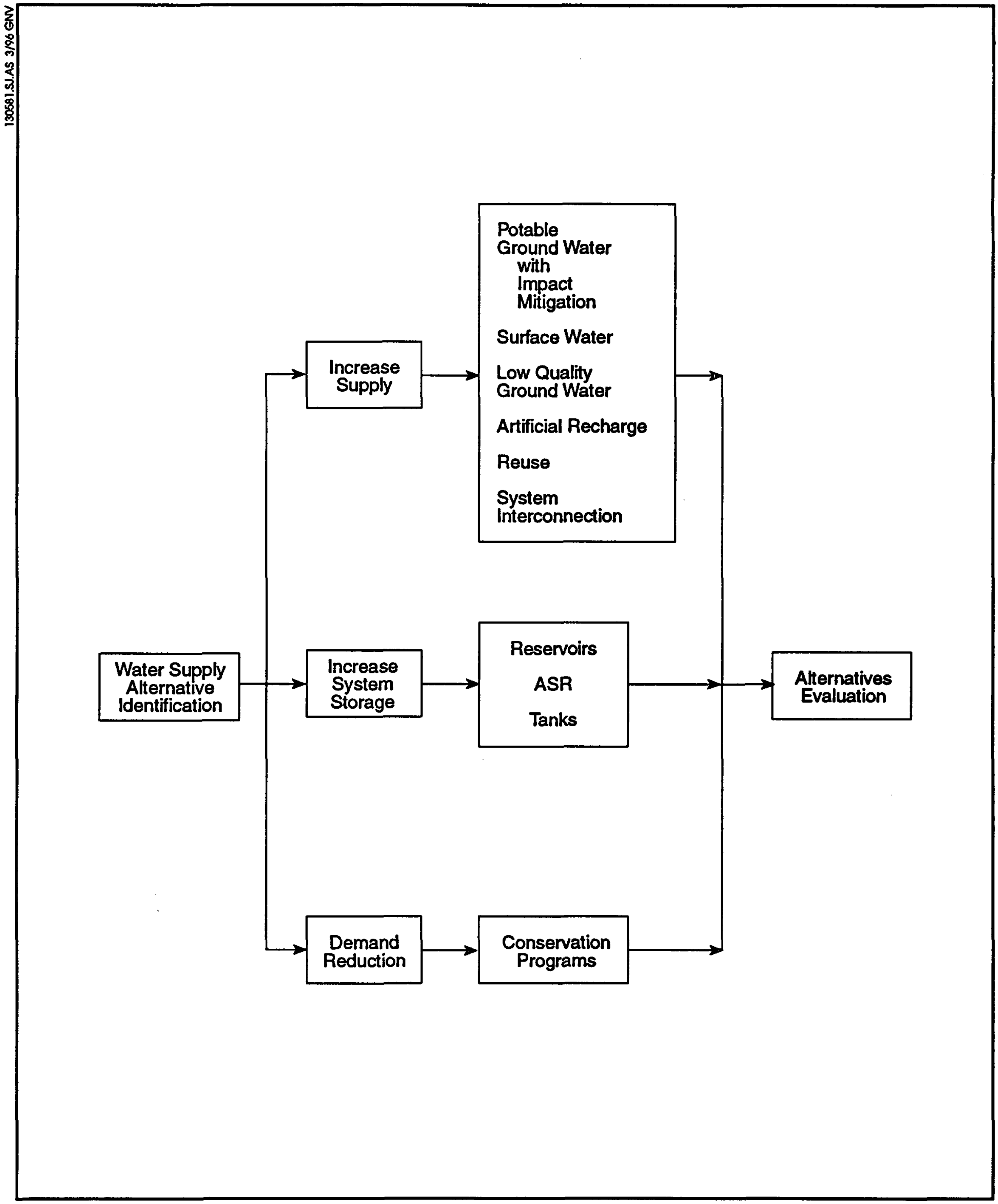

Figure 1. Water supply development options for the SJRWMD

- Potable ground water with mitigation of any adverse impact
- Surface water
- Low-quality ground water
- Artificial recharge
- Reuse of reclaimed water
- Water supply systems interconnection

Increased system storage could include the use of reservoirs, aquifer storage recovery facilities, or ground storage tanks. Demand reduction may be achieved by various water conservation initiatives. A combination of increased supply, increased system storage, and demand reduction, in many cases, may provide the most environmentally acceptable and cost-effective future water supply systems.

This project is part of CH2M HILL's first phase of the required alternative strategy investigation. Included in the investigation are the following additional water supply sources or water management techniques, collectively referred to as *alternative water supply strategies:*

- Surface water supply development
- Aquifer storage recovery (ASR)
- Development of low-quality water sources
- Mitigation and avoidance of impact of ground water withdrawal

PURPOSE AND SCOPE

Although often the main focus, water source is just one aspect of water supply planning. Whether the supply is ground water or surface water, temporal variation in supply and demand is a key issue that had been traditionally addressed by tank and/or reservoir storage facilities or increased treatment level. In recent years, ASR has been developed as an alternate means of water storage. Knowledge of ASR applications, related technical issues, and regulatory constraints provides a decision tool for assessing ASR feasibility at a particular site.

Pyne (1995) defines ASR as the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed. When the water supply exceeds the demand, a well serves as a recharge well. Water is recovered later from the same well during peak demand.

In addition to this conventional storage, ASR is a management tool that can be considered in utility planning. As a utility planning tool, ASR provides the potential to store large volumes of water, which may be a strategic method of delaying or eliminating treatment plant expansion. The increased storage may address new changes in peak demand. The ASR system may also reduce land requirements for treatment facilities; the ASR storage facility does not require land area as do tanks or surface reservoirs. ASR may also reduce the required peak withdrawal rate required. Although the total volume removed would be the same, the reduced peak rate may decrease intrusion or upconing of brackish water into the wellfield or may reduce or eliminate wetland impact.

With the potential benefit of this technology as an alternate storage method and as a water management tool, it is valuable to have guidelines to determine the feasibility of ASR in a particular area. Therefore, this technical memorandum has provided a tool that should be used by the SJRWMD and utilities in determining whether ASR would be a feasible alternative in solving a utility's water supply problems. The preliminary screening tool addresses the general aspects in Figure 1 by defining supply and demand in terms of storage need, then allowing evaluation of hydrogeologic conditions for a particular site. Cost are compared and regulatory issues are reviewed because these aspects may reduce the feasibility of applying a technically feasible ASR solution.

ASR OVERVIEW

As shown in Figure 1, supply, storage, and demand are the three components of water supply development. One type of storage developed in the last few decades is ASR, the practice of injecting water into an aquifer to be stored for future recovery and use. While this does not increase the volume of water available for supply, it allows more efficient storage of water when it is available.

ASR is a broader vision of a conventional artificial recharge because the recharged water is recovered for a beneficial use at the same location (Pyne, 1995). Implementation of ASR is accelerating in the U.S. and overseas because of benefits such as the ability to overcome the hydraulic limitations and the large land area requirements of many surface recharge sites.

This overview of ASR identifies objectives, presents example potable and agricultural applications, and describes preparation and operation of a typical ASR well.

OBJECTIVES

Although most ASR applications are for seasonal, long-term, or emergency storage of drinking water, many other applications have been considered or implemented at ASR sites. An ASR system can usually be designed and operated to meet a primary objective and one or more secondary objectives. For example, a primary objective would be to use an ASR well to store water for seasonal peak demand; a secondary objective would be to locate the ASR well to boost transmission line pressure. The following examples of ASR applications were derived from projects that are operational or in various stages of development (Pyne, 1995):

- Seasonal storage and recovery of water
- Long-term storage or water banking
- Emergency storage or strategic water reserve
- Disinfection by-product reduction
- Diurnal storage
- Restoration of ground water level
- Reduction of subsidence
- Maintenance of distribution system pressure
- Maintenance of distribution system flow

- Improvement of water quality
- Prevention of saltwater intrusion
- Reduction of environmental effects of streamflow diversion
- Agricultural water supply
- Nutrient reduction in agricultural runoff
- Enhancement of wellfield production
- Deferring expansion of water facilities
- Compensation for surface salinity barrier leakage loss
- Reclaimed water storage for reuse
- Soil aquifer treatment
- Stabilization of aggressive water
- Hydraulic control of contaminant plumes
- Fish hatchery water temperature control

The primary objective of ASR application for this report is to store water for potable and agricultural use in the study area (Figure 2). Although ASR storage of reclaimed water is a significant application of ASR to meet irrigation needs, it is not within the scope of this investigation. It must be determined from the technical, economic, and regulatory perspective whether ASR can replace traditional surface reservoirs and tanks. There are several secondary advantages to this subsurface storage:

- Provide an option to replacing source solutions, such as source expansion or water purchase from other utilities to meet peak demands

- Solve distribution problems, such as larger transmission requirements to meet peak demands or low pressure conditions

- Optimize plant operation, such as varying operating capacity or treatment requirements

- Address planning issues, such as reducing future land requirements for storage tanks or plant expansion

In each case, a storage need is identified that will meet the objective requirements. Storage need is the difference in supply and demand over a specified period caused by a variation in flow rate, quality, or both. It is a maximum volume required to meet demand for the period in which demand exceeds supply. When plotting supply and demand versus time, the storage need is the area between the two curves when demand exceeds supply. Figure 3 illustrates a typical supply, demand,

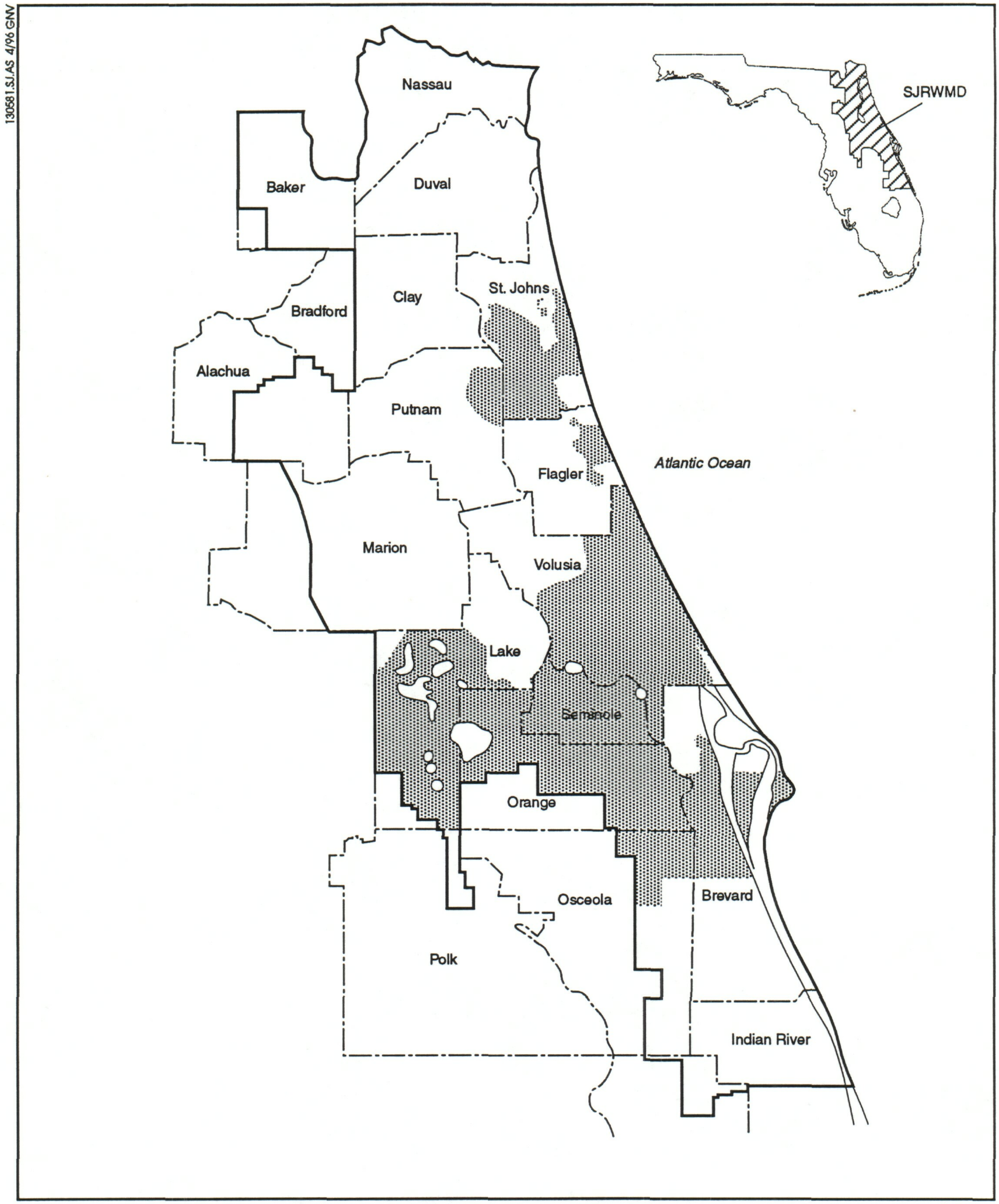

Figure 2. Approximate St. Johns River Water Management District Study Area (Vergara 1994).

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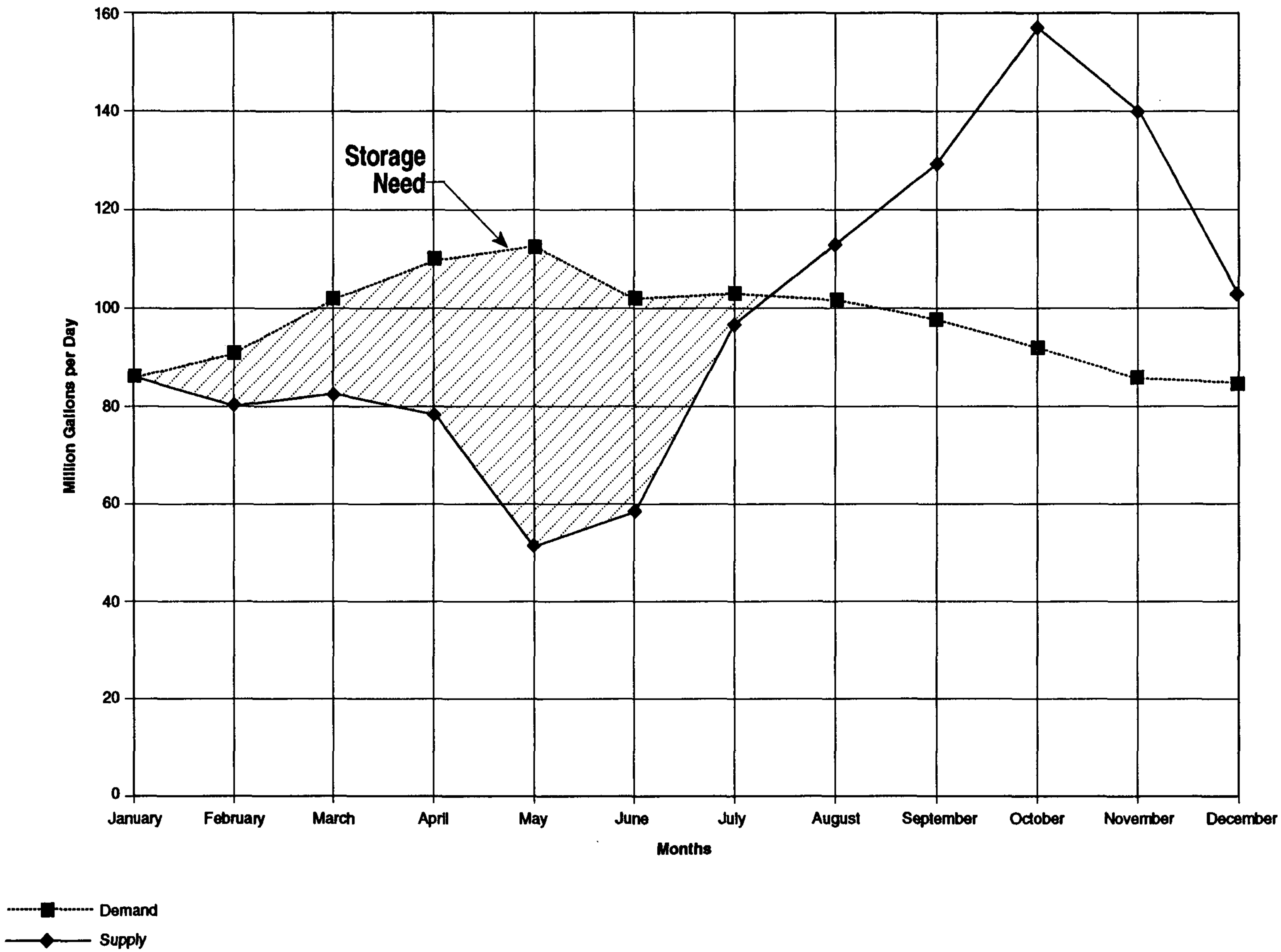

Figure 3. Storage need for typical supply-and-demand variation

and storage need. The storage need defines a possible application for ASR.

APPLICATIONS

There are many potential potable supply and agricultural applications for ASR in the SJRWMD. The applications fit into three basic scenarios (Figure 4), which incorporate storage as part of the solution to a potable or agricultural water supply problem. Each scenario includes developing a storage need quantity. However, although technically feasible, current regulations may restrict these scenarios.

Potable Water Use

Potable water supplied through public water supply systems is subject to federal and state regulation for specific primary and secondary drinking water quality standards. Figure 4 shows two scenarios for which storage may be required for a potable water system. Although storing treated water (Scenario 1) has generally been the practice in this emerging technology, it is also technically feasible to store raw water (Scenario 2).

Scenario 1 presented in Figure 4 uses ASR after the treatment process in order to store potable water. In this scenario, the raw water source can be either surface water or ground water. The raw water would be processed through the treatment facility at a fairly constant rate. During periods of low demand, excess water would be recharged into the storage aquifer using the ASR wells. To meet peak demand, stored water would be pumped from the aquifer to supplement plant production. In this case, ASR replaces or supplements the tanks of a more traditional water treatment system.

For ground water supply, the source water is generally reliable and storage need would depend on demand fluctuations caused by seasonal population change or weekday and weekend differences. In these cases, raw water would be supplied from a producing aquifer, treated to finished water quality, and delivered to a receiving aquifer for storage. For surface water supply, there are usually seasonal quantity and quality variations in flow. During drought conditions, raw water withdrawal could also be limited. In this case, peak use could often coincide with low supply.

During peak surface water supply, the treated water would be stored in the receiving aquifer to meet future demand. There could be

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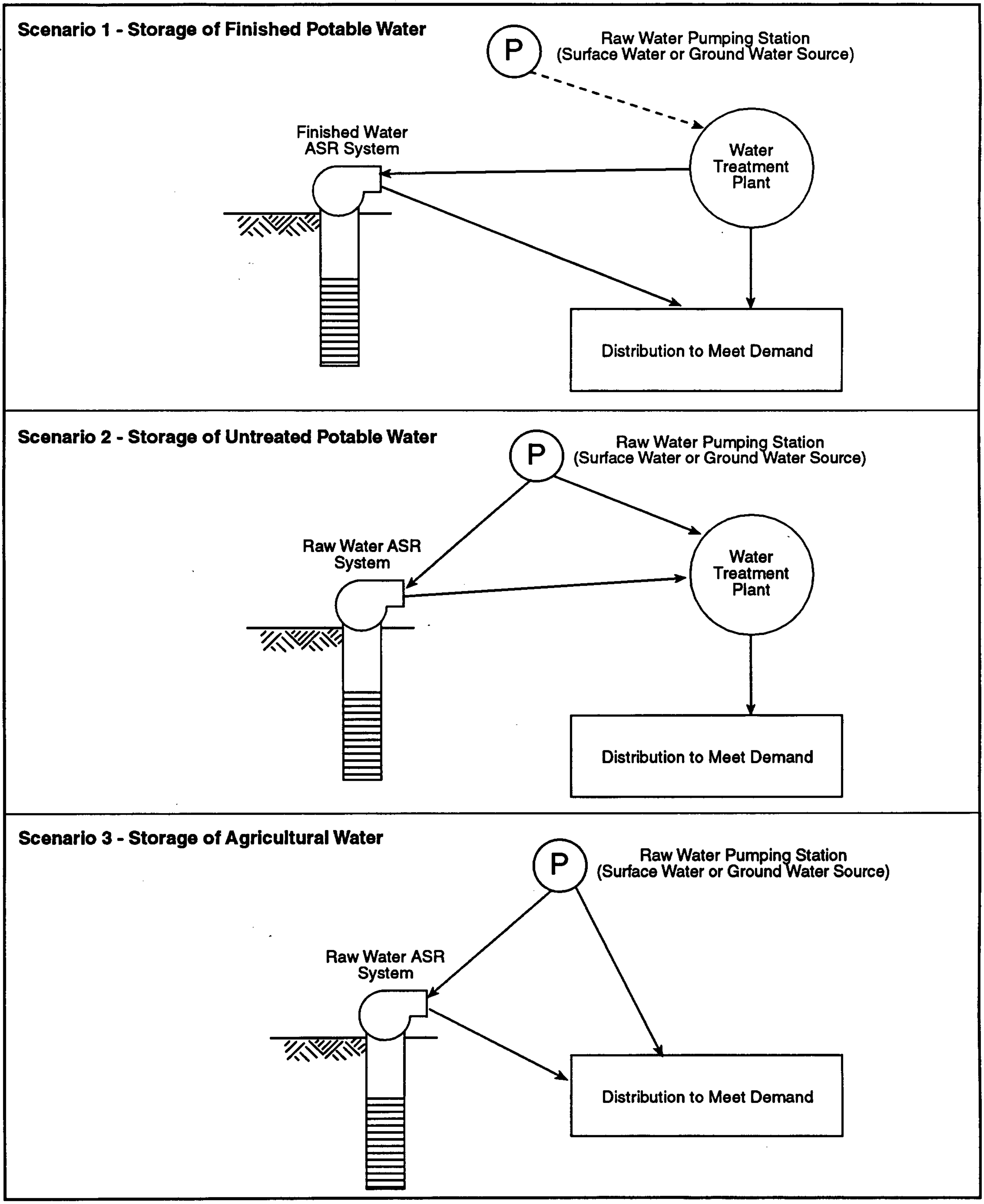

Figure 4. Potential ASR applications

seasonal or daily variation in demand that increases storage need. In short, Scenario 1 provides a storage location for treated potable water.

Scenario 2 considers either surface water or ground water as the raw water source that is stored in the ASR system. The stored water is recovered, processed, and distributed. This application is used when water treatment capacity exceeds peak demand, but raw water capacity is seasonally limiting. It is also used when peak supply does not occur during peak demand. For ground water as the raw water supply, this would be an interaquifer transfer—storing better quality water in a brackish aquifer. Although transferring water from a producing to a receiving aquifer for storage prior to treatment is technically feasible for ground water as the raw water supply, an application could not be identified within the SJRWMD.

For surface water supply, Scenario 2 represents a means of fairly constant intake in order to operate the plant at an even rate, rather than varying during periods of peak supply and demand. As previously discussed, this could address both seasonal variation in supply flow and quality as well as seasonal or daily variation in demand. Although associated regulatory issues make implementation difficult, this is a technically feasible alternative. Further review and discussion of this scenario is provided in the Regulatory Issues section.

Agricultural Water Use

Although agricultural water is not subject to water quality regulation, water quality is important for crop success and ultimate yield as well as for livestock use. As previously discussed, variation in water quantity and quality may point to an ASR storage solution. Because treatment is not typically provided for agricultural use, this would be an interaquifer transfer for a ground water source and a raw water storage system for a surface water source (Scenario 3).

Although each scenario is technically feasible, implementation would be difficult under current regulation. To date, raw surface water storage has only been accomplished in Florida through water quality exemption for secondary standards and disinfection to meet primary standards. Further review and discussion of this is provided later in the regulation section.

Storage Need

Storage need is a function of water quantity and water quality. A storage need associated with temporal variation in supply quantity and quality as it relates to demand is a typical issue for potable water applications. Water may also be stored for a specific purpose, such as emergency supply or consistent plant operations. The storage need and/or supply and demand curves are adjusted for these objectives to determine the long-term, seasonal, or short-term storage need.

Long-Term Storage

Long-term storage involves producing and storing excess water for several years to postpone other infrastructure change, such as:

- Source surface reservoir expansion
- Water purchase from other utilities
- Larger transmission requirements to meet peak demands
- Increase in operating or treatment capacity
- Land requirements for storage tanks or plant expansion

Figure 5 shows how increased ASR storage is projected to delay source expansion in Eversham, New Jersey. Although average daily demand (ADD) could be met by the wellfield capacity, the maximum day demand (MDD) could not be met. Adding a 1.7 mgd ASR system is to delay wellfield expansion. Excess water is overproduced during low demand months and stored in an ASR system to meet MDD.

Seasonal Storage

A seasonal storage need relates the variability of the quantity or quality of the source water to the variation in demand. A surface water source during low flow months may not provide adequate volume or quality water; however, during the wet season, excess water may simply flow into the ocean. In many cases, storing excess water from one month will meet demand for the next dry month without increasing the treatment plant capacity. Similarly, storing the higher quality water that may be available in high-flow periods may allow demand to be met during months when the source is of lower quality. This may allow drinking water standards to be met without changing the treatment process.

Short-Term Storage

A short-term storage need meets variation in daily or hourly use. The short-term storage need may be apparent in coastal communities where there is a higher draw to the area on weekends. Also, the short-term storage need addresses the higher water use found in the morning for most communities. Although short-term storage needs

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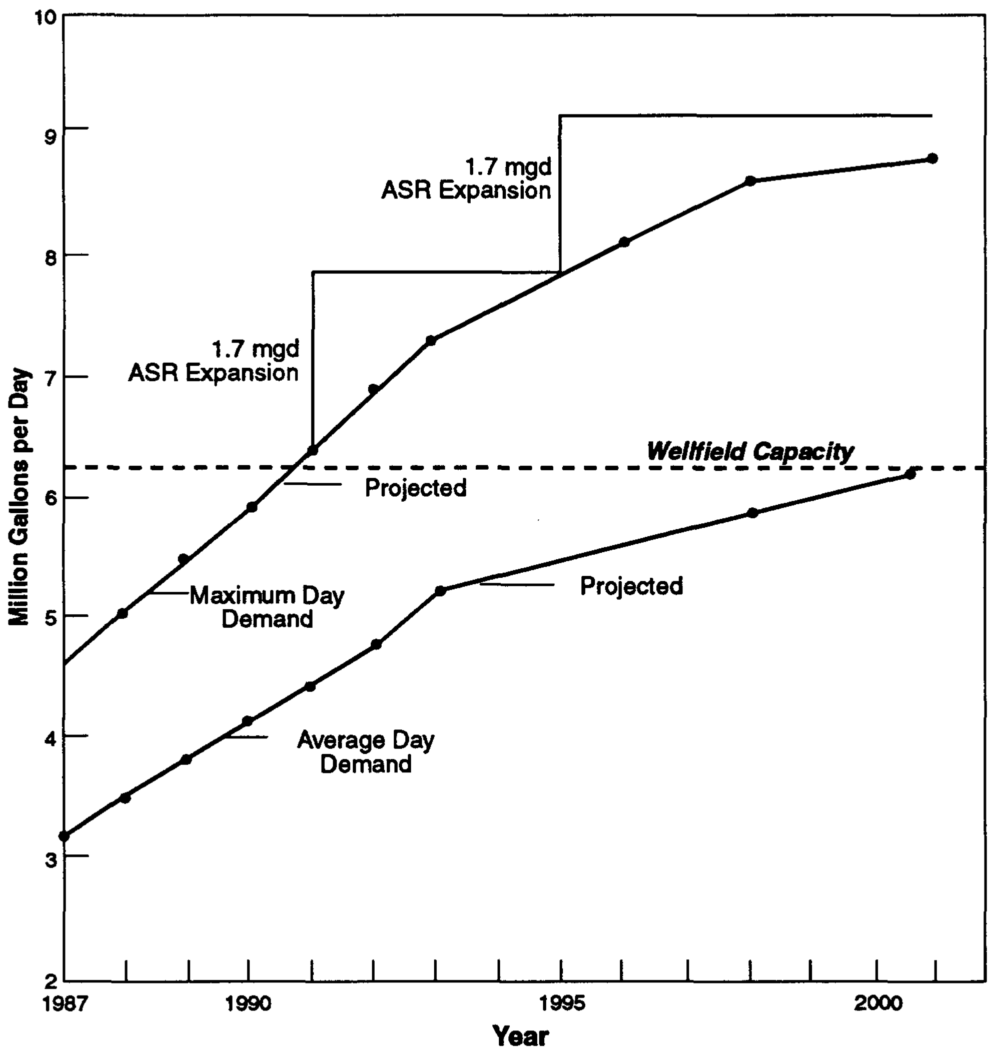

Figure 5. Supply-demand relationship with new ASR facilities, Eversham Municipal Utilities Authority, New Jersey.

Adapted from Pyne, 1995

are actual issues for water planning, the quantities alone may not be sufficient to justify an ASR system. These issues are further quantified for the screening tool, which is presented later in this report.

The parameters for determining storage need are demand quality or use, demand quantity, source water quality, and source water quantity. The first parameter, demand quality, is based on the proposed water use—agricultural or potable. There are various quality standards associated with the ultimate water product in potable and agricultural uses. Federal and state primary and secondary drinking water standards apply to potable supply delivered through public water supply systems. Treatment is generally required to meet the standards. Disinfection using chlorination, ozonation, or ultraviolet radiation is usually the minimum treatment required to meet the applicable potable standards.

Specific standards are not regulated for most agricultural uses. Agricultural water quality must only assure that irrigation or livestock application would not be harmful. Although treatment is not typically found in agricultural systems, the water quality is often lower than drinking water standards. Therefore, water that may not be acceptable without treatment for potable use, may be acceptable for a specific agricultural use. Although a variation in quality may be unacceptable for potable water, the variation may be within an acceptable range for agricultural use. To meet consistent potable quality, there may be a storage need that would not be needed were the resource used for agriculture. Therefore, the ultimate use is important in determining the storage need.

Another parameter is demand quantity and its variation. It is generally understood that water demand varies during certain times of the day or certain months of the year. Examples for potable water demand variation include the following:

- Peak water use during weekday mornings before work and school
- Peak water use during summer evenings for lawn watering
- Higher demand during weekends because of area attractions
- Higher demand during the winter caused by seasonal population increases
- Larger seasonal requirements because of tourism events, such as spring break or the Daytona 500

Agricultural water use is higher during the growing season, part of which may coincide with periods of lower rainfall. Rainfall in amounts less than expected may result in higher irrigation water demand for crops. Therefore, fluctuation in supply quantity may create a storage need for the facility.

Water supply quality is another factor related to storage need. Although ground water sources are fairly consistent, a surface water supply or blended brackish water supply may vary in quality. For example, the quality of river water may be unacceptable during low flow. The lower quantity of water may increase the level of total dissolved solids (TDS). Following the wet season, the water may be sufficiently diluted to be of acceptable quality for the ultimate use. Storing excess water would meet at least part of the demand during periods of unacceptable water quality instead of requiring additional treatment to reach potable standards.

Because treatment generally is not provided for agricultural use, this storage can determine whether the source is acceptable for long-term agricultural use. For instance, low flow in a surface water source may increase dissolved substances, collectively called salts. Because the effects of increased salinity are reduced crop growth and/or poor soil structure (SCS, 1982), this may eliminate the source as an irrigation supply if storage is not provided. The ASR system may provide the storage to meet the irrigation need at the appropriate quality. Therefore, water supply quality is an important consideration, usually gauged in conjunction with the proposed demand quality required.

The most obvious factor for storage need is source water quantity. For ground water supply, the issue may be the consumptive use, or maximum pumping, requirement or the plant capacity. If the consumptive use quantity allowed exceeds peak use during most of a given period, the excess may be stored to meet peak demand when demand exceeds the consumptive use. Similarly, if the plant capacity is inadequate for peak demand during a certain period, ASR storage may help meet demand while deferring plant expansion (Figure 5). For surface water, the supply is tied to hydrologic conditions. For a river, there is probably significant difference in wet season and dry season flow available for withdrawal. During high flow periods, excess can be stored for use during high demand or low flow periods.

In summary, the timing of water demand and supply, in terms of quantity and quality, affects the storage need calculation.

Traditionally, storage needs were addressed with tanks or surface reservoirs while quality variation was handled by additional treatment. ASR provides an alternative storage mechanism, which may provide secondary benefits.

OPERATIONS

Operation of ASR consists of injecting water to be stored into an aquifer for later recovery. Understanding several aspects of this operation is essential in considering ASR as a storage option. Based on site-specific hydrogeology and recharged water, several ASR terms are defined below.

- Test Cycle—When an ASR well is initially constructed, testing is required to observe the hydraulic and chemical response of the storage zone to ASR. After a specified volume is injected, the water is stored for a short period, then the water is recovered and its quality is monitored. This injection and recovery is called a test cycle. For an initial cycle, recovery usually occurs until the background water quality is re-established, or 100 to 150 percent of the injected volume is recovered. For subsequent test cycles, recovery usually occurs until quality reaches a target TDL level appropriate for the site or until the stored water is fully recovered, whichever occurs first.

- Recovery Efficiency—The recovered water is monitored for several water quality parameters and the volume removed is recorded. When the recovered water quality exceeds the applicable product water standards, recovery is terminated. The recovered water volume below the specified concentrations, as a percent of the total injected water volume, is called the recovery efficiency. Since a cycle is the completion of one injection and one withdrawal period for the ASR well, the efficiency represents the amount of water withdrawn from ASR during any single recovery cycle. At most ASR sites, ASR recovery efficiency reaches 100 percent after a few test cycles at the same volume.

- Blending and Buffer—Trends in ASR systems suggest that the initial recovery efficiency in brackish aquifers could be low (possibly 30 percent), based on the volume of water initially stored. The reason for this low percentage is because the initial water injected into the system blends with the native water in the aquifer, providing a mixed-water buffer zone that has a water quality between that of the native water (possibly brackish) and that of the injected water, leaving a small amount of unmixed potable water to be initially recovered in the aquifer storage zone.

As typical ASR systems are operated, the buffer water is not available to the public water supply for direct distribution. However, the buffer water is not lost to the aquifer because it remains between the native water and the stored water providing a vital role for the ASR system. In some emergencies, it may be possible to recover a portion of the stored buffer water and minimally retreat the water to appropriate water quality standards. However, the loss of the buffer water will affect subsequent use of the ASR system and the buffer must be replaced for proper operation.

During initial ASR system testing, several cycles are needed to achieve an optimal performance efficiency level. As the buffer grows to a required volume, recovery efficiency increases during successive cycles continually approaching 100 percent recovery at most sites. However, to achieve this level of efficiency, there may be variations in the number of cycles of operation and the volume of buffer zone water invested. When 100 percent recovery efficiency is not attained after several test cycles, there may be several contributing factors:

- Inappropriate ASR well or wellfield design or operation
- Cycle testing at a scale that is too small for the storage zone
- Insufficient number of cycles to develop the storage zone
- Density stratification in highly saline aquifers
- High transmissivity of storage zone, particularly with brackish- or poor-water-quality aquifers

Recovery efficiency below 100 percent may still represent a cost-effective water management decision. The annual investment in water that is not recovered may be small compared to the cost of alternatives to supply water during emergencies, such as loss of water treatment or transmission facilities during a hurricane.

After the system has been fully tested, it is important to cycle the system during normal operation. The following reasons explain why a utility should not inject continuously into ASR wells without recovering the stored water, even for aquifer recharge without recovery needs:

- Reverse of the flow in these wells allows for periodic redevelopment of the wells. This helps to avoid plugging from suspended solids moved in the aquifer material.
- The well has an associated radius of influence or capture zone, based on the aquifer parameters, well construction, and pumping rate. Water outside this radius is unaffected by the action of a pumping well. If water is continuously stored and not recovered, it is possible to store water beyond the hydraulic influence of the ASR wellfield during recovery, thereby losing water to the aquifer and, under natural aquifer gradients, possibly having it flow away from the site.

ASR Case Studies in Florida

These selected case studies are successfully operated ASR systems located in Florida. To date, six ASR systems are currently operational in Florida, and approximately 14 are either proposed or in the construction and testing phase (Pyne, 1996). Today, 25 ASR systems are operational across the country, and approximately 50 systems are under development. Some of these sites are described below. Several existing ASR sites are presented at the end of the hydrogeological, design and operational factors section, later in this report.

Manatee County, Florida

This was the first ASR system in Florida. Constructed and tested between 1978 and 1983, this system has been operational since 1983. It includes two ASR wells with a combined recovery capacity of about 5 mgd, located at the County's surface water treatment plant (WTP) at Lake Manatee. Treated drinking water is stored in a confined, limestone artesian aquifer at a depth of 400 to 700 feet. During 1996, the County plans to expand this system to 10 mgd recovery capacity. Plans also include construction of a reclaimed water ASR system at the County's three wastewater treatment plants, to reduce wet weather effluent discharges and to conserve water for agricultural irrigation use during the dry season. Capacity of this planned reclaimed water ASR system is estimated at about 12 mgd.

Peace River, Florida

The source of water is from the Peace River, which is highly variable in quantity and quality with periods of up to 2 months with no allowable diversions as relatively normal events and periods of up to 7 months can occur. An offstream reservoir is used to meet demands during periods of no diversion from the river and to improve water quality.

ASR operation began in 1985 with two wells in the Tampa and Suwannee formations at depths of about 400 to 500 feet and 700 to 900 feet, respectively. The transmissivity for these storage zones range from 37,000 to 45,000 gallons per day per foot (gpd/ft). Initial capacity was about 1.4 mgd. The system was expanded in 1988 to include three new wells and retrofitting of one existing well. It was expanded again to a total of 9 wells in 1995, with a recovery capacity of 7.7 mgd. The next phase of expansion will begin during 1996 and will include 14 additional wells, increasing total recovery capacity to about 20 mgd. A recent analysis of operational performance to date indicates that full recovery of the stored water should be achieved once the target storage volume for the system is reached. The target storage volume for this site is 350 mg per mgd of recovery capacity, or about 2.8 billion gallons (BG) in 1995. Present storage volume is 1.5 BG.

Testing is underway at one well in the Avon Park formation at a depth of 1,300 to 1,500 feet to confirm its suitability for ASR storage. Recovery yield from this well is 3 mgd. If feasibility is confirmed, future ASR storage will occur in three zones beneath the WTP, thereby saving the cost of extensive piping for a dispersed ASR wellfield.

Cocoa, Florida

Operation began in 1987 with the first ASR well, which had a capacity of about 1 mgd. Expansion occurred in 1992, increasing recovery capacity to 8 mgd from 6 wells. Four additional ASR wells are being designed at the 44-mgd WTP site, storing treated drinking water in a brackish, limestone artesian aquifer with a TDS of 1,000 to 2,000 mg/L. The water source is the Cocoa wellfield, the capacity of which is 48 mgd. The storage zone is a confined limestone aquifer with a transmissivity range of 36,000 to 101,000 gpd/ft, which contains brackish water. Water is treated and stored beneath the plant at a depth of 300 to 360 feet. After approximately three cycles of operation, essentially the same volume of water stored can be recovered from this system. The target storage volume is currently 100 MG per mgd of recovery capacity, or 0.8 BG.

Palm Bay, Florida

Operation began in 1989 at one well with 1 mgd recovery capacity, deferring the need for expanding the 6-mgd WTP. The storage zone is a brackish, limestone artesian aquifer with a TDS of about 1,360 mg/L. After the target storage volume of 90 MG was stored, the water system lost a major wholesale customer who switched to onsite wells for an industrial supply. No water was recovered for about 4 years. At that time, demand had increased to the point where ASR recovery would be beneficial, however only about 60 percent of the water could be recovered before quality exceeded potable standards. The industrial water supply wells were located about one mile from the ASR site and are in the same aquifer. They are believed to have created a significant change in the local hydraulic gradient, causing stored water to move slowly away from the ASR well. Operation of the ASR well is continuing as originally planned, with seasonal storage and recovery to meet peak demands. No loss of water is apparent with this annual mode of operation. The WTP has recently been expanded to 10 mgd capacity, meeting local needs for the near future. No ASR expansion is needed for several years.

Marathon, Florida

Investigations began during 1986 to evaluate the feasibility of storing treated drinking water in a seawater aquifer. Native water TDS concentration in the storage zone is 37,000 mg/L. One ASR well and two observation wells were constructed and tested and the system became fully permitted and operational during 1993. The storage zone is a confined, sand aquifer at a depth of 388 to 428 feet beneath the Marathon pump station. Testing has shown that treated drinking water can be stored economically to meet emergency water supply needs that are assumed to require a recovery rate of 3 mgd for 30 days. Not all of the water is recovered, reflecting density stratification losses in the seawater aquifer. Recovery efficiency is within a typical range of 40 to 70 percent, depending upon the duration of water storage. This is the only water system in the world to store treated drinking water in a seawater aquifer.

When the eye of Hurricane Andrew passed over the Florida City WTP in 1993 and threatened water supply to the Florida Keys, the Florida Keys Aqueduct Authority had 10 MG of water that was available for recovery at Marathon. At that time, water in south Miami was selling for $6.00/gallon. Emergency water supply is the primary reason for ASR in the Keys because water to Key West crosses 43 bridges and travels 120 miles. Average hurricane frequency in this area is about every 5 to 7 years.

Boynton Beach, Florida

One ASR well began operation during 1993, storing treated drinking water in a confined, limestone artesian aquifer with brackish water with a TDS of 3,900 mg/L. The storage zone is at the base of the Hawthorn formation at a depth of 800 to 900 feet. Recovery is at a rate of 2.5 mgd. Target storage volume for this well has been 60 mg, although a smaller target volume may be sufficient in the future to meet seasonal and short-term variations in system water demand. The water source is from several wells in the shallow, unconfined aquifer. This water is treated and stored in the ASR well at the 22-mgd WTP site.

Recovery efficiency has climbed during seven cycles completed to date, from 30 to 73 percent. Continued improvement in recovery efficiency is expected with successive cycles. During the last cycle, water was stored for about 6 months before recovery, and recovery efficiency dropped to about 65 percent. However, it is unclear whether this reduction really occurred because there may have been equipment problems or density stratification and mixing may have caused some loss of the stored water.

Okeechobee, Florida

This ASR system was designed to divert surface water from Taylor Creek-Nubbin Slough away from Lake Okeechobee. The surface water was overloading the lake with phosphorous, making the lake highly eutrophic. The objective of the ASR system is to store the surface water during seasonal peak flows from the slough and recover the water later to meet agricultural irrigation needs. The ASR storage zone was selected at a depth of 1,200 to 1,700 feet, located within the Upper Floridan aquifer.

This zone has a transmissivity of 4.38 MG/day/ft with a TDS concentration of 7,000 mg/L. This transmissivity is the highest of any storage zone used for an ASR site tested to date. Initial tests indicated recovery efficiencies in the range of 35 percent, with potential to increase to 60 percent after storing a much greater volume of water. While this recovery efficiency may be quite low, further analysis has shown that any recovery efficiency greater than about 40 percent is a net gain to the regional water management system.

Other ASR Systems in Florida

Additional Florida ASR systems in development, construction, or testing include:

- Miami-Dade Water and Sewer Department (two sites)
- Tampa
- West Palm Beach
- Fort Lauderdale
- Broward County
- Seacoast Utilities (Delray Beach)
- Collier County (two sites)
- Lee County
- Punta Gorda
- Hillsborough County (reclaimed water at two sites)
- New Smyrna Beach (reclaimed water)

ASR Systems in the United States

Florida offers excellent conditions for ASR technology to be successful, but ASR can be successful in almost any location. Other operational ASR systems located across the United States include:

- Mount Pleasant, South Carolina
- Chesapeake, Virginia
- Swimming River, New Jersey
- Wildwood, New Jersey
- Gordons Corner, New Jersey
- Haddon, New Jersey
- Kerrville, Texas
- Denver, Colorado
- Highlands Ranch, Colorado
- North Las Vegas, Nevada
- Las Vegas Valley Water District, Nevada
- Calleguas Municipal Water District, California
- Foothills Municipal Water District, California
- Goleta Water District, California
- Oxnard, California
- Pasadena, California
- Salt Lake County, Utah
- Tucson, Arizona
- Seattle, Washington

ASR IMPLEMENTATION PROCEDURE

The typical procedure for implementing ASR includes three general phases. The first phase is the preliminary feasibility assessment and conceptual design. In this phase, initial information is gathered to assess whether ASR should be considered as a storage option. After ASR is determined a potential storage option, hydrogeological, financial, and regulatory issues are investigated to determine whether ASR can be feasible for the specific water supplier. The second phase includes the initial field investigation and permitting for a test ASR well. Detailed information collected from this well is used to assess the final feasibility of an ASR system. After the well is complete, several tests are performed to define the applicability of the ASR system and determine the proper expansion needed to meet the water supplier's needs. The third phase includes the expansion of the ASR system to match the demand on the utility.

Although ASR technology is not new, it is complex and should be investigated with a degree of caution throughout all phases of implementation. In the initial phase of an ASR investigation, competent professionals experienced in ASR should be consulted to guide the ASR feasibility process, which will facilitate the success of this storage option. When correctly implemented, ASR can be the most cost-effective option for many applications.

ASR FEASIBILITY SCREENING TOOL

Determining the feasibility of ASR as a ground water supply storage option is a moderately complex process. The ASR feasibility flowchart is presented as Figure 6. Many factors must be considered at every step to complete the study of how an ASR system will work in certain subsurface geological environments and whether the results of such a system would meet the ultimate goal. Many ASR systems provide working models of how these systems can benefit the state water management districts and the individual water suppliers in Florida.

This document and screening tool (Figure 7) has been developed to aid in the first two phases of the ASR implementation procedure. This screening tool identifies information and concerns that must be addressed to better assess an ASR system's potential to meet a water supply objective. When this tool is first utilized, it will be evident that the screening of an ASR system will be repeated in several stages during the two initial phases of investigation. The ultimate feasibility

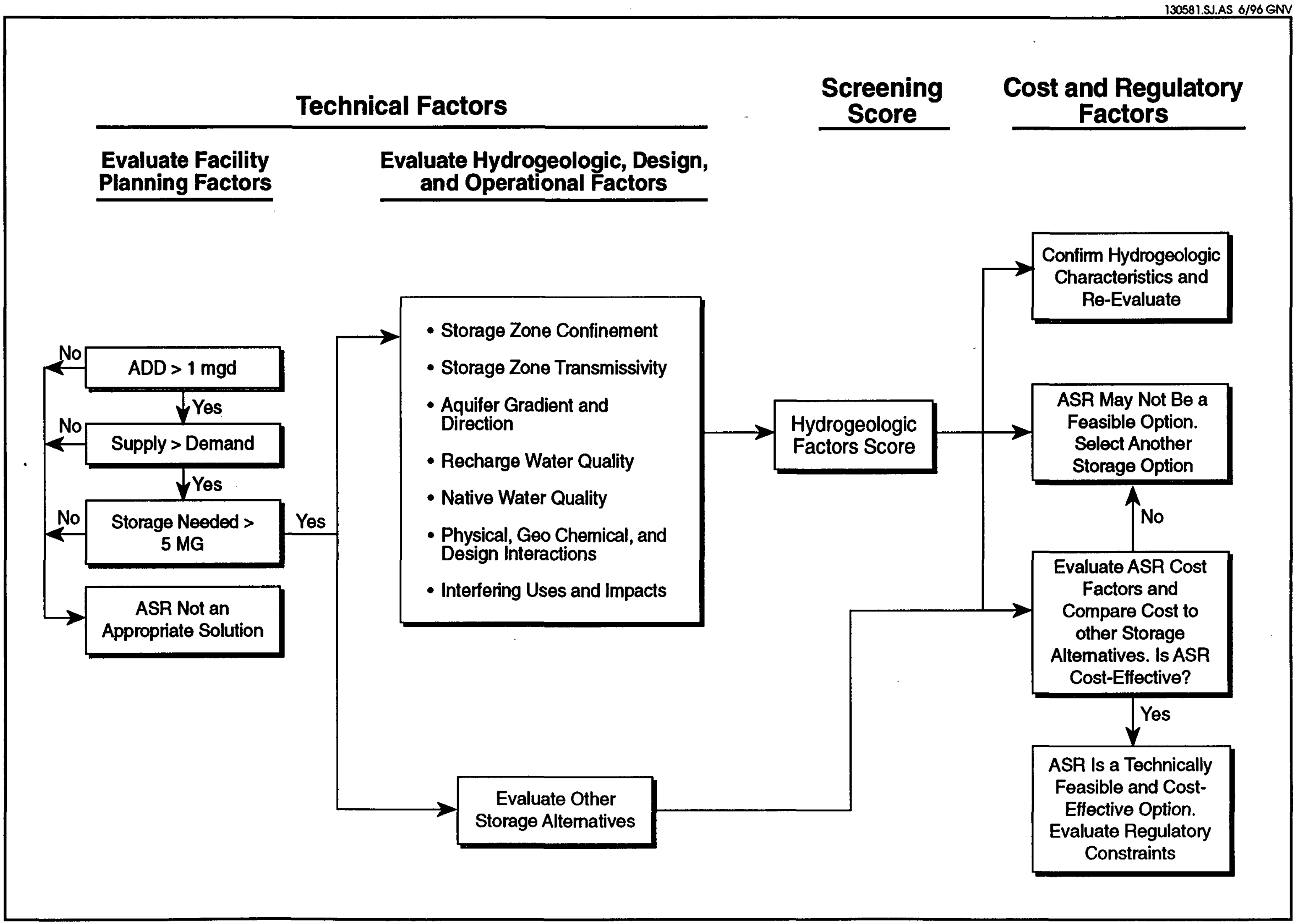

Figure 6. ASR feasibility flowchart

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Facility Designation ______________________ Water Source ______________ Date ____________

Facility Director ______________________ Intended Use ______________

Water Management District St. Johns River Water Management District Date ____________

District Officer ______________________

PART A FACILITY PLANNING FACTORS

1	Average Daily Demand (End of Planning Period):	________ MGD	Is ADD Greater Than 1 mgd?	____ YES	____ NO
2	a. Total Supply Volume for Planning Period: b. Total Demand Volume for Planning Period:	________ MG ________ MG	Is the Supply Volume Greater Than Demand Volume?	____ YES	____ NO
3	List Storage Need Volumes Calculated: a. Long Term Volume: b. Seasonal Volume (For Quantity and Quality): c. Short Term Volume: d. Other (Emergency, Plant Operations, etc): e. Total a. through d., above	 ________ MG ________ MG ________ MG ________ MG ________ MG	Are any of the Volumes Greater Than 5 MG ?	____ YES	____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

	ASR Hydrogeologic, Design and Operation Factor Scores							
	1	2	3	4	5	6	7	
Section Points	Storage Zone Confinement	Storage Zone Transmissivity	Local Aquifer Gradient/Direction	Recharge Water Quality	Native Water Quality	Physical, Geochemical Interactions	Interfering Uses and/or Impacts	
5								High Feasibility Zone
4								High Feasibility Zone
3								Further Investigations Needed Zone
2								Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	Total Score
Score								

Score	Feasibility Level	Type of Study Recommended
160-215	*High Confidence*	*General – Confirm Assumptions*
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Figure 7. Feasibility screening report, Parts A and B

of an ASR system can only be finalized after the first ASR well has been thoroughly tested.

The screening tool is divided into the following three sections:

- Technical feasibility factors—provides the majority of the screening tool in two subsections: 1) facility planning factors, which determine the need for ASR over other storage options, and 2) hydrogeologic, design and operational factors, which aid in determining whether ASR will satisfy the specific needs of the utility.
- Cost factors—provides approximate costs for ASR systems for specific flow rates compared to other options related to storage or expansion.
- Regulatory factors—provides the existing regulations that govern the ASR concept.

The screening tool incorporates a scoring sheet, which is provided for the first three sections (designated Part A, B, and C on the scoring sheet). The scoring sheet is used to record the respective ranking scores for each subsection or utility information important to ASR. Instruction on completing the scoring sheets can be found as the last subheading in the technical feasibility section.

The ASR feasibility flowchart (Figure 6) and the parameters indicated on the chart form the basis of the ASR feasibility screening tool. Many factors must be considered in order to determine how an ASR system will work in certain subsurface geological environments. These factors also must be considered to determine whether the results of such a system would benefit the ultimate goal. Several ASR systems are working models of how these systems can benefit the water management districts and the individual water suppliers in Florida.

TECHNICAL FEASIBILITY FACTORS

Two types of technical factors are used to aid in the determination of the feasibility of ASR. The first group of factors relates to facility planning and includes projected supply-and-demand values, treatment and transmission, and storage need. The second group is hydrogeologic design and operational factors, such as aquifer characteristics, local and regional uses, and water quality. The screening tool from Figure 7 and the scoring parameters are included in Appendix A.

FACILITY PLANNING FACTORS

The first screening levels for ASR feasibility, facility planning factors, involve the demand, supply, and storage required to solve a water supply problem. This ASR feasibility screening includes characteristics such as ADD, total annual supply-and-demand volumes, and long-term, seasonal, or short-term storage need based on variations in source quantity and quality. These issues are addressed by collecting historic water use data and/or projecting future demand and comparing these to water supply quantity and reliability. This subsection discusses each facility planning parameter and the associated minimum values for the feasibility screening. Part A of the facility screening tool (Figure 7) provides a *yes–no* decision point for each parameter. A *yes* decision for all three parameters means that the user could proceed to the hydrogeologic parameters. A *no* decision identifies that other water use or storage options are expected to be more economic; therefore, no further investigation into ASR is required.

Demand

To define facility needs as they relate to new service areas or existing system expansion, the projected capacity needs and water use patterns are required. These are the *demand*. For potable use, annual average daily demand (AADD) records in million gallons per day (mgd) for a minimum of 5 years, and projections for the planning period are used. For agricultural use, this is the irrigation requirement expected for the crop.

For the screening tool, the first decision point is the magnitude of the demand. For potable use, the data required is the MADD or AADD for at least 5 years (Figure 8). The largest year's average daily demand is entered in Part A, Item 1 in Figure 7. If this value is greater than

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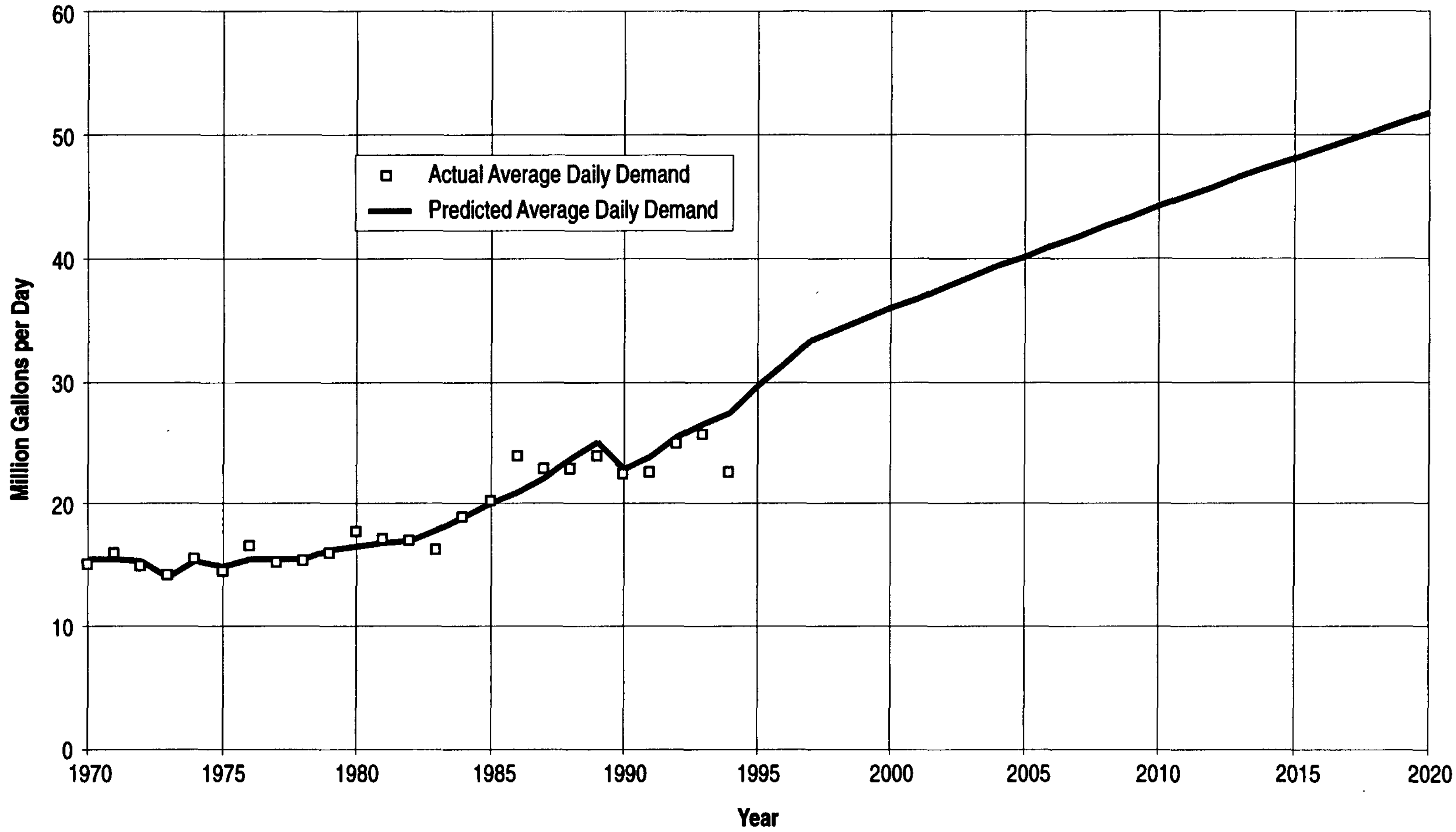


Figure 8. Dyal water treatment plant example actual and predicted demand, City of Cocoa, Florida

1 mgd, the system may be of sufficient size for an ASR application. This daily demand level is based on experience with planning ASR systems and on basic economic comparisons presented in a later section. For systems with at least the 1 mgd average demand, ASR remains a possible solution. Therefore, a *yes* decision routes the user to the next parameter. Owners of systems with lower flow should consider other storage options. In this case, the required storage would be better provided in ground or elevated storage tanks, and no further ASR feasibility issues need to be addressed. For agricultural use, this decision point is not relevant; therefore, the user proceeds to the next parameter.

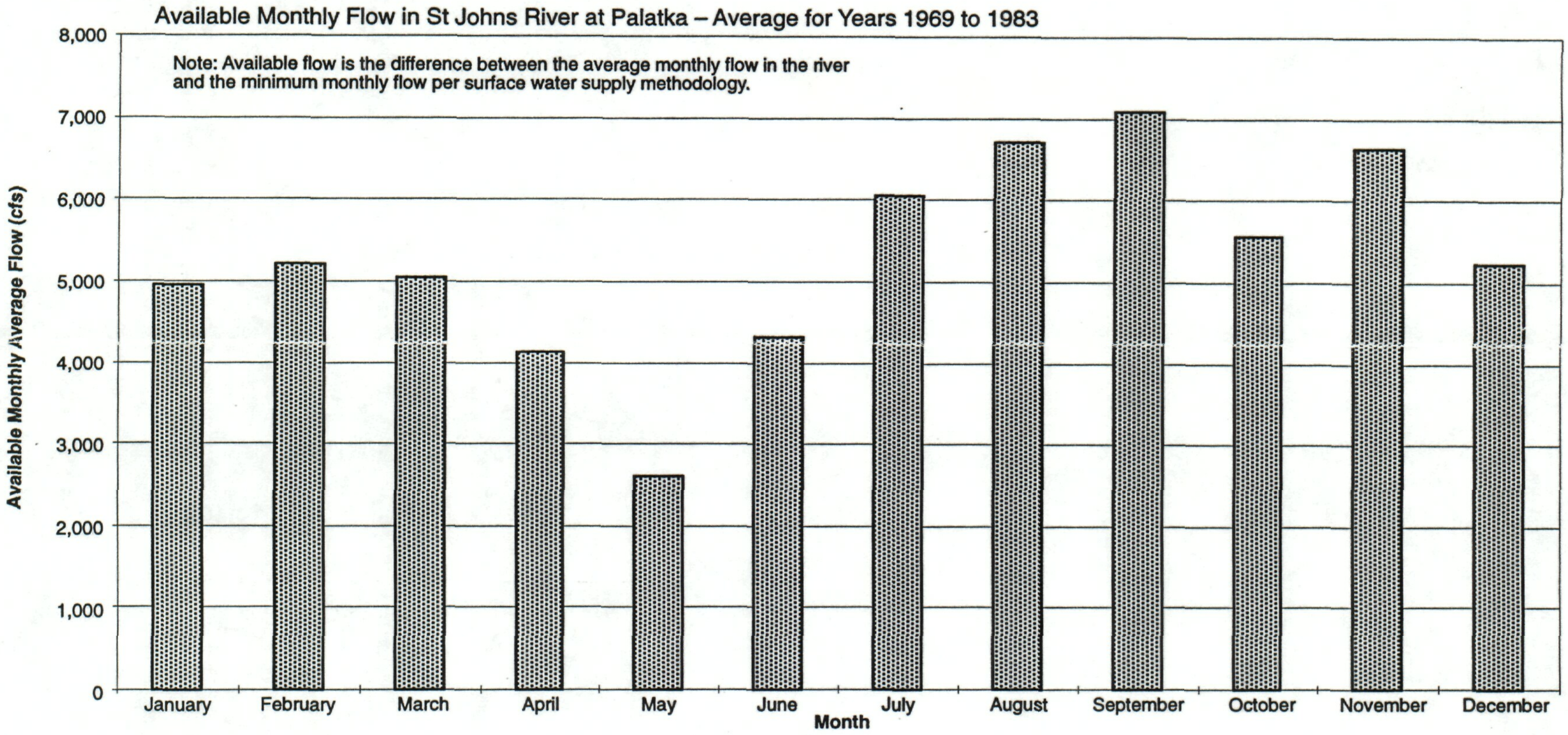
Long-Term Supply and Demand

The second issue in facility planning is long-term supply and demand. If the total water demand is greater than the total supply, then there are supply-and-demand issues that cannot be solved with a storage solution. Typically, water supply master planning is for a period of 20 years. Comparing the total volume available for supply (million gallons) and the total volume for demand (million gallons) of the 20-year period indicates whether a storage solution may address the issue. When considering delay of facility expansion, the planning period may be much shorter. For instance, an objective may be to delay facility and supply expansion for 5 years by adding ASR.

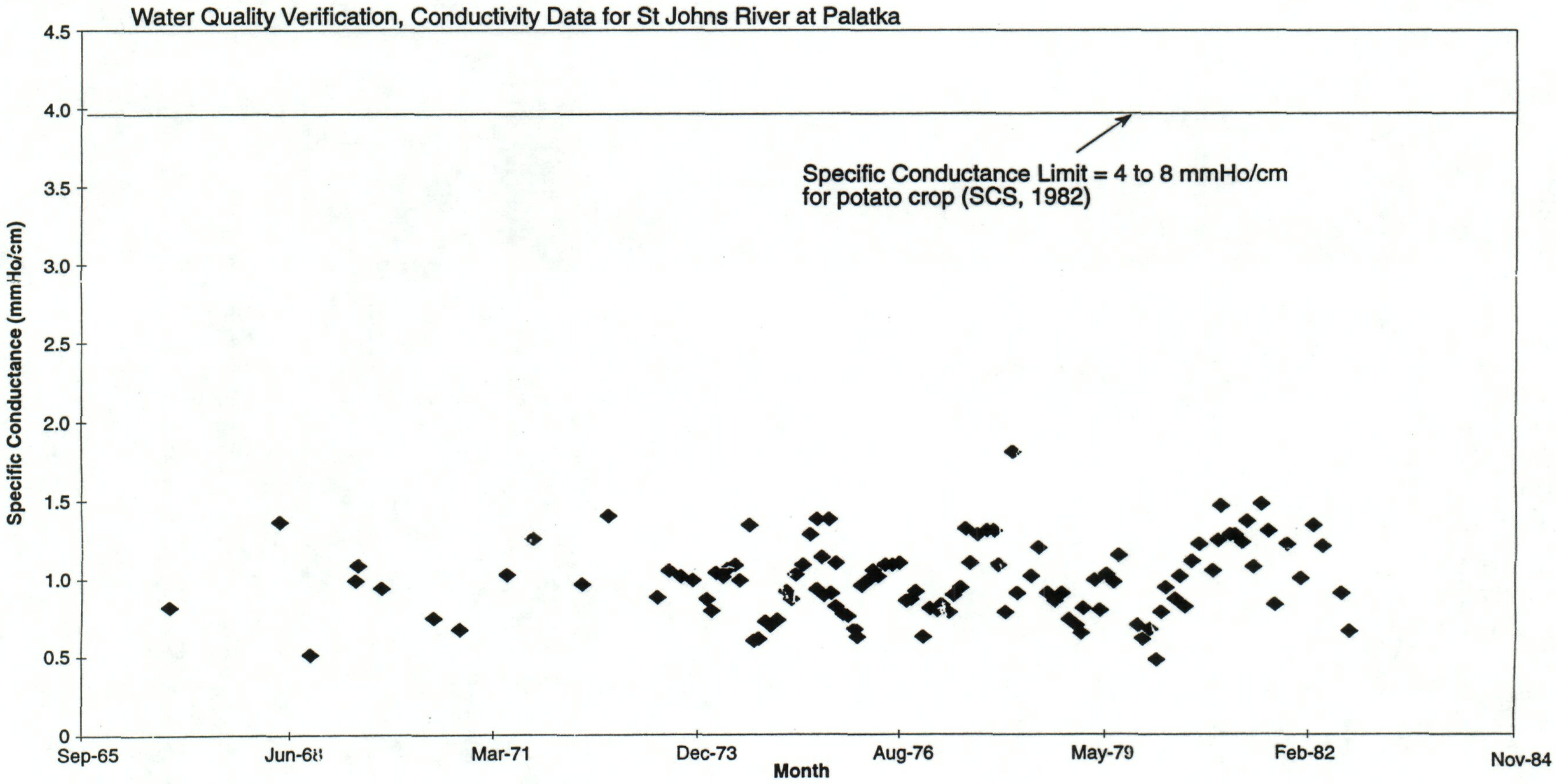
Supply and demand must reflect the quality as well as the obvious quantity volumes. First, the minimum quality of the raw water needs to be established. In the case of a potable system, this means determining the minimum intake quality for the treatment system anticipated. For agricultural use, this is the toleration level of the crop required to meet the desired yield. Next, the source quality records are reviewed. Records may show particular months or quarters in which the quality may be insufficient for the planned potable treatment system or for the untreated agricultural use. The supply quantity for those periods would be reduced to zero.

Figure 9 presents an example of developing a supply curve based on water quantity and water quality data. This example is provided as a possible agricultural irrigation scenario near Hastings, Florida. In this district, the ground water supply may not be of sufficient quality to support agricultural interests in the area; however, existing records were evaluated in order to determine the supply available from the St. Johns River.

Step 1 Evaluate Flow Records and Determine Available Flow



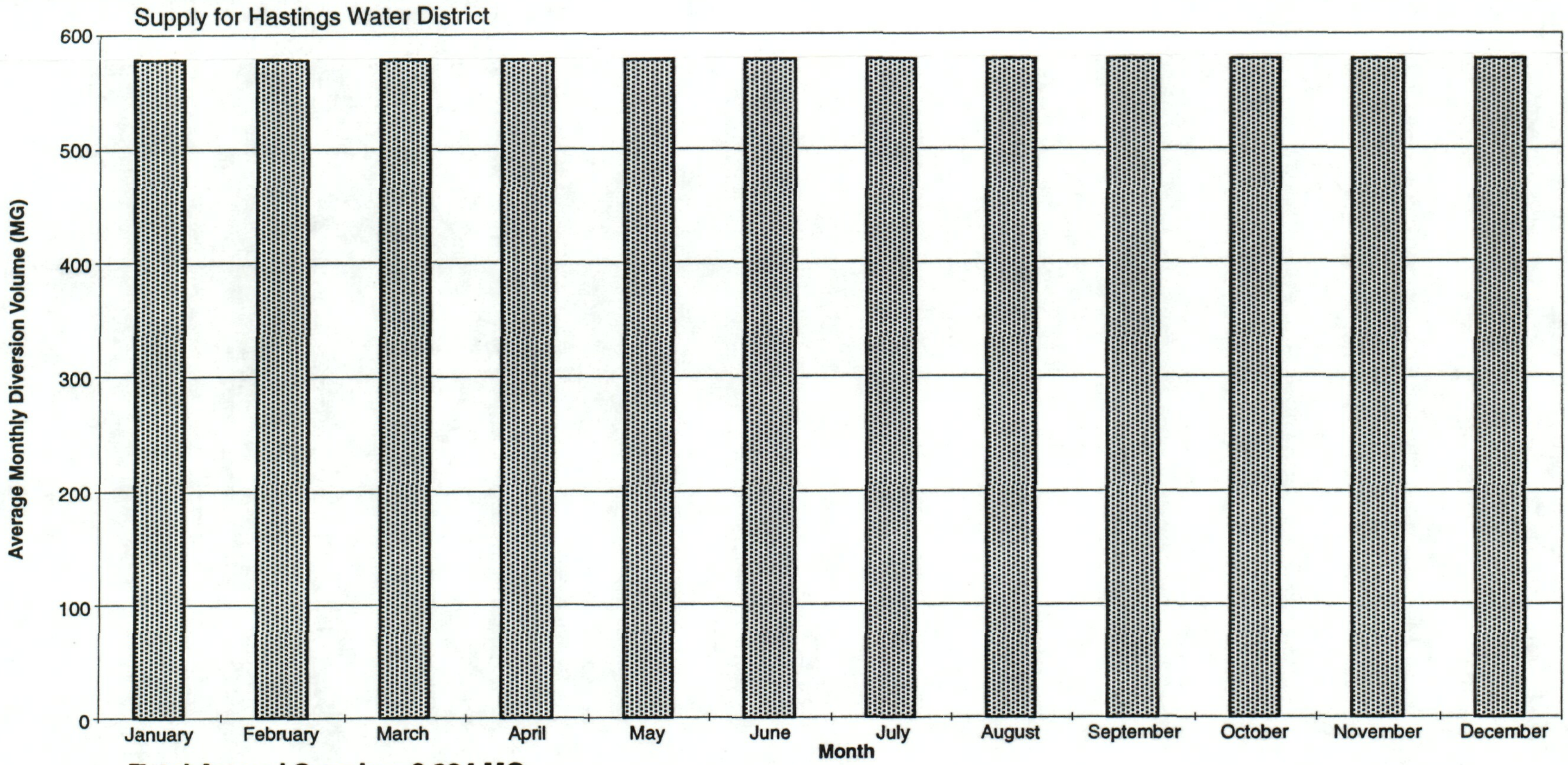
Step 2 Review Water Quality Records



Conclusions:

1. Water quantity does not have to be adjusted for water quality for use in this example.
2. Use 0.5 percent of available monthly flow as supply.

Step 3 Determine Monthly Diversion Capacity



Total Annual Supply = 6,924 MG

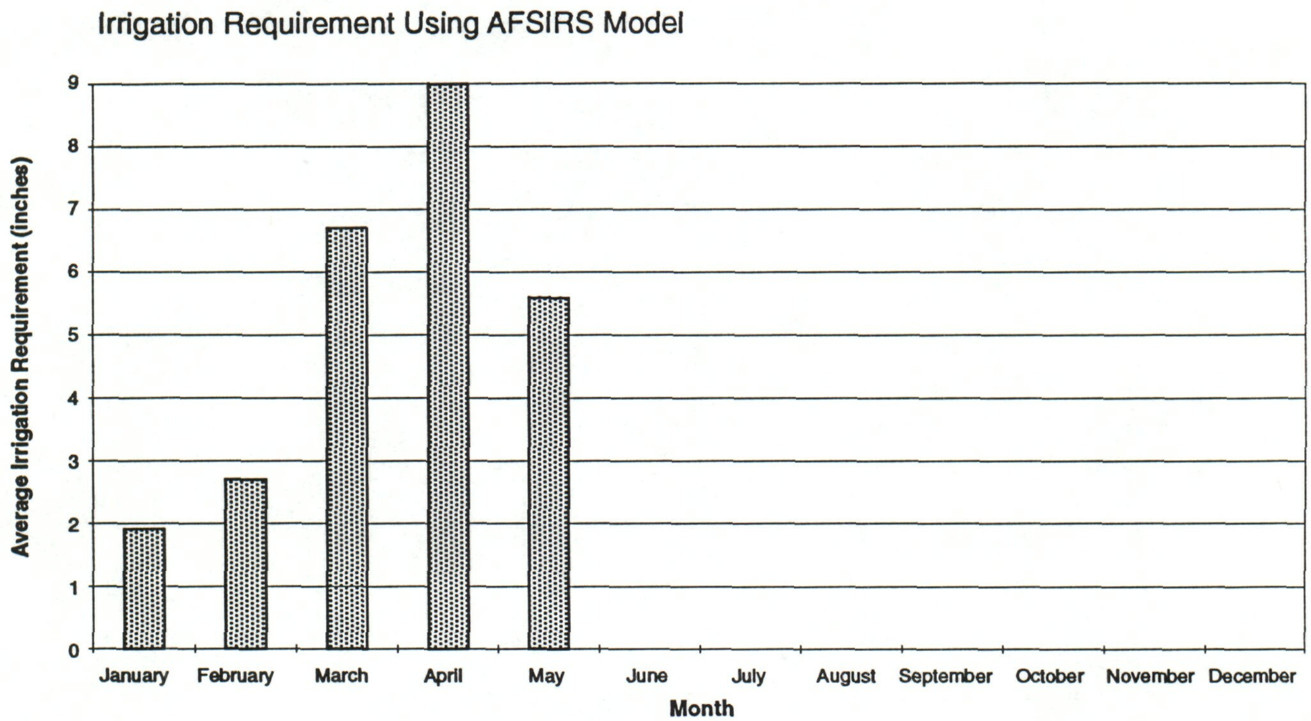
Figure 9. Calculation of available water supply for the Hasting Water District example.

In the first step, water flow records were reviewed. The EarthInfo data base was used to determine monthly average flow rates at the Palatka gauging station. The available flow, graphed in Figure 9 (Step 1), is the difference between the gauged monthly flow and the minimum flow levels established according to the surface water TM (CH2M HILL, 1995). The available water quality records were reviewed in Figure 9 (Step 2) to determine if the source is consistently of suitable quality. Specific conductance correlates to the relative amount of dissolved substances in the water, which are also called salts. Salt content, which is different than chloride levels in this sense, is the key water quality parameter for irrigation planning.

Because individual crops have varying tolerances to the irrigation water quality, the recorded specific conductance values and the threshold levels are compared. For a potato crop in Hastings, the specific conductance is well below the crop tolerance, as shown in the second step of Figure 9. Therefore, adjustments are not required to the quantity available for planning purposes. If threshold exceedances had been found, the records would be converted to monthly average specific conductance values in order to identify the months that have zero supply expected because inadequate quality.

Figure 9 (Step 3) is used to determine the diversion capacity allowed for the project and convert the rate to monthly volume. In this case, a diversion of 0.5 percent of the available flow plotted in the first step was used. Although this is an arbitrary proportion selected to illustrate the storage need in the next example, this flow rate is likely to require a reasonable-size transmission pipeline (approximately 48 inches).

This example is continued in Figure 10 with the corresponding demand curve and the storage need illustration. The irrigation demand was calculated using the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) Model. The AFSIRS model computes irrigation requirements for the crop based on historic rainfall records and expected evapotranspiration rates. As expected, the irrigation demand extends from the dry winter months through the beginning of the growing season, which corresponds to periods of reduced rainfall and increased demand, respectively. Plotting this monthly demand volume and the monthly supply volume from Figure 9 shows the demand in excess of supply for a portion of the year, which is the storage need.



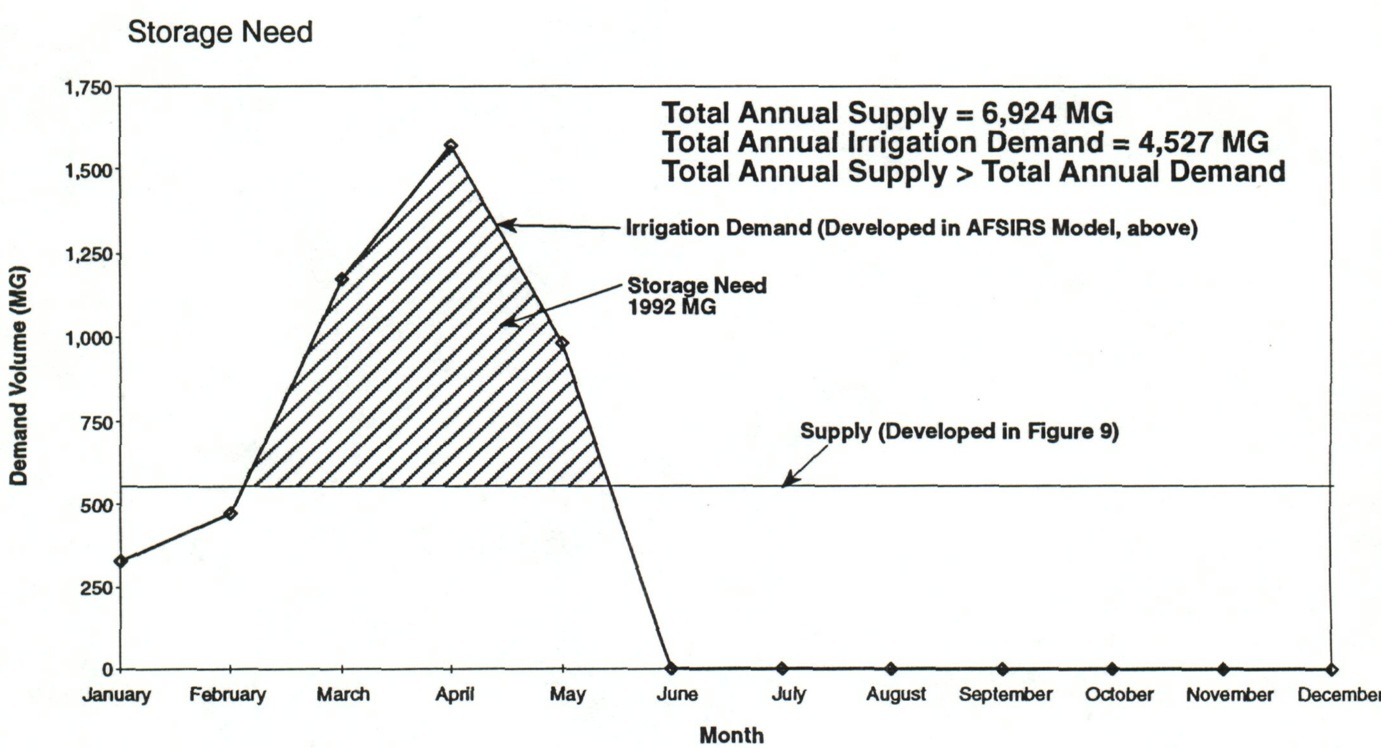


Figure 10. Calculation of storage need for the Hastings Water District

In this agricultural illustration, the supply volume is 6,920 MG, which is greater than the 4,530 MG demand volume for the period of interest.

Comparing total supply and demand is also valid when addressing facility expansion; the total volume must be available within the planning period in order to use a storage solution. An objective may be to delay expansion, for which the planning period may be much shorter than 20 years. Figure 11 illustrates a WTP scenario in which adding ASR wells in 1989 would delay required source expansion. For this example, the supply volume is 158,410 MG between 1989 and 2002, which exceeds the 155,170 MG demand volume for the same period. Note that this is a *preliminary* screening tool; therefore, it is an indicator that further exploration may yield a storage option rather than a source expansion.

To address total supply and total demand, the second item in the decision tool is a *yes–no* decision point that compares these. Data required is the available supply volume and the total demand volume for the planning period. For new potable facilities, the planning period should be 20 years. For expansions, it should be at least 3 to 5 years. Average annual planning periods are relevant for agricultural supplies. Other planning periods may also be useful based on economics. The supply-and-demand volumes are entered in the appropriate locations in Part A, Item 2 of the screening tool (Figure 7). If supply exceeds demand, then an ASR solution may be feasible. Therefore, a *yes* decision routes the user to the next parameter. If the demand exceeds the supply for the period of interest, then the actual problem is water source. Therefore, ASR alone would not be able to meet demand. For this case, no further investigation is required.

Storage Need

As previously discussed, storage need is important for water supply development. Water supply and demand are compared over specific periods to determine storage need. The data must incorporate water quality. For the feasibility screening tool, storage need is the third *yes–no* decision point. Data required is supply and demand for the following three periods:

- Planning period—Plotting annual average daily flow data for supply and demand over the planning period identifies long-term storage potential. As shown in Figures 11 and 12, the area between

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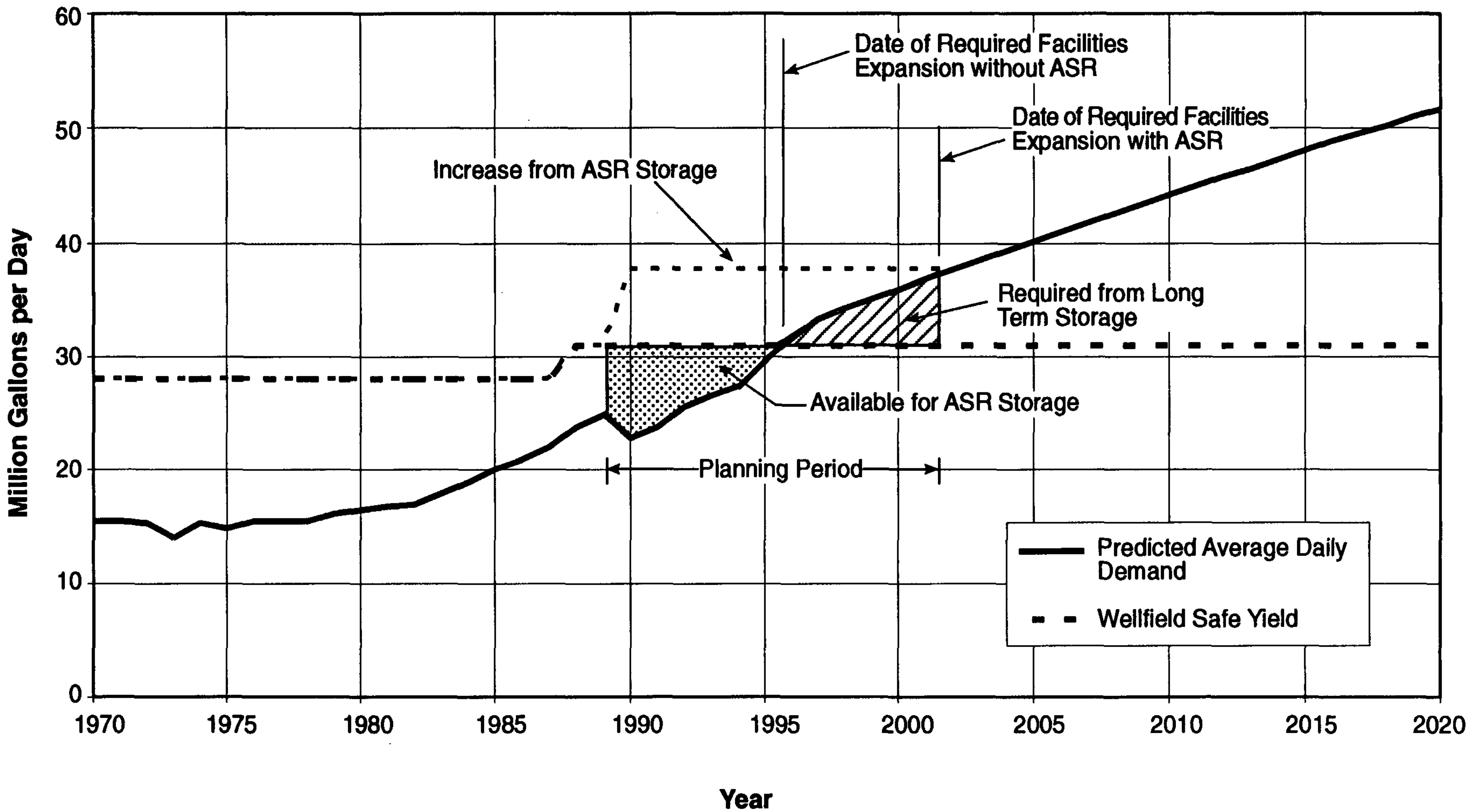

Figure 11. Dyal water treatment plant example long-term storage need for delayed facilities expansion, City of Cocoa, Florida

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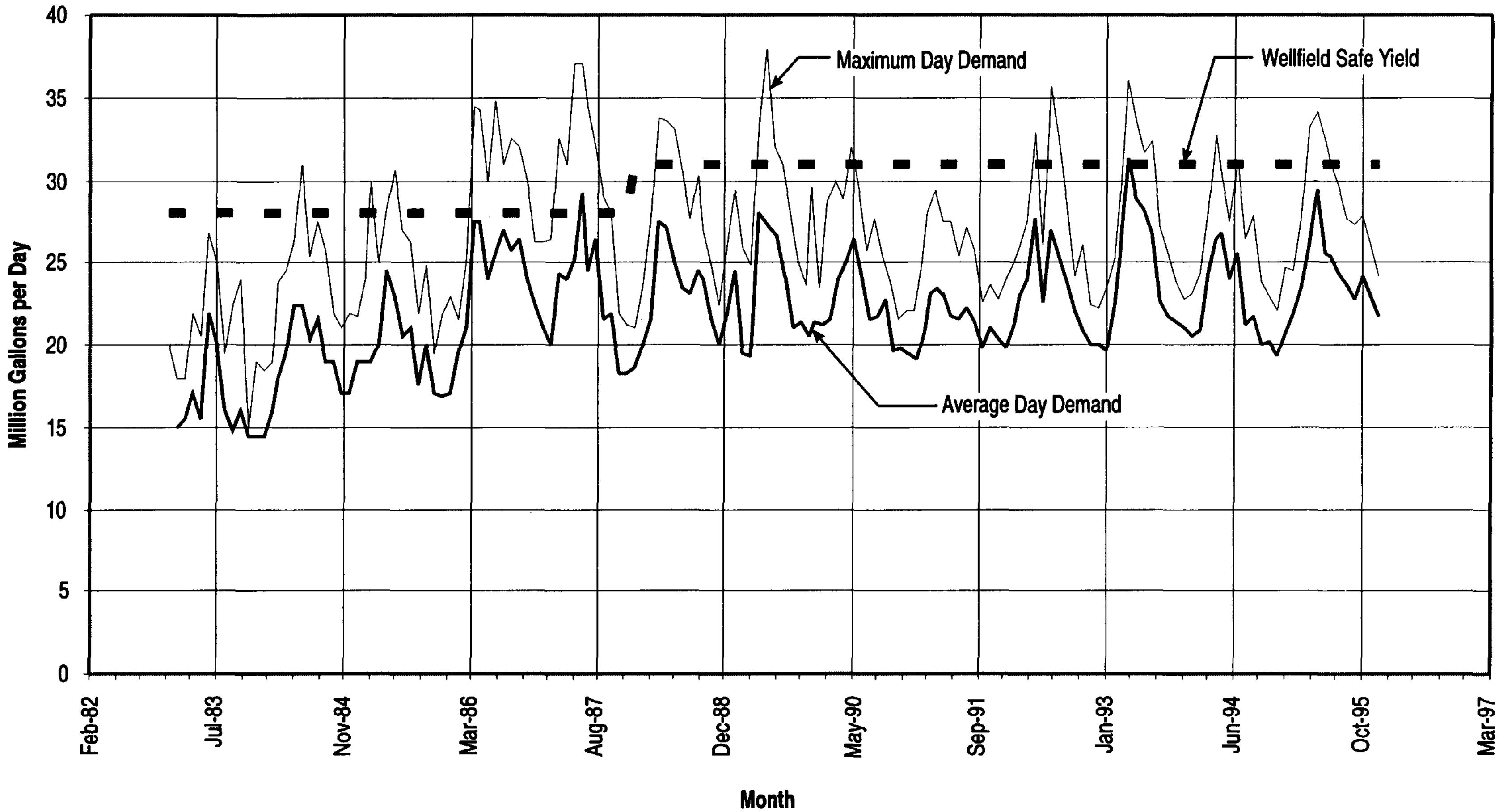

Figure 12. Dyal water treatment plant example identification of seasonal storage need, City of Cocoa, Florida

the supply and demand curves, when demand exceeds supply, is the long-term storage need.

- Several years—Plotting the historic and/or predicted monthly average flow or daily flow data for supply and demand distinguishes seasonal and/or monthly storage need. (Remember to adjust the flow data needs for water quality.) In Figure 12, the highest demand is in the summer with fairly constant potential ground water supply for the Cocoa WTP. This indicates potential seasonal storage need. Figure 10 is another illustration of seasonal storage need for an agricultural use.
- Average year—Plotting daily flow for supply and demand over the average year distinguishes the quantities identified in Figure 12. As shown in Figure 13, the area between the supply and demand curves, for the period when demand exceeds supply, identifies storage need. The intercession between the periods of demand in excess of supply, must be checked to assure that there is adequate recovery of the storage volume. Otherwise, the storage volume is accumulative for the portions not recovered. Figure 13 shows the maximum unrecovered volume during the intercession, which is the seasonal storage need. Short-term storage need (monthly, weekly, or daily) would be similarly calculated.

There may be another unique storage need associated with the facility in addition to the common evaluations above. For example, a facility may want to maintain an emergency storage volume in case the WTP is out of operation. This objective may be to maintain storage for 14 days at 2 mgd, or 28 MG, for emergency use.

Once all storage needs are determined, each storage need value is entered into the appropriate lines (long-term, seasonal, short-term, and other) of Item 3 in Part A, of the screening tool (Figure 7). If any exceeds 5 MG, then an ASR solution may be feasible. The sum of all storage needs indicates the preliminary target storage need at the ASR site unless some storage needs do not occur at the same time of year and, therefore, can be combined. This storage volume is based on experience with planning ASR systems and on basic economic comparisons presented in a later section. A *yes* decision routes the user to the hydrogeology parameters. Systems with lower storage need should look at other storage options. In this case, the required storage would be better provided in ground or elevated storage tanks and no further ASR feasibility issues need to be addressed.

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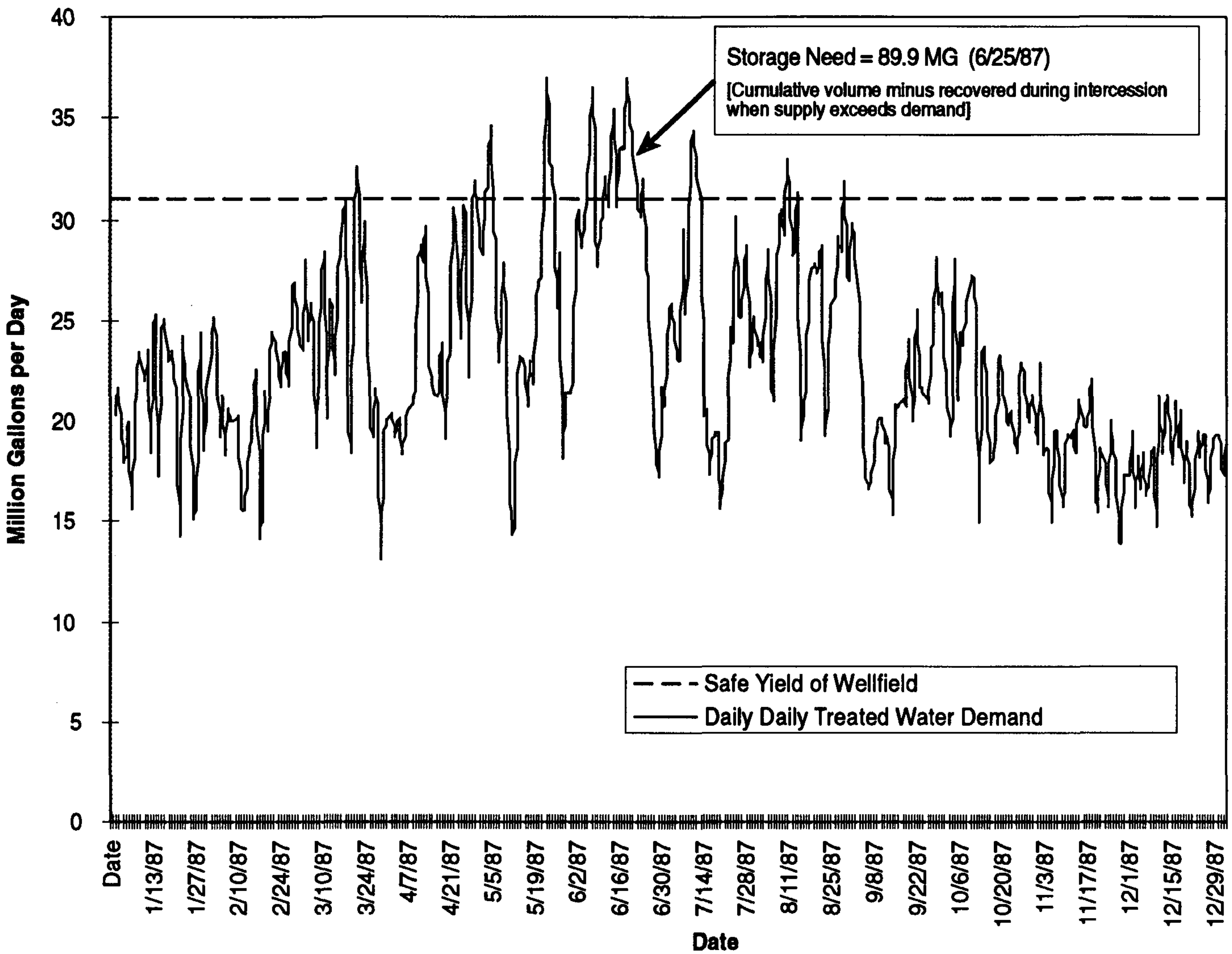

Figure 13. Dyal water treatment plant seasonal storage need calculation, City of Cocoa, Florida

HYDROGEOLOGIC, DESIGN AND OPERATIONAL FACTORS

Once Part A of the feasibility tool is completed using the facility planning factors, the hydrogeologic, design and operational factors are reviewed. An ASR scoring system included as Part B of the screening tool (Figure 7) should be used to evaluate the feasibility of an ASR storage option from the hydrogeology, design and operational perspectives. The feasibility factors discussed include storage zone confinement, transmissivity, local gradient, storage water quality, native water quality, interactions, and interfering use. As each hydrogeological, design, and operational section is reviewed, a score is determined that best represents the site-specific characteristics. At the end of the ranking process, each score is weighted as to its degree of importance and a final score is calculated. The magnitude of this score identifies a relative ASR feasibility for the site.

After completing the Part B screening tool, the final feasibility scores are divided into three categories based on confidence levels that ASR is a feasible solution for a given application (Table 1). The type of study recommended is provided for the first screening of an ASR system and suggests the type of study that is appropriate for the three score ranges.

Table 1. ASR Feasibility Score for Hydrogeologic, Design, and Operational Factors

Score	Feasibility Level	Type of Study Recommended
160 - 215	High confidence	General—confirm assumptions
100 - 159	Moderate confidence	Focused—investigate specific factors
43 - 99	Limited confidence	Detailed—evaluate impact of critical factors

High confidence or *Moderate confidence* in Table 1 indicates that more detailed, site-specific information is required to better assess whether the ASR is the appropriate solution. If a *Limited confidence* score is obtained and some information or parameters were assumed or default scores were used, additional site-specific information may be useful in verifying the first screening score, or determining missing parameters could help achieve a higher score.

The ultimate feasibility of ASR is directly related to the specific needs of the utility. A low feasibility score does not necessarily mean that ASR is not feasible; however, it does imply that a higher degree of caution should be exercised. Caution should be used when determining whether ASR will solve the utilities needs, and methods of addressing the lower ranking factors should be addressed. This screening tool is not to be utilized as an absolute *yes–no* decision tool, but it is designed to enlighten the users on the factors that are issues for an ASR system.

All of the factors introduced in the following sections are ranked based on the most optimal range associated with the highest rank, and the least optimal range associated with the lowest rank. The ranges for some of these factors are based on sources such as published and unpublished data and ASR experience in Florida and in other parts of the country. Most of the data used to compile the hydrogeologic factor ranges presented in the following sections were collected from information provided by the existing ASR systems. All of these systems use treated ground water or treated surface water as the potable water source for public supply. Today, no ASR systems exist that use untreated surface water as the water source; therefore, information is very limited. Many new ASR systems are presently proposed and, as more systems are installed, additional data will become available that can give better ranges for these hydrogeology factors. These factors are intended to be used for planning purposes only and should be verified by site-specific data.

The general use of this document and screening tool should include the first screening (Phase I) of an ASR system, using available hydrogeological information and including the cost effectiveness and regulatory constraints study, which determines whether ASR should be considered as an option. A second screening (Phase II) should be initiated after absent or assumed information has been identified from the first screening and investigations have been conducted to provide such information. This second screening should include a test ASR well installation after which additional site-specific ASR information can be obtained from test cycles to better delineate an ASR system's applicability to the utility's specific needs. Phase III would include the expansion of the system to include multiple wells, which will meet an ultimate goal.

The initial hydrogeological information needed to complete the first screening of the hydrogeologic, design, and operations factors section

(Part B) of the screening tool will initially be obtained from published SJRWMD or other state and federal public reports and records. The ASR option should initially be investigated and rated with this general information and/or with existing site-specific data. A default score is provided for some of the hydrogeological issues if initial information for these issues is not currently available. However, the default scores for these issues should also be recognized as a flag for additional information that needs to be collected in order to rate the ASR system correctly.

Storage Zone Confinement

The presence, hydraulic conductivity, and thickness of vertical flow restrictive layers classifies an aquifer type as confined, semi-confined, or semi-unconfined. Although suitable storage zones for ASR may be found in each type, most ASR experience is associated with semi-confined aquifers, some of which have been partially dewatered because of overdevelopment. Storage in unconfined aquifers also can be feasible in other parts of the country; however, in Florida, the following factors severely impact feasibility of ASR in the surficial aquifer (Pyne, 1995):

- The rate and duration of recharge may be limited by buildup of a mound in the water table that intersects the ground surface or the invert of local drainage systems, causing loss of stored water.
- Overlying land use in the vicinity of the ASR well may be inconsistent with the need for protecting the quality of stored water.
- Ground water velocity is usually higher in unconfined aquifers, resulting in the tendency of the stored water volume to move away from the well, thus reducing recovery efficiency. Where the distance that the stored water moves between the time of recharge and the time of recovery exceeds the diameter of the stored volume, it may not be possible to recover the stored water. This is a greater concern where native water quality is not as good as recharge water quality.

A confining or semi-confining unit can protect the ASR system from impact and effect of external sources of contamination or competing withdrawals above or below the storage zone.

Throughout Florida, the top of the Floridan aquifer is defined as the first occurrence of vertically persistent, permeable, consolidated carbonate rocks (Tibbals, 1990). Above this permeable limestone is an upper confining unit (Hawthorn Formation) of interbedded sands and clays which separates the Floridan aquifer from the surficial aquifer composed mainly of sand and shell fragments. The Floridan aquifer is further divided into two aquifer systems by a middle semiconfining unit, composed of dense limestone, into the Upper and Lower Floridan aquifers.

In the study area, the target storage zone confining units are the dense, carbonate zones within the Upper Floridan aquifer, and also the upper confining clay units between the Floridan and surficial aquifers. Although having clay units above the Upper Floridan is ideal because it may create the confined or semi-confined conditions desired for the entire aquifer, it is not necessary because the storage zone containment will rely on the vertical flow restrictive layers above and below the individual ASR storage zone within the aquifer. In the study area, especially in the coastal areas, the clay unit is thin or nonexistent. Without the presence of the clay above the Floridan, the Upper Floridan is covered by a deposit of sandy shell lithology; therefore, the aquifer may be unconfined or semi-unconfined.

To find an ideal target ASR zone, the storage zone confining units should be found within the carbonate aquifer itself. In this report, the term *storage zone confining unit* or *aquitard* will represent the vertical flow restrictive layers that bound the top and bottom of the target storage zone, and will not necessarily represent the actual confining units of the Floridan aquifer system. These vertical flow restrictive zones are crucial to keeping the stored water volume contained in the storage zone from migrating vertically, which ultimately improves the recovery efficiency.

Because the storage zone confining units may be within the aquifer, the depth is important in targeting an ASR zone. It may be necessary to drill a deeper well to avoid the undesirable conditions from a storage zone that may be close to the surface and could have impacts from surface sources. This greater depth implies increased well construction cost and a possible degradation of native water quality. If investigated lithology indicates that a suitable upper and lower confining unit does not exist, then the ASR wells will need to target a deeper zone.

Where the clay formation is not present above the Upper Floridan, the depth to the suitable confining unit from ground surface should be a non-critical distance of approximately 100 feet. This allows a minimum distance from ground surface impacts on the ASR system. The thickness of the Upper Floridan in the study area is 200 to 500 feet and may be encountered at less than 100 to 300 feet below land surface depending on location (Tibbals, 1990).

The need for vertical confinement is related to native ground water quality and the allowable degree of mixing that may occur at a site while meeting recovered water quality criteria. Where native ground water quality is good, poor confinement may be acceptable. Where native ground water is very poor, mixing must be minimized and a thin tightly confined zone must be selected. The areal extent of the confining zone must be considered for proper containment of the stored water.

Example ranges for hydraulic conductivity (K) of suitable storage zone confining units media type are provided in Table 2. The range for the Floridan limestone is typical for the area, although K values have been measured above and below this range.

Table 2. Example Ranges for Hydraulic Conductivity of Suitable Storage Zone Confining Units

Flow Restricting Medium	K (ft/sec)	Source
Limestone (general)	$1x10^{-9}$ - $1x10^{-3}$	Freeze and Cherry, 1979
Limestone (Floridan)	$1x10^{-6}$ - $1x10^{-5}$	ASR Experience
Clay (general)	$1x10^{-9}$ - $1x10^{-12}$	Freeze and Cherry, 1979

Table 3 provides example values for K based on 1-, 10-, and 100-foot thicknesses for the upper and lower confinement zones used in the ASR feasibility scoring. The examples show how the scoring ranges relate to any aquitard thickness and the hydraulic conductivity of the zone. This relationship and the scoring zones are provided in Figure 14.

Because the ratio of conductivity-to-thickness is defined as leakance, the actual conductivity and thickness can vary to give an equivalent confining unit leakance value. For example, a higher conductivity can be tolerated for a thicker unit, whereas, in a thin confinement unit, the conductivity must be lower to provide adequate storage zone confinement. In short, as the permeability increases, the thickness must increase to provide the same level of zone confinement that a lower conductivity unit would provide. A default score of 2 is provided for instances when the confinement is not critical, for instance, recharging a fresh aquifer with untreated fresh ground water.

Table 3. Example Ranking Aquitard K Criterion Based on 100-foot Thickness

Rank	Aquitard K Criterion (ft/sec)		
	1 foot thickness	10 feet thickness	100 feet thickness
1	$K > 1.2x10^{-6}$	$K > 1.2x10^{-5}$	$K > 1.2x10^{-4}$
2	$0.2x10^{-6} < K < 5.8x10^{-7}$	$0.2x10^{-5} < K < 5.8x10^{-6}$	$0.2x10^{-4} < K < 5.8x10^{-5}$
3 (default)	$5.8x10^{-7} < K < 2.9x10^{-7}$	$5.8x10^{-6} < K < 2.9x10^{-6}$	$5.8x10^{-5} < K < 2.9x10^{-5}$
4	$2.9x10^{-7} < K < 1.2x10^{-7}$	$2.9x10^{-6} < K < 1.2x10^{-6}$	$2.9x10^{-5} < K < 1.2x10^{-5}$
5	$K < 1.2x10^{-7}$	$K < 1.2x10^{-6}$	$K < 1.2x10^{-5}$

In the following examples, the aquitards have different conductivities and thicknesses, but have the same leakance. However, there is a point at which the conductivity will become too large for vertical flow restrictions to occur, regardless of the thickness. This situation then becomes an unconfined condition.

Thickness	1 foot	10 feet	100 feet
K	1.2×10^{-7} ft/sec	1.2×10^{-6} ft/sec	1.2×10^{-5} ft/sec
Leakance	1.2×10^{-7}/sec	1.2×10^{-7}/sec	1.2×10^{-7}/sec

Even though conditions are excellent in Florida for ASR, the following general factors for confining bed depth and thickness could indicate low feasibility of ASR as a suitable storage option:

- The target zone is too deep to achieve suitable confinement
  - It is too costly to drill numerous deeper wells; the utility cannot afford the number of wells required to meet their specific needs
  - The water quality is extremely poor (poor mixing with potable water); the utility needs high initial recovery efficiencies

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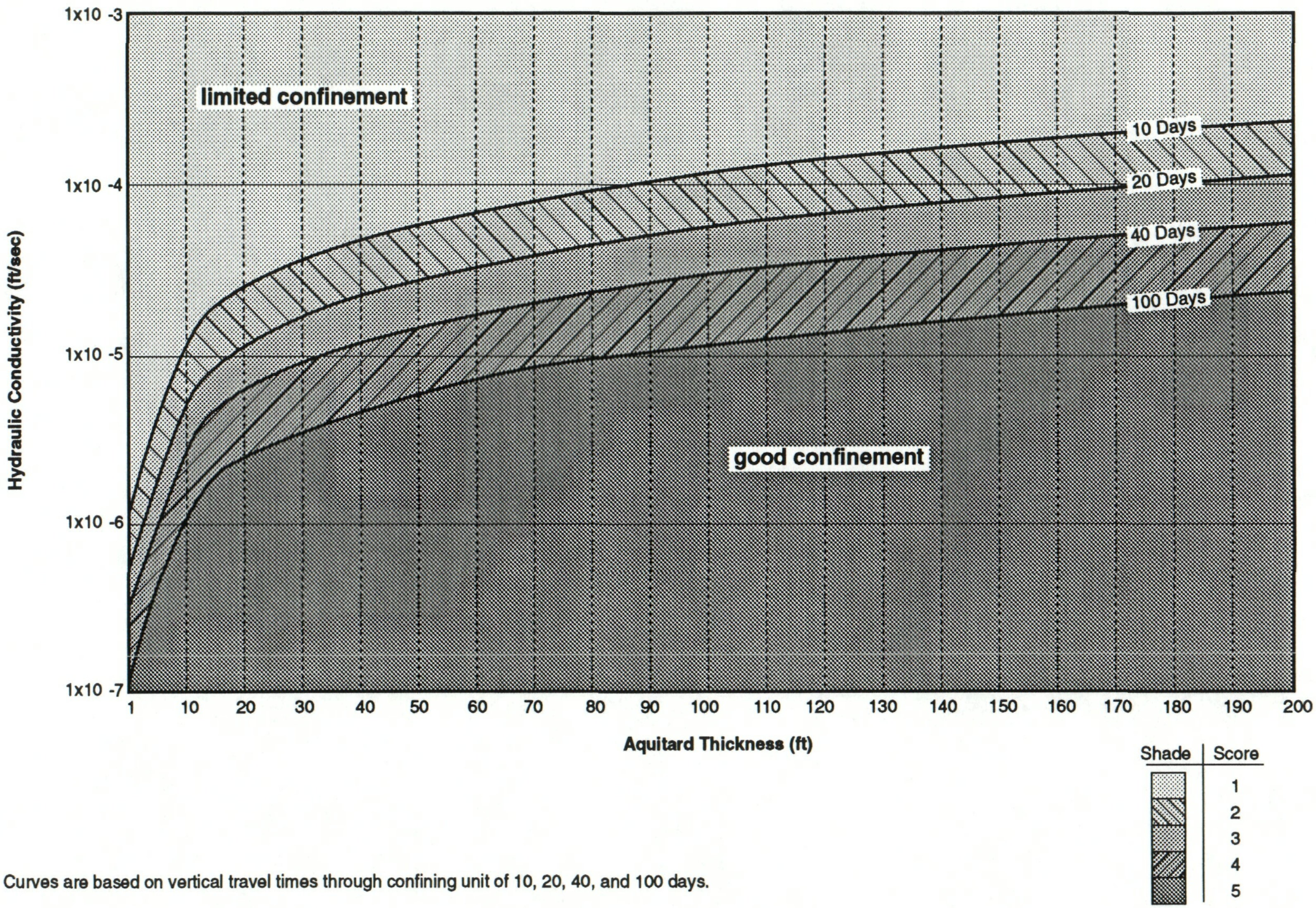

Note: Curves are based on vertical travel times through confining unit of 10, 20, 40, and 100 days.

Figure 14. Aquitard confinement as a function of thickness and hydraulic conductivity

- The storage zone with a suitable confinement is too shallow (less than 100 feet below land surface); the storage zone could be affected by nearby environmental impacts, if existing

- Confining unit lithology and thickness are unsuitable; there are no vertical flow restricting zones

The relationship between hydraulic conductivity and the thickness of the storage zone aquitards is based on vertical travel time curves of 10, 20, 40, and 100 days, provided as Figure 14. If these curves indicate the aquitard thickness and conductivity required to achieve a specific vertical travel time through the aquitard. This figure will be used to rank the site-specific data in the tool in Appendix A. As a known conductivity value is selected on the left axis of the graph, the thickness of the aquitard can be determined based on the rank to be targeted. This graph can also provide an approximate vertical travel time for an aquitard of known conductivity and thickness.

Storage Zone Transmissivity

The transmissivity (T) is the flow rate through a vertical section of aquifer, one unit wide, extending the full saturated height of the aquifer under a unit hydraulic gradient. It is a function of the aquifer media, the structure, and the fluid. The transmissivity of the target zone should be in a range over which a volume of treated water can be injected at reasonable wellhead pressure or under gravity. Adequate storage also means that the same volume of water can be recovered from the storage zone without excessive drawdown in the well during peak demand. The proper transmissivity range for the target storage zone also can be related to the specific use of the stored water. If the recharge water will be stored for short durations before recovery and will have high recovery rates, then a higher transmissivity zone would be appropriate. Also, if the recharge water will be stored for longer durations, as in an emergency water supply, then a lower transmissivity zone could provide the more appropriate target storage zone.

Floridan Aquifer Transmissivity Ranges

Transmissivity for the entire Upper Floridan aquifer in the study area ranges from 75,000 gallons per day per foot (gpd/ft) to 3 million gallons per day per foot (mgd/ft) and the aquifer thickness ranges from 200 to 700 feet (Tibbals, 1990). The thickness of the middle confinement zone between the two layers of the Floridan aquifer ranges from 0 to 800 feet (Tibbals, 1990). The transmissivity for the entire Lower Floridan aquifer is approximately 4 mgd/ft for the study area with a thickness range of 1,200 to 1,700 feet (Tibbals, 1990). Very little information exists on the Lower Floridan aquifer. Collection of this information has just begun for future reference.

Potable ASR Transmissivity Ranges

The general transmissivity range for a potable water ASR zone in east-central Florida is approximately 20,000 to 300,000 gpd/ft based on ASR field experience. Beyond this wide range, the ASR concept may be limited as a storage option depending on the purpose and the need of the stored water. However, storage zones with transmissivities as low as 8,000 gpd/ft have been used successfully in ASR systems in other parts of the country. The approximate transmissivity range in which the optimal performance of an ASR system can be achieved is 20,000 to 300,000 gpd/ft for a target ASR zone. Although, Florida ASR systems have been installed in zones with transmissivities above and below this optimum range, storage zones below the lower optimal T range may not yield an adequate ASR target zone for the specific needs of the user. However, an aquifer zone above the optimal range may yield a well that requires a larger volume of treated water to condition the system and may operate with an unsuitable initial recovery efficiency. The optimal range of transmissivity values for a potable water ASR system is based on existing Florida ASR experience. Many new potable ASR systems are presently proposed and, as more systems are installed, more information will become available that can provide better ranges for these hydrogeology factors.

Above the optimal range, a much higher transmissivity will drive the screening score downward, appropriately reflecting the increased limited feasibility. The relationship of the transmissivity values to potable (treated or untreated ground water or treated surface water)ASR feasibility is provided as Figure 15. ASR will work in nearly every transmissivity range; however, the specific needs of the ASR user will determine whether a transmissivity at either end of the optimal range will satisfy the user as a storage option. Based on water supply data, the upper range limit of 300,000 gpd/ft is a conservative number in which ASR should perform best. Above this value, it is possible that ASR would work better with a higher-grade native water quality.

Low-end transmissivity ranges tend to limit the recharge and recovery rate that water can be stored or recovered in the specific zone. If the transmissivity of the target zone is too low, then the recharge rate that the storage zone can accept or the withdrawal rate that the zone can withstand may not be adequate to satisfy the water need at seasonal high peak demand. Also, wellhead injection pressures may be unsuitably high. Therefore, additional ASR wells may need to be installed and ASR may receive low feasibility rating for the specific situation. However, if a long storage duration is needed, then a lower T range zone may be more appropriate.

Untreated Surface Water ASR Transmissivity Ranges

Because untreated surface water ASR systems currently do not exist in Florida or in the country, transmissivity ranges provided for this type of ASR system cannot be completely tested. Figure 15 includes guidelines for the viability of raw water ASR at different storage zone transmissivity levels. The difference in optimum transmissivity ranges between the treated and untreated recharge water graphs is mainly related to the increased opportunity for well plugging for the raw water source based on suspended solids, biological and geochemical experience. Also, the recharge raw surface water source will be predominantly used for nonpotable agricultural applications or treated after storage potable supply; therefore, increased mixing with the native storage zone water that occurs in higher transmissivity zones is tolerated. Recovery efficiency of such raw water wells would tend to be lower than for treated water ASR wells, but the wells may still be cost-effective because of the low investment in the recharge water. Raw water and treated water ASR wells are designed differently, reflecting different needs and opportunities at each site.

Storage Zone Selection Issues

Extremely high transmissivities can generally be found at greater depths along with lower water quality in the area. If native water quality is brackish, as in the lower portion of the Upper Floridan or in the Lower Floridan aquifer, and the transmissivity is very high (greater than 1 mgd/ft), the injected water will not displace the brackish water in a recoverable volume surrounded by a mixing buffer, and there will be an excessive mixing front. Large volumes of the initially stored water will be needed to create the buffer in the storage zone for the ASR system, resulting in initial poor recovery efficiencies. It is important to note that the large volume of water

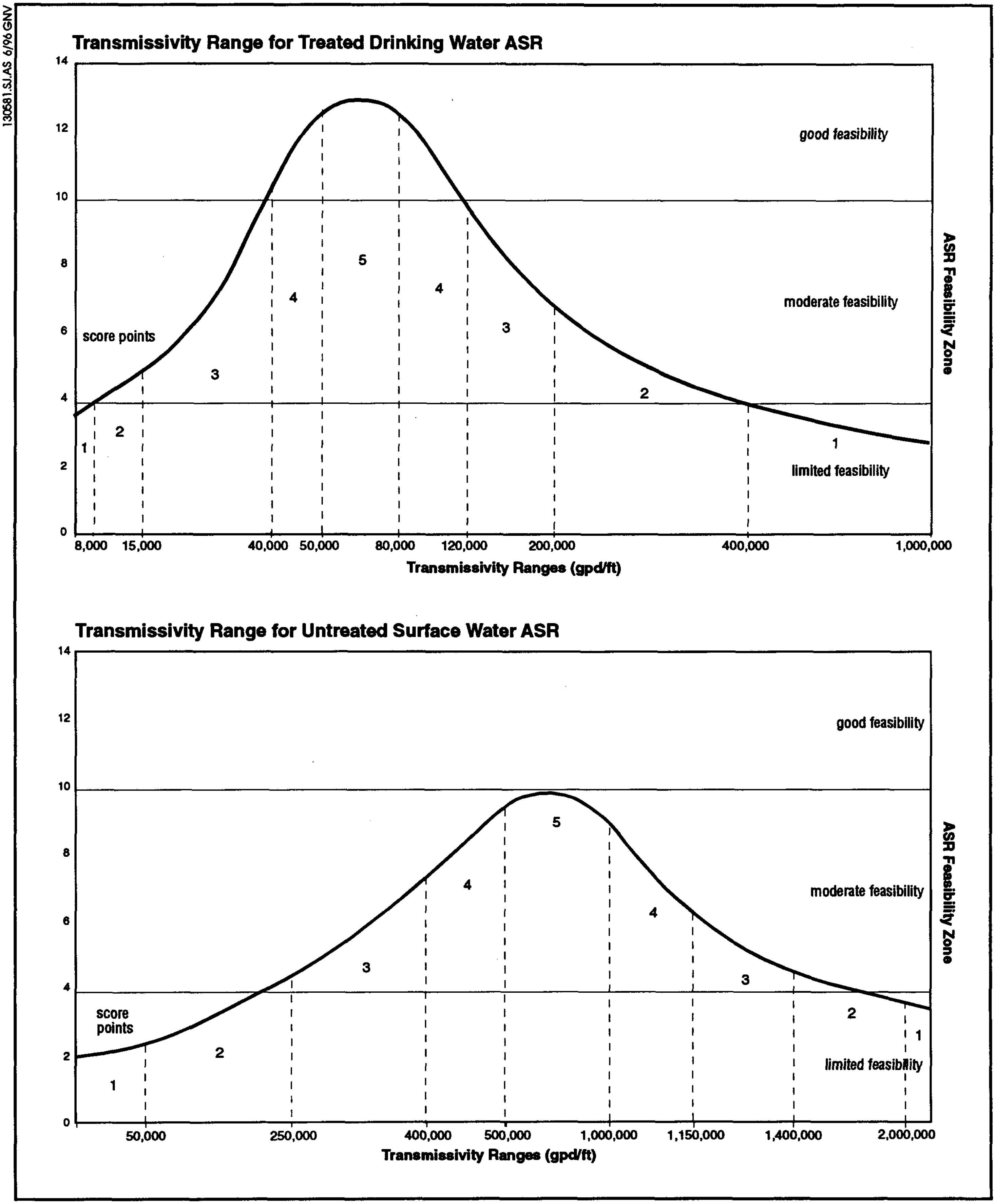

Figure 15. Storage zone transmissivity range classification

needed to be initially stored must be supplied by the utility while the existing utility customers are also being supplied during low demand periods. This ASR system recovery efficiency will slowly improve over successive cycles with additional volumes of treated water; therefore, ASR in this type of situation is applicable only where a large volume of excess water is available to be stored or if the utility can still benefit from low initial recovery efficiencies.

Although the Lower Floridan has a substantially higher transmissivity and a tendency to be cavernous, the water quality is generally brackish (chloride level between 1,000 and 35,000 mg/L) and quickly degrades with increasing depth in much of the study area. An aquifer zone with a very high transmissivity and poor water quality will greatly reduce the efficiency of the ASR system recovery (i.e., the amount of potable water stored is much greater than the volume of water below potable water quality standards that can initially be recovered because of mixing). The ideal situation is to have an aquifer of a medium-to-low transmissivity and marginal-to-good water quality. This type of aquifer provides the best hydrogeologic setting for ASR development and best describes the Upper Floridan in the study area.

Selection of the storage interval requires greater care in areas where the transmissivity of the storage zone is high and the native water quality is brackish or contains water of such quality that mixing is to be minimized. Thin intervals that have excellent vertical confinement are best suited for minimized mixing. In less extreme cases of water quality difference, thicker storage intervals with less confinement may be sufficient to provide the desired recovery efficiency. It should be noted that acidizing a potential ASR zone can increase the transmissivity around the borehole. However, in one instance it caused a soft, thick lower confinement zone to be breached, connecting the target zone to a deeper, highly transmissive, poor water quality aquifer. The use of this well is now questionable.

Table 4 provides transmissivity ranges for both treated (potable) and untreated surface water (to be used for agricultural applications or treated after recovery for potable supply) and the appropriate scoring values. A test ASR well may be necessary to accurately estimate this value.

Table 4. Storage Zone Transmissivity Ranking

Rank	Transmissivity Criterion (gpd/ft)		Applicability
	Potable Water	Untreated Surface Water	
1	Less than 8,000	Less than 80,000	Limited
2	8,000 to 15,000	80,000 to 250,000	
3	15,001 to 40,000	250,001 to 400,000	
4	40,001 to 50,000	400,001 to 500,000	
5	50,001 to 80,000	500,001 to 1,000,000	Optimal
4	80,001 to 120,000	1,000,001 to 1,150,000	
3	120,001 to 200,000	1,150,001 to 1,400,000	
2	200,001 to 400,000	1,400,001 to 2,000,000	
1	Greater than 400,000	Greater than 2,000,000	Limited

Aquifer Gradient and Direction

Determination of the aquifer gradient identifies any external influence in the subject area from sources (e.g., recharge areas) and sinks (e.g., operating wellfields, springs) in the same recharge zone as the ASR system. Such external gradient influences can adversely alter the effectiveness of an ASR system. Studying the water level or potentiometric map of a specific zone or of the regional aquifer provides a visual aid identifying areas that could have steep gradients that may negatively impact the stored water of an ASR system. However, if the gradient influence is not in the same zone as the ASR zone, there may be no adverse effect if sufficient confinement is available, as previously discussed. The regional water level map will provide general gradients and directions for the region of the site and could show locations of wellfields and existing springs. A local water level map provide more detail of the gradient for the area immediately surrounding the ASR site. In the case of a nearby spring, the gradient could change enough to move the stored water away from the recovery wells out of the capture zone during recovery. This scenario will have the greatest effect in the unconfined zones of the aquifer, which may pose no threat to the ASR system in the confined zones below. The presence of a nearby wellfield could also move the stored water away from the recovery wells and into the capture zone of the neighboring wellfield. This scenario will have the greatest effect in the same ASR target zone.

The acceptable gradient for the target storage zone will also be related to the specific use of the stored water. If the recharge water will be stored for short durations before recovery and have high recovery rates, then a steeper gradient in the storage zone would be acceptable. Also, if the recharge water will be stored for longer durations, as in an emergency water supply, then a lower gradient would be more acceptable in the target storage zone. Table 5 provides the ranking criteria for the aquifer gradient and direction factor. The storage zone travel time in the third column are provided for approximate travel times, which are a function of the aquifer transmissivity, gradient, and specific duration and use of the stored water.

Table 5. Aquifer Gradient and Direction Ranking

Rank	Aquifer Gradient (in same recharge zone)	Direction Criterion
1	Many strong influences exist	Extreme artificial gradient, reevaluate location of ASR system
2	Several strong influences	Exaggerated gradient, investigation needed
3 default	Multiple minor influences exist	Affected gradient worth investigating
4	Single minor influence or abnormal natural gradient	Minor investigation or existing data search
5	No influence	No influence

Evaluation of Gradient Influences Methodology

The gradient influence for a specific site can be assessed from the average linear velocity of the water in the specific zone. The linear velocity is dependent upon the transmissivity of the site storage zone, the thickness and porosity of the storage zone, and the gradient, all of which will not change because of external influences, except gradient. Calculating the critical ground water velocity, for which would cause the stored water to move away from the ASR wells, requires knowledge of the above factors (storage zone thickness, transmissivity, porosity, and local gradient) and the volume of water stored between recovery periods, and a range of storage durations. From this calculation, it would be evident how far the stored water would move away from the ASR wells for a specific storage duration. This calculation could then be expanded to include estimate recovery efficiency or the volume of stored water that can be recovered (captured) after the specified storage duration.

Capture zone or velocity calculations also can indicate the desired distance an ASR wellfield should be located from any influence in the area associated with the planned duration of ASR storage (i.e., seasonal or long term). After a radius of influence is estimated and all influences within this area are identified, consideration should be given to the need for any measures that would protect against future possible adverse impacts (wellhead protection issues).

Recharge Water Quality

The quality of the water recharged into the storage zone is important for determining whether the initial recovered water quality will be sufficient to satisfy the utility's specific needs. This is important for the storage of treated, potable water, which will have no further treatment (except chlorination) after recovery prior to distribution.

When compared to a treated water source, the option of storing raw surface water tends not to be a critical issue for this scoring factor because the surface water will be fresh with seasonal fluctuations of TDS concentrations. This water source will be recovered for agricultural use or sent through the treatment process and distributed as a potable public supply.

If the quality of the finished water falls just within the drinking water (DW) standards (e.g., 240 mg/L Cl^- ;DW standard = 250 mg/L Cl^-), and the native water quality is significantly above DW standards, the initial recovery efficiencies will be lower (depending on the initial volume of water stored) than if the finished potable water quality falls well within the DW standards (e.g., 50 mg/L Cl^-).

The lower recovery efficiencies result from the mixing, which occurs between the recharged water and the native water. In the first situation, more of the recharge water volume is blended with the native water to form the buffer zone, all of which has a concentration of chlorides above the DW standard; therefore, the volume of potable-grade water removed will be much lower than the volume of potable water initially stored in the storage zone. In the second situation, the better quality finished water is blended with the native water to form a buffer zone, all of which has a concentration of chlorides below the DW standard, which can still be considered potable; therefore, 100 percent (or more) of the water initially stored can be recovered. Native water quality is discussed in the following section.

Two options can remedy poor recovery efficiencies related to the quality of the recharged water. First, the amount of water initially stored in the aquifer should be large enough to create an adequate buffer zone. This procedure will ensure that a buffer exists in the aquifer far enough away from the ASR well so that it will not be intersected during subsequent test cycles. Second, the water to be stored in the ASR system can receive, or may require, additional treatment to give it a better quality for storage; however, cost constraints could prohibit this option. The storage in an ASR system of captured good quality raw surface water can provide at certain times of the year, the volume of water needed to properly develop the buffer zone.

Initial testing of the Cocoa ASR system used raw water diverted from the wellfield to the ASR well. The objective was to immediately store sufficient raw water underground at the WTP to adequately supplement the water supply during high demand periods. However, in succeeding test cycles, the specific capacity of the well significantly decreased. The raw water from the well field contained sufficient organic material from the water stripping tower operated in the wellfield to induce well plugging during injection. If treated water had been utilized, the plugging would not have occurred. Treated water was used for the remainder of the cycle testing with greatly improved results. For most sites, treated water should be used as the test water medium for the cycle tests assuming that such testing represents how the final system will be utilized.

For storing raw water for potable or agricultural use, the water quality requirements are based on the proposed treatment after recovery and crop tolerance, respectively. Although the numeric values may be different from those of potable water supplies, the same conditions for blending and recovery apply.

As discussed in the regulatory section, raw water recharge is not permitted unless primary drinking water standards are met at the point of compliance. The ranking criteria are based on the potable water-use scenario because raw water recharge is more problematic under current regulations. For raw ground water recharge (this scenario is not considered in this document), these standards are usually met. For raw surface water recharge, quality may be excellent at some sites and certain times of the year; however, naturally occurring coliform bacteria will tend to be present. Coliform bacteria are included in federal primary drinking water standards.

In addition to raw water recharge from a surface water source, with minimal treatment, recharge of stormwater could have several regional benefits. In Orlando and Gainesville, Florida, existing systems now directly recharge the Floridan aquifer with surface water; however, there are regulatory issues regarding recharge, which are explained in the Regulatory Factors section of this TM. Although a technically feasible application, and possibly also viable from a regulatory viewpoint, this application of ASR is beyond the scope of this report.

Table 6 provides two constituents for ranking purposes: chloride and total dissolved solids (TDS). The secondary drinking water (SDW) standards maximum contaminant limits (MCLs) are 250 mg/L for chloride and 500 mg/L for TDS. If information is available for both parameters, rank this section for only one constituent.

Table 6. Recharge Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Compliance with SDW Standards
1	Greater than 200	or	Greater than 450	Just within SDW standards
2	200 to 171		450 to 351	
3	170 to 101		350 to 201	Moderately meets SDW standards
4	100 to 50		200 to 100	
5	Less than 50		Less than 100	Well within SDW standards

Native Water Quality

Native water quality of the target storage zone is important in determining the feasibility of an ASR system. One factor that governs feasibility is the efficiency of the recovery operation. If the storage zone is very thick, the transmissivity is very high (greater than 1 mgd/ft), and the native water quality is very poor (seawater), then ASR may not be a feasible storage option because of the negative effects of density stratification within the storage zone, which could make a portion of the stored water irrecoverable. On the other hand, thin storage zones with moderate transmissivity and poor water quality may be suitable for ASR, requiring only developing and maintaining an appropriate buffer zone.

In the water of the Floridan aquifer system, dominant cations are calcium, magnesium, sodium, and potassium. The dominant anions are bicarbonate, chloride, and sulfate. Locally, smaller amounts of dissolved iron, manganese, nitrate, phosphate, fluoride, strontium, sulfide, and silica may contribute to the dissolved-solids concentration, which varies with depth (Tibbals, 1990).

In about 40 percent of the study area, the TDS concentration in water in the Upper Floridan aquifer is less than 250 mg/L (Tibbals, 1990). The areas of relatively low concentration of dissolved solids generally correspond with the good recharge areas of the Upper Floridan aquifer. In the discharge areas along the Atlantic Coast and along the St. Johns River, the TDS concentration is generally more than 1,000 mg/L and ranges to more than 25,000 mg/L (Tibbals, 1990).

Chloride is the single most important indicator of the presence of brackish water. In most of the area, the chloride concentration in the Upper Floridan aquifer is less than 250 mg/L (Tibbals, 1990). Chloride concentrations are generally higher than 1,000 mg/L in the Upper Floridan aquifer along most of the St. Johns River and along the Atlantic Coast from about Cocoa north to about St. Augustine (Tibbals, 1990).

Table 7 provides two constituents for ranking purposes, chlorides and TDS. The MCLs are 250 mg/L for chlorides and 500 mg/L for TDS. If information is available for both parameters, rank this section for only one constituent.

Table 7. Native Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Water Quality
1	Greater than 6,000	or	Greater than 10,000	Very brackish
2	6,000 to 3,001		10,000 to 5,001	
3	3,000 to 801		5,000 to 1,301	Slightly brackish
4	800 to 400		1,300 to 700	
5	Less than 400		Less than 700	Near fresh water

Physical, Geochemical, And Design Interactions

Several parameters from physical, geochemical, and design interactions can contribute to aquifer plugging, which can cause major efficiency and performance degradation of the ASR system. The ranking system for this section consists of parameter-specific subranking sections. The sub-categories are ranked individually and added together at the end of the section for an overall score for physical, geochemical, and design interaction factors. This score is then ranked to compare it to the other sections in the final ASR feasibility score.

Physical Interaction of Suspended Solids

Some level of suspended solids is present in the recharge water for virtually all ASR systems constructed to date. Physical plugging by suspended solids is a challenging technical aspect for ASR projects. The presence of total suspended solids (TSS), with a concentration as small as 1 mg/L, could contribute to physical plugging of some aquifers. A schedule of backflushing may need to be established through testing at each well site to remove TSS from the aquifer. Backflushing consists of interrupting a recharge segment and pumping the ASR well to waste or retreatment for several minutes or hours, in order to restore the specific injectivity. Turbidity is not a good indicator of TSS.

Ground water may have small amounts of TSS depending on the aquifer material content, which may cause some physical plugging caused by partial rearrangement. Surface water may contain organic matter and debris, which can introduce severe physical plugging, unless the debris is removed prior to injection or by backflushing to waste. Higher transmissivity storage zones are needed for surface water ASR.

Physical Interaction from Biological Growth (Biofouling)

Plugging caused by biological growth during recharge is not well understood. Plugging mechanisms include accumulation of impermeable slimes, development of a mat of dead cells and byproducts, and dispersion or alteration of colloidal particles in the soil-aquifer matrix (Pyne, 1995). The degree of biological growth is directly related to the amount of carbon and nutrients present. Although the concentration of nutrients in the source water may be low, the process of concentrating suspended particles near the well, caused by filtration, often provides the substrate needed to foster biological growth. Careful design of the wellhead can help to control biofouling. Providing a disinfectant residual in the well at all times ensures that biological growth will only occur a sufficient distance from the well so that flow rates are not adversely affected.

Bacteria can be present in aquifers to at least a depth of 1,500 feet (Pyne, 1995). Most bacteria in ground water are attached to formation surfaces and are typically not well represented using ground water as the sampling medium. Subsurface cores are required to confirm the presence of subsurface bacteria. Biofouling is as effective as TSS in reducing permeability in the aquifer around the ASR well. The factors that strongly enhance biofouling potential are temperature between 20 and 40°C; pH between 7.8 and 8.6; total phosphorus that exceeds 0.1 mg/L; nitrate that exceeds 1 mg/L as N; dissolved organic carbon that exceeds 5 mg/L; total iron that exceeds 1 mg/L; DO that exceeds 3 mg/L; and a slow flow sequence.

In general, ground water is without the required nutrients and oxygen needed to sustain biological growth. If water is allowed to cascade into the well, then some biological growth may occur. This can be controlled through appropriate wellhead design and operation. A surface water supply could provide more than enough nutrients and oxygen to sustain high biological activity, unless it is treated prior to storage.

Geochemical Interaction

The correct conditions of temperature, pH, dissolved oxygen, oxygen reduction potential, and specific minerals can cause certain precipitation that reduces the productivity or efficiency of ASR wells. Some minerals can exist in the aquifer core samples and not be evident or be only found in trace amounts in the native water quality and the concentration can increase following the injection of the treated water. The most notable of the possible adverse geochemical reactions are precipitation of calcium carbonate (calcite), the precipitation of iron and manganese oxide hydrates, and the formation, swelling, or dispersion of clay particles. Chemical and physical change that can adversely affect the ASR system is a function of:

- Recharge water quality
- Native ground water quality
- Aquifer mineralogy

- Changes in temperature and pressure that occur during recharge and recovery

In areas with proven long-term satisfactory performance of ASR systems and no sign of geochemical problems, it is reasonable to assume that such problems will not occur in future projects. This applies to all existing Florida ASR systems that store treated drinking water in brackish limestone artesian aquifers. The solution of limestone near the well from occasionally low pH of injected waters appears to be the only geochemical concern in Florida.

Design Interaction by Gas Binding

Typically, the possibility of air entrainment is prevented by proper wellhead design and operation. Maintaining positive pressure in the injection tube or pump column prior to discharge below the water level in the well is a common method of preventing entrained air. Preventing air from entering the well eliminates air entrainment, even though the recharge water may cascade within the well's annular space, injection tube, or pump column.

If air entrainment occurs, it can temporarily, but significantly, reduce the permeability in the aquifer near the well. During recharge, air bubbles may be entrained by the free fall of water inside the well casing or by allowing air to enter the recharge piping where negative pressure occurs. If recharge water with entrained air is allowed inside the well, there is the danger that these air bubbles will be carried downhole through the well screen, perforations, or open hole and out into the aquifer formation. When the entrained air enters the formation material, the bubbles tend to lodge in pore spaces. This increases resistance to flow, resulting in higher water level within the well. This increased resistance to flow levels off in a matter of hours.

Gas binding is a plugging mechanism related to air entrainment and is caused by release of dissolved gas within the aquifer formation after recharge. The result is reduced permeability. DO is an indicator of the concentration of gas in solution. Generally, gas dissolution is not a concern unless DO concentration exceeds 10 mg/L. If dissolved gas is present, it may be released because of the increase in temperature or decrease in pressure, causing dissolution of gas contained in the recharge water.

Overall Physical, Geochemical, and Design Interaction Ranking

Table 8 presents the overall score for physical, geochemical, and design interaction is determined from the sum of the scores for each sub-category.

Table 8. Overall Physical, Geochemical, and Design Interaction Ranking

Sub-Category	Rank	Recharge Water and Criterion	Selected Rank
Physical Interactions from Suspended Solids			
TSS	1	TSS>2.0 mg/L	
	2	2.0 mg/L>TSS>0.05 mg/L (default)	
	3	TSS<0.05 mg/L	
Biological Growth and Geochemical Interactions			
pH	1	7.8<pH< 8.6 (default)	
	2	pH>8.6	
	3	pH<7.8	
Total Phosphorous	1	P>0.1 mg/L	
	2	0.1 mg/L>P>0.05 mg/L (default)	
	3	P<0.05 mg/L	
Nitrate as N	1	N>1 mg/L	
	2	1 mg/L>N>0.5 mg/L (default)	
	3	N<0.5 mg/L	
Dissolved Organic Carbon (DOC)	1	DOC>5 mg/L	
	2	5 mg/L>DOC>2.5 mg/L (default)	
	3	DOC <2.5 mg/L	
Total Iron (Fe)	1	Fe>1 mg/L	
	2	1 mg/L>Fe>0.3 mg/L (default)	
	3	Fe<0.3 mg/L	
Dissolved Oxygen (DO) of Recharge Water	1	DO>3 mg/L	
	2	3 mg/L>DO>1.5 mg/L (default)	
	3	DO<1.5 mg/L	
Point Totals			
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)			

Note: Use the default value if data for any parameter is unavailable. Determine the overall rank from the following point totals:

Rank	Physical, geochemical, and design criteria (total of above points)	
1	7-10 points	Higher potential for plugging
2	11-12 points	
3	13-16 points	Moderate potential for plugging
4	17-18 points	
5	19-21 points	Low potential for plugging

Interfering Uses and Impacts

An interfering use, such as existing wells (industrial, public, or residential) or an impact, such as existing or future contamination release sites (existing landfills, injection wells, future planned industrial complexes, etc.) in the subject area can leave the ASR system prospect with a very limited feasibility (see Table 9). Several issues associated with water rights and environment can cause a utility to question the use of an ASR system.

Table 9. Interfering Uses and Impacts Ranking

Sub-Category	Rank and Criterion		Selected Rank
Interfering Uses			
Distance to Domestic or Public Supply Wells	1	0.10 mile<Wells<0.25 mile	
	2	0.26 mile<Wells<5 miles (default)	
	3	Wells>5 miles	
Interfering Impacts			
Distance to Contamination Source	1	0.10 mile<Source<0.25 mile	
	2	0.26 mile<Source<1 mile (default)	
	3	Source>1 mile	
Point Total			
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)			

Overall Interfering Uses and Impacts Rank determined from the following totals:

Rank	Interfering Use and/or Impact Criteria (possibility of impact)	
1	2 points	High use/impact
2	3 points	
3	4 points	Moderate use/impact
4	5 points	
5	6 points	Low use/impact

Water rights include assuring that the water stored for future use remains in place. With a large volume of fresh water in a brackish aquifer, a neighboring user could install a domestic well and withdraw the stored water. Two issues arise out of this situation. First, the water is treated, then introduced into the storage aquifer for use at a later date, which implies "ownership" because money was spent to withdraw, treat, and store the water under an approved permit. Second, when the neighboring user puts in a domestic well that intersects the stored water, the neighbor assumes better-quality native water. After the utility starts the recovery cycle, the water quality of the neighbor's well degrades to the true native water quality of the area, possibly making his water supply periodically unusable. Also, a nearby industrial complex could use the native water quality of the ASR storage zone in its daily production. The industry could cause an artificial gradient and slowly divert ASR water from the ASR wellfield and, eventually, intercept the stored water. Many interfering use scenarios must be carefully considered.

Environmental issues include the possibility of having existing or obvious potential for contamination in the target aquifer a distance away, but within the capture zone of the ASR system. Wellhead protection issues and constraints for water supply wells should be incorporated into the ASR system design.

To determine a rank for interfering use, two criteria are considered: 1) the distance to any supply or injection well in the same aquifer zone and 2) the distance to any contamination source.

ASR FEASIBILITY SCORING

Scoring for hydrogeologic parameters is completed in Part B of the ASR Feasibility Screening Tool (Figure 7). Appendix B presents an example ASR feasibility screening tool that has been completed for both the fictitious Hastings Water District (agricultural water use) and the City of Cocoa, (potable water use). The rank determined for each section (storage zone confinement, storage zone transmissivity, aquifer gradient and direction, recharge water quality, native water quality, physical, geochemical, and design interactions, and interfering use impacts) is entered by placing the score obtained in the appropriately labeled factor column, on the same line as the numbers (1 through 5) provided in the score column provided on Figure 6. For parameter ranks of 1 through 3, there is high possibility that (additional) field investigation is needed to better understand the impact of the particular factor. For parameter ranks of 4 and 5, field investigations may be needed to confirm particular factors.

Each section has a score weight factor on the bottom row, which is incorporated to prioritize the most critical factors of the ASR feasibility study. The most important ASR factors have a larger weight factor, compared to the other factors. The obtained score is multiplied by the associated weight factor, and the final score is placed in the box on the line below it. If a low rank is achieved in any of these highly weighted sections, then the ASR feasibility will be reduced significantly. The low-weighted sections could have a low rank and ASR could still be highly feasible. Some of these low-ranked sections could possibly be corrected or minimized with additional information, treatment technology advancements, or imposed local regulations. After the initial scores are multiplied by their corresponding weighting factors, the scores are added and the final feasibility score is placed into the double-lined box.

The overall ASR feasibility will never be scored as *not feasible* by this document and screening tool because ASR has many applications (see ASR Overview section). The only method of determining ASR as not feasible for a specific situation is based on how well ASR will satisfy the utilities needs. A low score from this screening tool may not provide the needed results for one utility, while the same low scored ASR system may provide a much needed resource for a different utility even though the immediate results may be less than desirable.

The graphical relationship of the final feasibility score to an imaginary "caution factor" is provided as Figure 16. This chart implies that the more a score deviates from the best score obtainable, the more caution is needed in the final decision about ASR feasibility to match with the specific needs of the utility considering this option. At the lowest score possible, ASR has a limited feasibility as a storage option which means it may not satisfy 100 percent of the utilities needs immediately, but it could still be the best available option. However, at the highest score, there still remains a degree of caution that must be recognized in order for the ASR system to be successful. This figure correlates with the ranges specified in Table 1 for high confidence, moderate confidence, and limited confidence for ASR feasibility. Florida is fortunate to have many ASR systems in operation for a variety of uses. These systems can be assessed, and the true effectiveness of ASR as a storage option is evident.

EXISTING ASR SYSTEM SCORING SUMMARY

Because limited information is available to support the ranges provided for the hydrogeological factors, a scoring study was conducted that provides information on how existing systems score in the feasibility study. The actual score sheets for Part B are provided in Appendix C. Table 10 summarizes the scoring study for the selected existing sites of Florida and the U.S.

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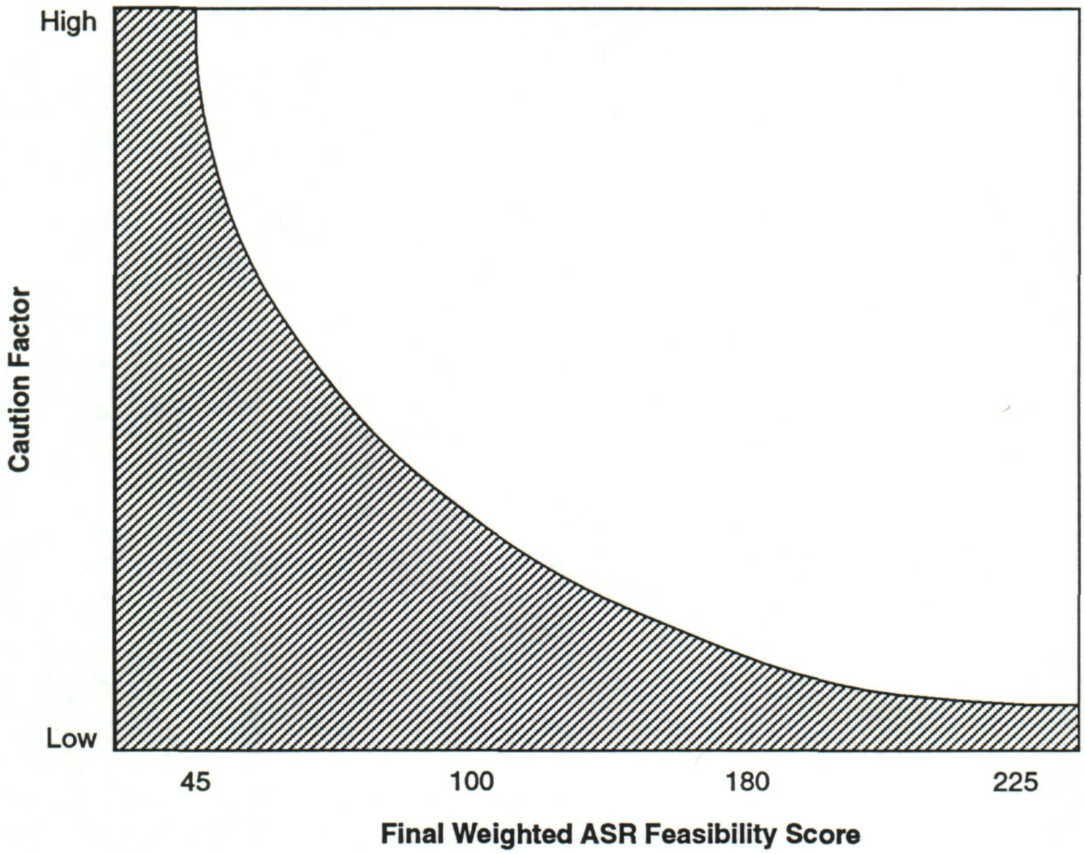

Figure 16. Final score versus caution factor

Table 10. Existing ASR System Scoring Summary

Existing ASR System	Hydrogeology Score Section							Total Score	Level of Confidence
	1	2	3	4	5	6	7		
Boynton Beach, FL	20	50	4	8	30	15	25	152	Moderate
Cocoa, FL	50	50	3	6	40	15	15	179	High
Manatee County, FL	20	20	5	8	50	15	25	143	Moderate
Marathon, FL	20	30	5	10	10	15	25	115	Moderate
Palm Bay, FL	50	30	3	8	40	15	25	167	High
Peace River, FL	50	40	4	8	50	15	25	192	High
Highland Ranch, CO	20	20	5	10	50	15	25	145	Moderate
Seattle, WA	30	20	5	10	50	15	25	155	Moderate
Feasibility Ranges:	160 - 215 100 - 159 43 - 99			High Confidence Moderate Confidence Low Confidence					

Three of these existing sites were scored as high feasibility, and the other sites were scored as moderate feasibility. Each factor must be weighed in relation to the other factors based on site- or water-use-specific information, which could render a moderate or high confidence score as not feasible or justify the attractiveness of a lower moderate confidence score. An example is the relationship of storage zone transmissivity to the native water quality. A high transmissivity ASR zone (which has a low factor score) can perform well, if the native water quality is near potable and the water is to be stored for a short period. However, that same zone would not be as attractive if the native water quality were very poor. Another example is an ASR site was rejected because many wells existed in the area of the proposed ASR site. Although the factor weighting score in this document is lower than other factor scores, this issue was important enough to change the proposed ASR site.

Each factor should be considered individual, then the list of factors should be related to the ultimate and future possible uses to determine the final feasibility of an ASR system. As more information becomes available from future sites, the applicable factor ranges will reflect the new information, providing better understanding of the many ASR applications to conserve our water resource.

COST FACTORS

Cost is a key issue in choosing an approach to meet water demand. For potable use, a cost comparison must be made among storage options (ASR, tanks, reservoirs) and possible management options (ASR, plant expansion, water purchase). Developing unit costs of typical utility infrastructure improvements for each option provides an economic comparison tool for potential water supply solutions. For agricultural use, the cost is based on the irrigation system, well placement, existing system retrofit potential, and recharge/recovery management. Because of the site-specific nature of the agricultural system requirements, a general cost comparison cannot be developed as part of the ASR screening tool. This section, therefore, provides order-of-magnitude cost comparisons for potable use. ASR costs, storage costs for tank and reservoir options, and costs for the management option of water plant expansion are addressed. A worksheet is provided as Figure 17 to log the annualized costs for each item for comparison. This worksheet is included in the general screening tool presented in Appendix A.

ASR wells usually are sized based on the required recovery rate. The recovery rate is a key cost factor for ASR wells, as it affects the required diameter, depth of the well, and size and speed of the pump. The total required recovery rate may be calculated in two ways. First, the required recovery rate per well should equal the maximum rate that ASR could sustain for the development and recovery duration. In this case, the finished water ASR would be designed to supply the MDD without a WTP in operation. Second, the required recovery rate may also be calculated, based on a known required storage volume, as the product of the peaking factor and the required storage volume, divided by the storage period duration:

$$\text{Req. Recovery Rate} = (PF * V_s) / \text{Duration}$$

The peaking factor is the ratio of the MDD to the ADD, and the required storage volume and storage period must be determined on a site-specific basis following evaluation of all relevant data.

Figure 18 provides ASR cost estimates in terms of the total required recovery rate. The costs represent installed order-of-magnitude estimates for construction and approximate operating and maintenance costs. Costs were developed based on the following

Facility Designation ______________________ Date __________

Facility Director ______________________

Water Management District St. Johns River Water Management District Date __________

District Officer ______________________

PART C COST COMPARISON SUMMARY

Cost Comparison for Storage Options

Storage Need (SN): __________ MG Peak Factor (PF): __________ Recovery Duration (RD): __________ ASR Recovery Rate $\frac{PF \bullet SN}{RD}$ = __________ mgd

Equivalent Annual Costs

Tank $ __________

Reservoir $ __________

ASR $ __________

Cost Comparison for Management Options

Plant Rate Increase: __________ mgd

Equivalent Annual Costs

Plant Upgrades	Base Cost	Option 1	Option 2	Option 3	Option 4
Lime Softening and					
Sulfide Reduction by	Tray Aeration				
	Packing Tower				
	Ozonation				
TOTAL					

Equivalent Annual Cost for Options

Plant Upgrade $ __________ (total cost from option selected from the table above)

ASR $ __________ (annual cost from cost comparison for storage options)

PART D REGULATORY SUMMARY

	YES	NO	
Injected water meets all standards	______	______	(refer to Figure A2 for regulatory requirements)
Injected water meets federal standards and state minimums	______	______	(refer to Figure A2 for regulatory requirements)
Injected water exceedes one or more federal standards	______	______	(refer to Figure A2 for regulatory requirements)

Figure 17. Feasibility screening report, Parts C and D

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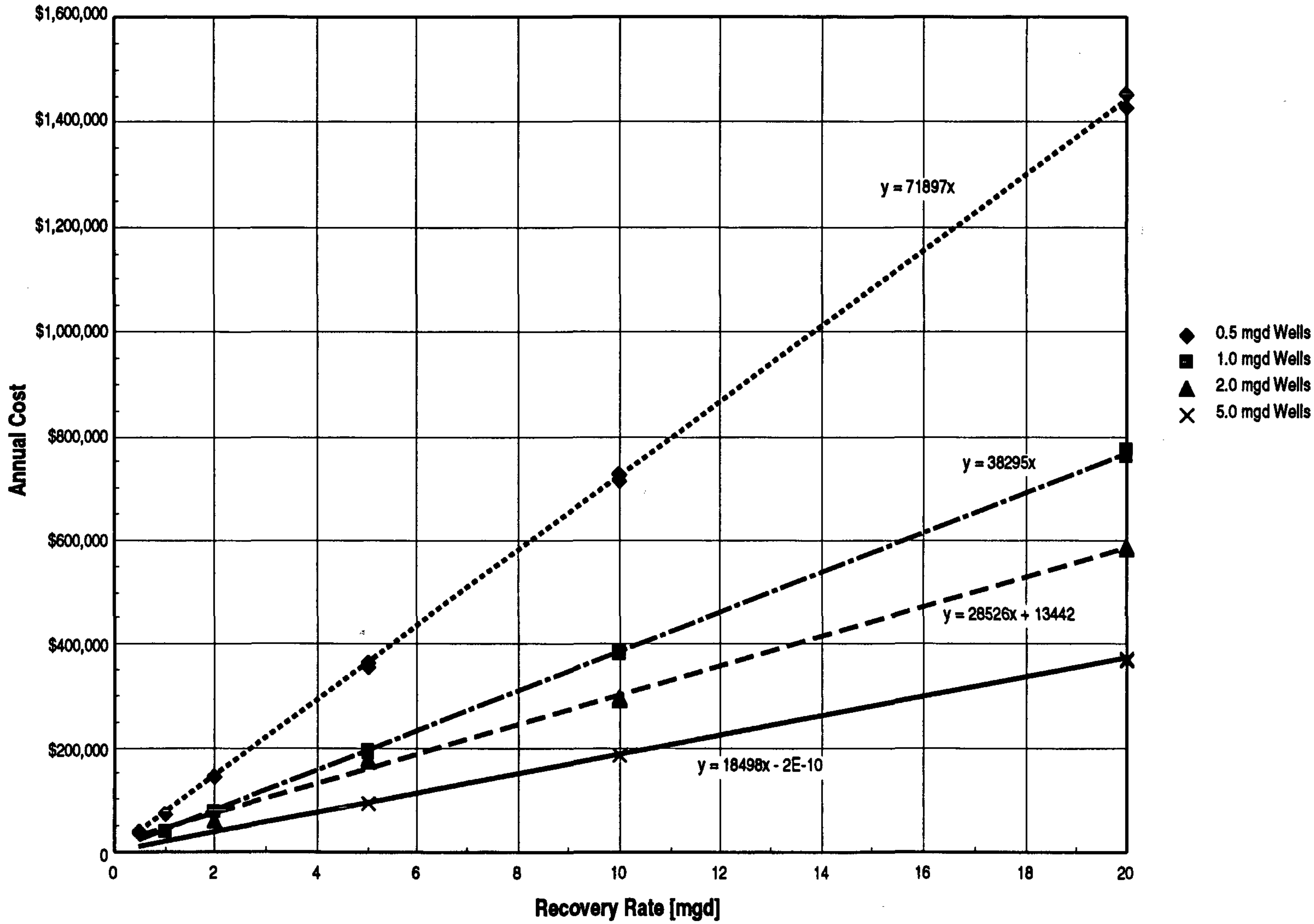

Figure 18. ASR annual cost versus recovery rate.

criteria, which are in agreement with cost estimating criteria previously established (SJRWMD, 1996):

- ASR land requirement is approximately 1 acre per well (includes any required pipeline corridors).
- Land costs calculated based on $5,000 per acre for rural parcels and $20,000 per acre for suburban parcels.
- Land acquisition cost of 25 percent of the land parcel cost included in the total capital cost.
- Non-construction capital cost allowance of 45 percent included to cover engineering, permitting, administration, and contingency.
- Costs are in 1996 dollars with a time value of money at 7 percent.
- ASR wells assumed to have an economic service life of 40 years. Pumps are assumed to have an economic service life of 20 years.
- Capital recovery factor used to convert capital costs:
  - CRF (i = 7%, n = 20) = 0.09439
  - CRF (i = 7%, n = 40) = 0.07501
- Equivalent annual costs calculated using a weighted capital recovery factor. Weighted CRF calculated based on:
  - 10 percent, 20-year life; 90 percent, 40-year life for 0.5 mgd wells
  - 13 percent, 20-year life; 87 percent, 40-year life for 1.0 mgd wells
  - 25 percent, 20-year life; 75 percent, 40-year life for 2.0 mgd wells
  - 33 percent, 20-year life; 67 percent, 40-year life for 5.0 mgd wells
- Costs for disinfection prior to distribution are not included.

STORAGE OPTIONS

The three primary water storage options to be considered for any water supply system are ASR, tanks, and reservoirs. ASR wells are sized according to recovery capacity because storage volume can vary.

Tanks and reservoirs are sized according to the storage volume required. Figures 19 and 20 provide cost estimates which represent installed order-of-magnitude estimates for construction and approximate operating and maintenance costs. Costs were developed based on the following:

- Tank cost estimates based on manufacturer quotes (Pruder, 1996).
- Land area required for tanks calculated as a square or rectangular plot with side dimensions 50 feet greater than the tank diameter and allowing 100 feet between multiple tanks.
- Reservoir area calculated assuming one-half acre required per million gallons storage.
- Land costs calculated based on $5,000 per acre for rural parcels and $20,000 per acre for suburban parcels.
- Land acquisition fee of 25 percent of the land parcel cost included in the total capital cost.
- Non-construction capital cost allowance of 45 percent included to cover engineering, permitting, administration, and contingency.
- Costs are in 1996 dollars with a time value of money at 7 percent.
- Reservoirs and tanks assumed to have an economic service life of 40 years.
- Capital recovery factor used to convert capital costs to equivalent annual cost: CRF (i = 7%, n = 40) = 0.07501.
- Chlorination prior to distribution is required of each option; therefore, this is not included in the cost estimates.

MANAGEMENT OPTIONS

As discussed throughout this TM, ASR can be used as a management tool to defer or avoid WTP expansion, or as an alternative to purchasing water to meet peak demands. Therefore, in some applications, it is relevant to compare ASR costs with these other options.

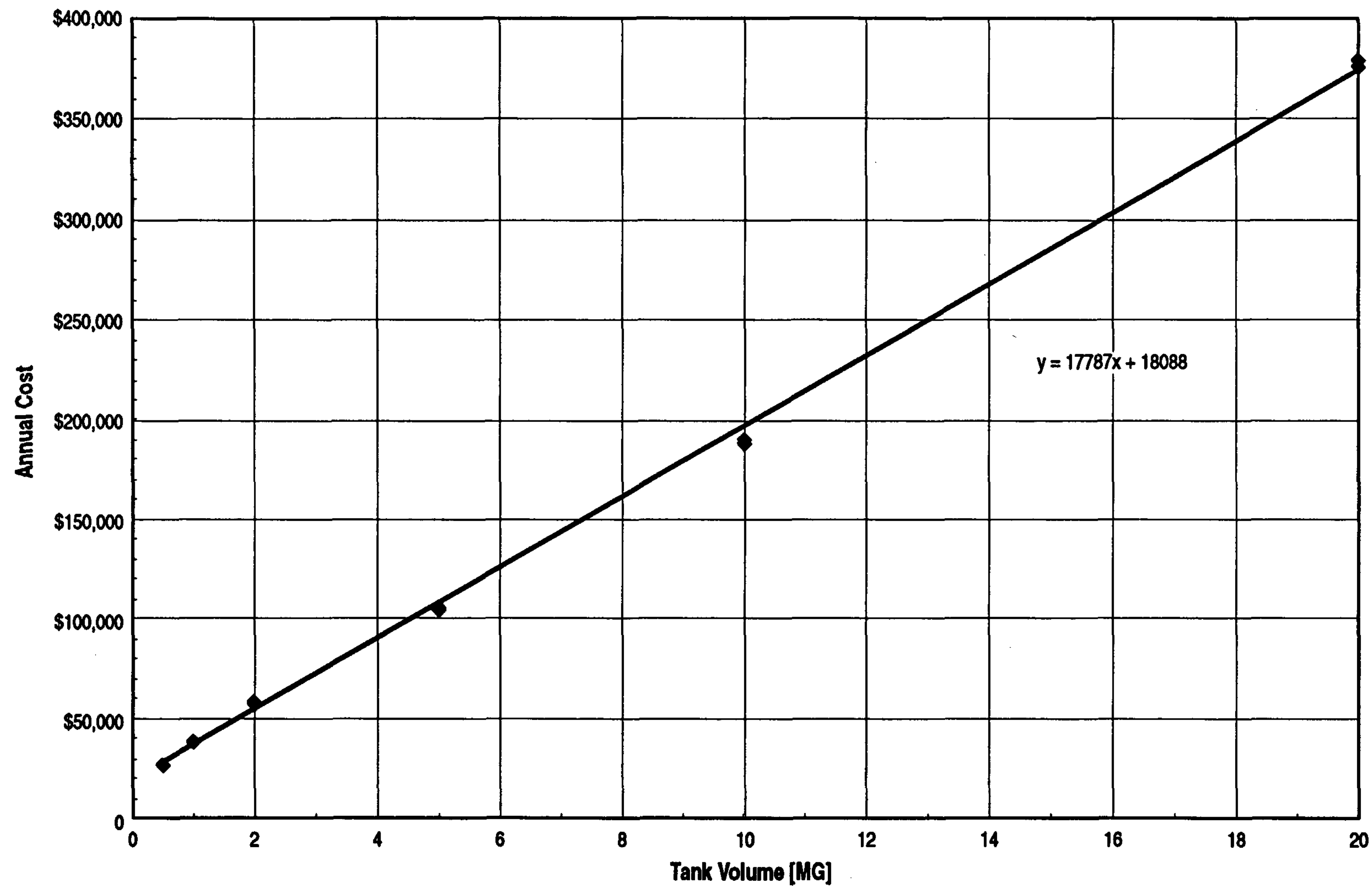

Figure 19. Storage tanks annual cost versus tank volume.

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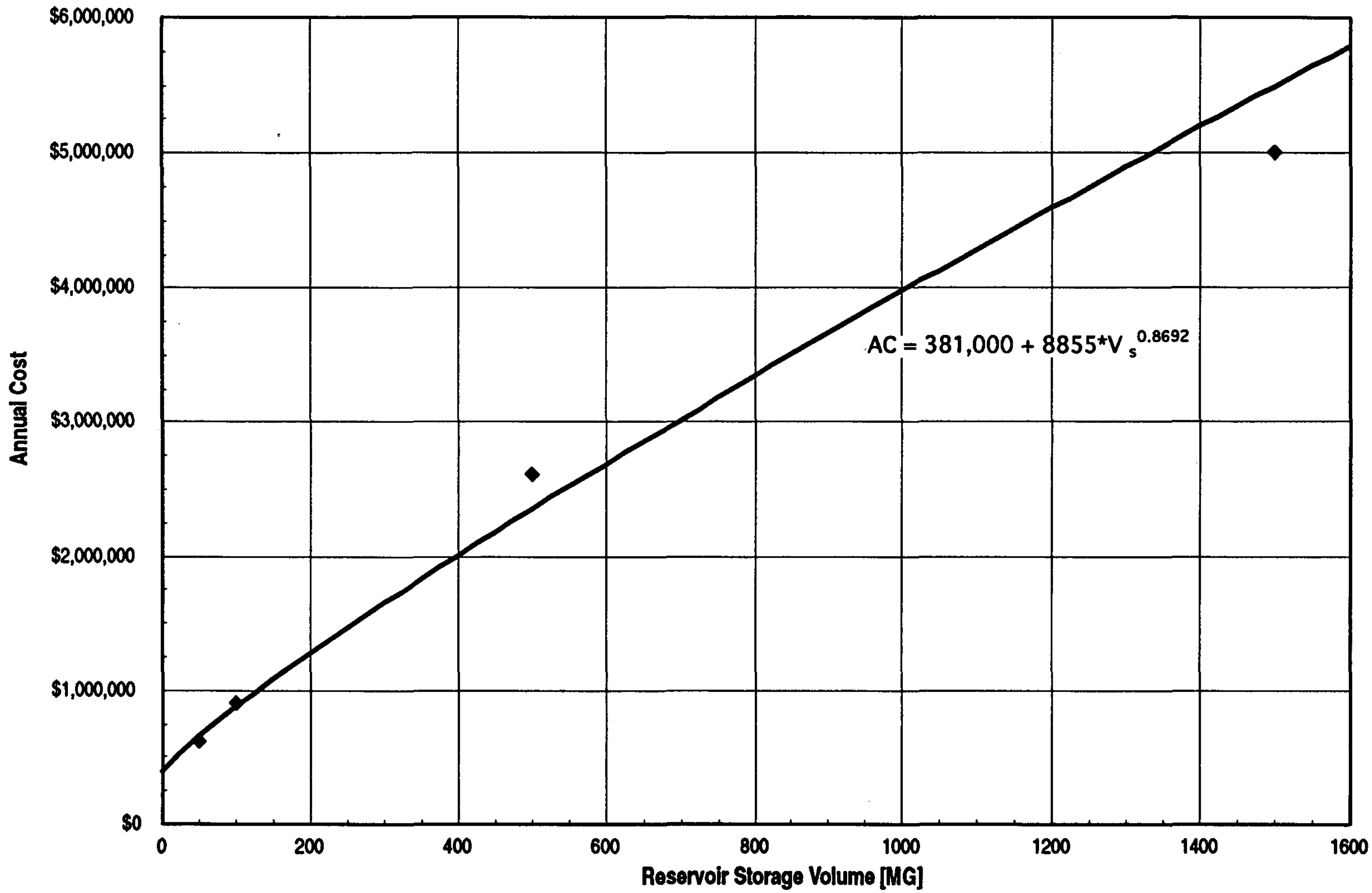

Figure 20. Storage reservoirs annual cost versus storage volume.

Water Treatment Plant Expansions

Treatment of potable ground water in the SJRWMD requires chlorination prior to distribution at a minimum. Higher levels of treatment for potable water supply may include lime softening and/or sulfide reduction. To expand a typical existing lime softening plant, new clarifiers, sludge handling facilities, piping, and pump stations must be constructed. Similarly, to increase capacity for sulfide reduction, tray aerators, packed towers, or ozonation facilities must be constructed. ASR can be used to defer water treatment plant expansion by providing system storage to reduce peak flow requirements through the treatment facility.

If the treatment plant is composed of chlorination facilities only, ASR can only provide system storage. No significant treatment costs can be deferred through the use of ASR. Therefore, we have not compared ASR to the cost of chlorination. Where water treatment costs are a significant portion of the water supply expansion costs, using ASR to defer the treatment component of those costs can be beneficial.

Figures 21 through 24 present the costs for each of the management options. The costs represent installed order-of-magnitude estimates for construction and approximate operating and maintenance costs. Costs for chlorine disinfection prior to distribution are not included with the other plant upgrade cost curves because disinfection is required as a minimum for a public water supply system. The costs provided should be used to determine the costs effectiveness of different plant upgrades to ASR, all of which will require chlorine disinfection. Costs were developed based on the following:

- Tray aerator cost estimates based on manufacturer quotes (Pruder, 1996).
- Lime softening, chlorination, ozonation, and packed tower costs were determined using EPA Cost Digest (EPA, 1984) cost curves. Costs were adjusted to current dollars. Additional adjustments were made to conform with previously established cost estimating criteria (SJRWMD, 1996).
- An area of 7 acres was assumed for plants from 0.5 to 5.0 mgd, and 10 acres for plants from 10 to 50 mgd.
- Land costs in 1996 were calculated based on $5,000 per acre for rural parcels and $20,000 per acre for suburban parcels (SJRWMD, 1996).

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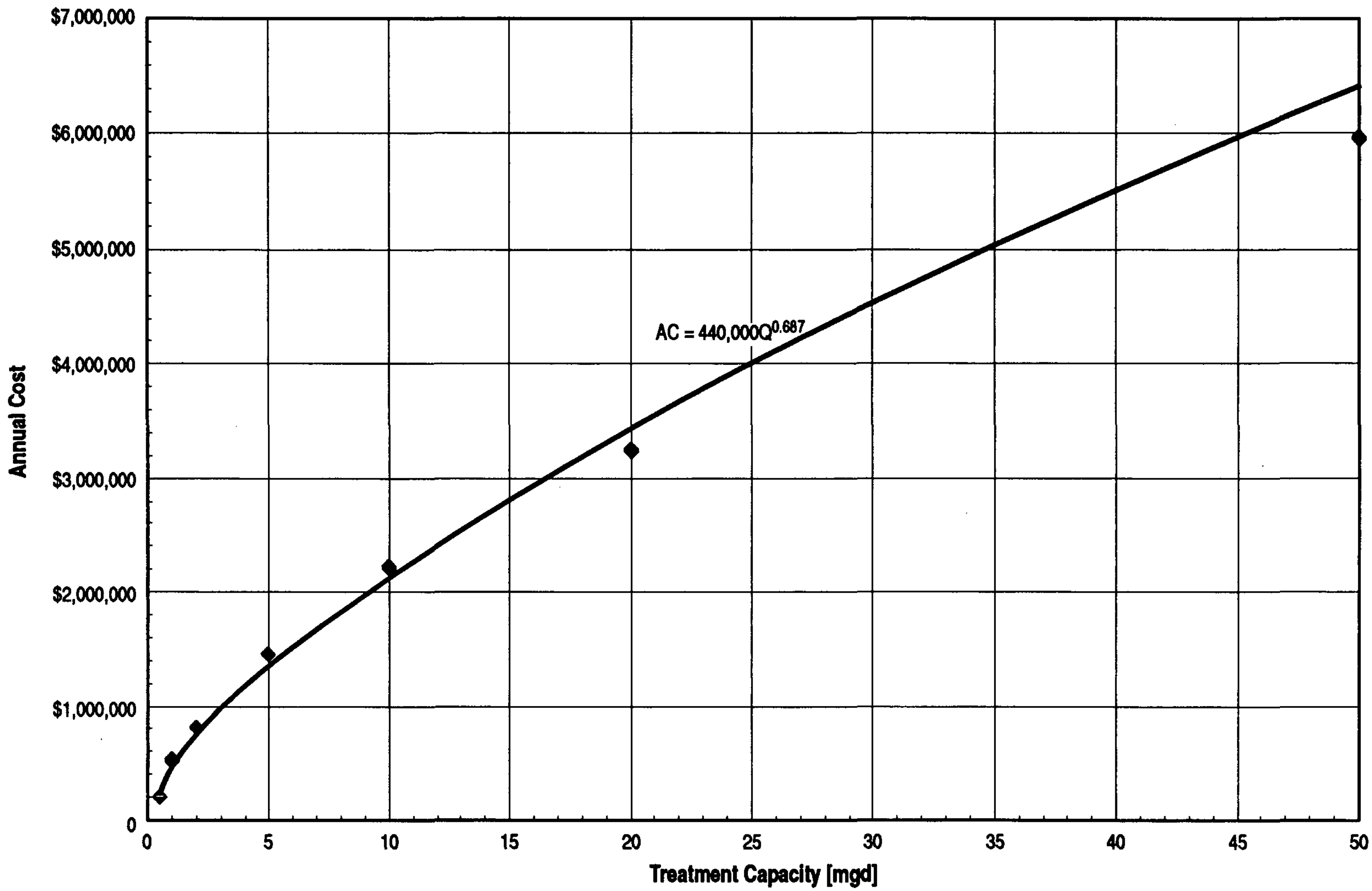


Figure 21. Lime softening annual cost versus treatment capacity.

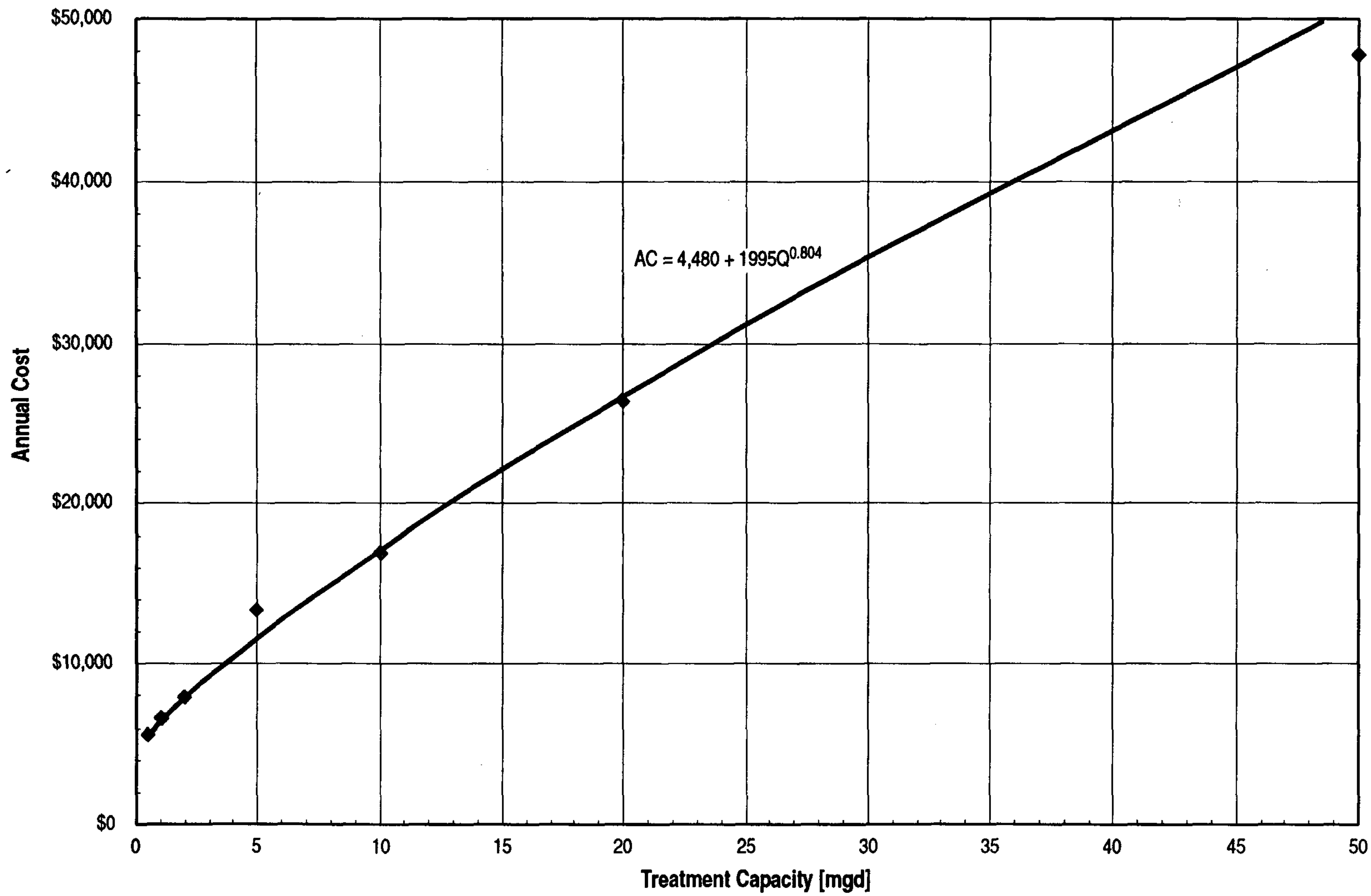


Figure 22. Tray aeration annual cost versus treatment capacity.

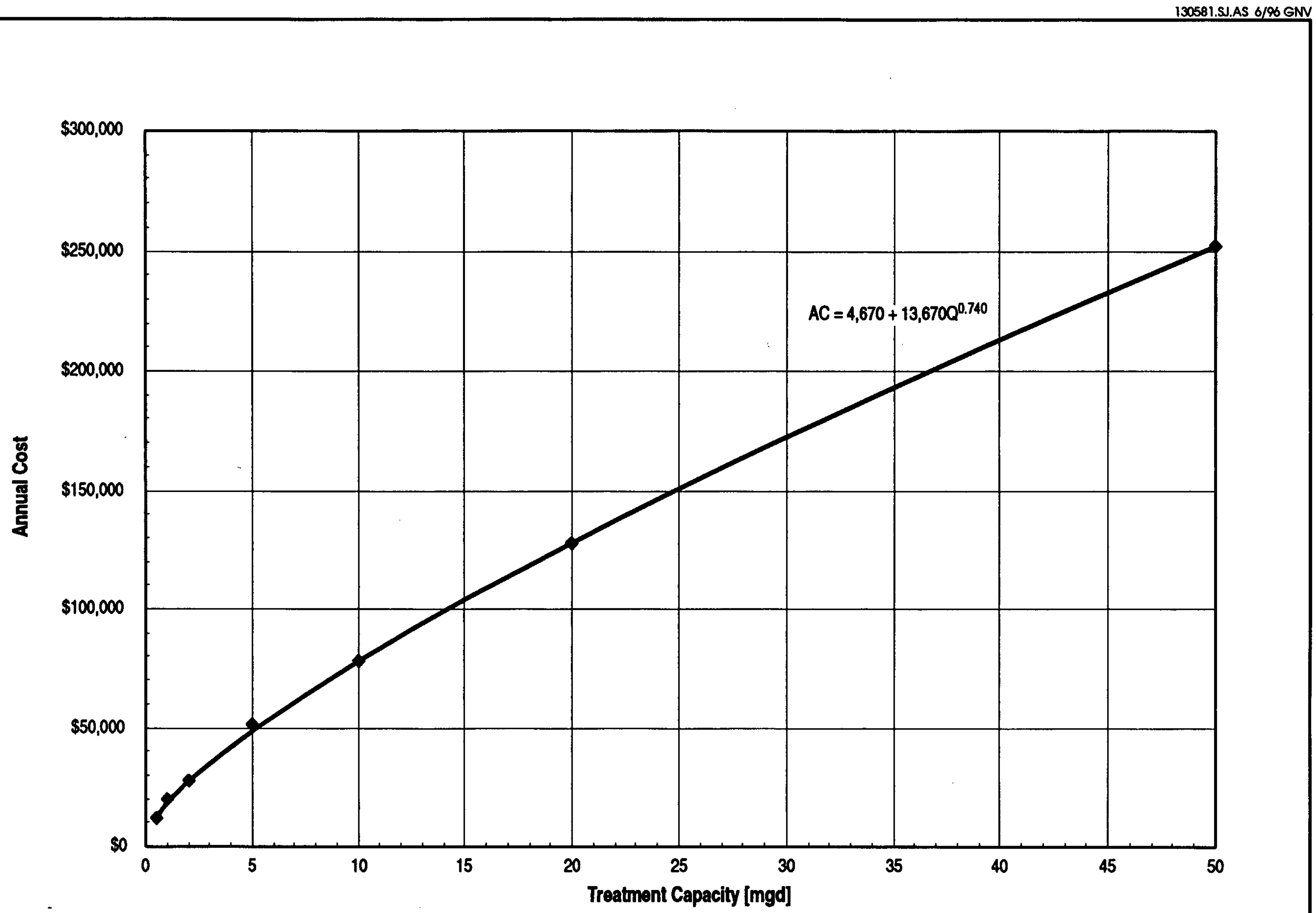


Figure 23. Packed towers annual cost versus treatment capacity.

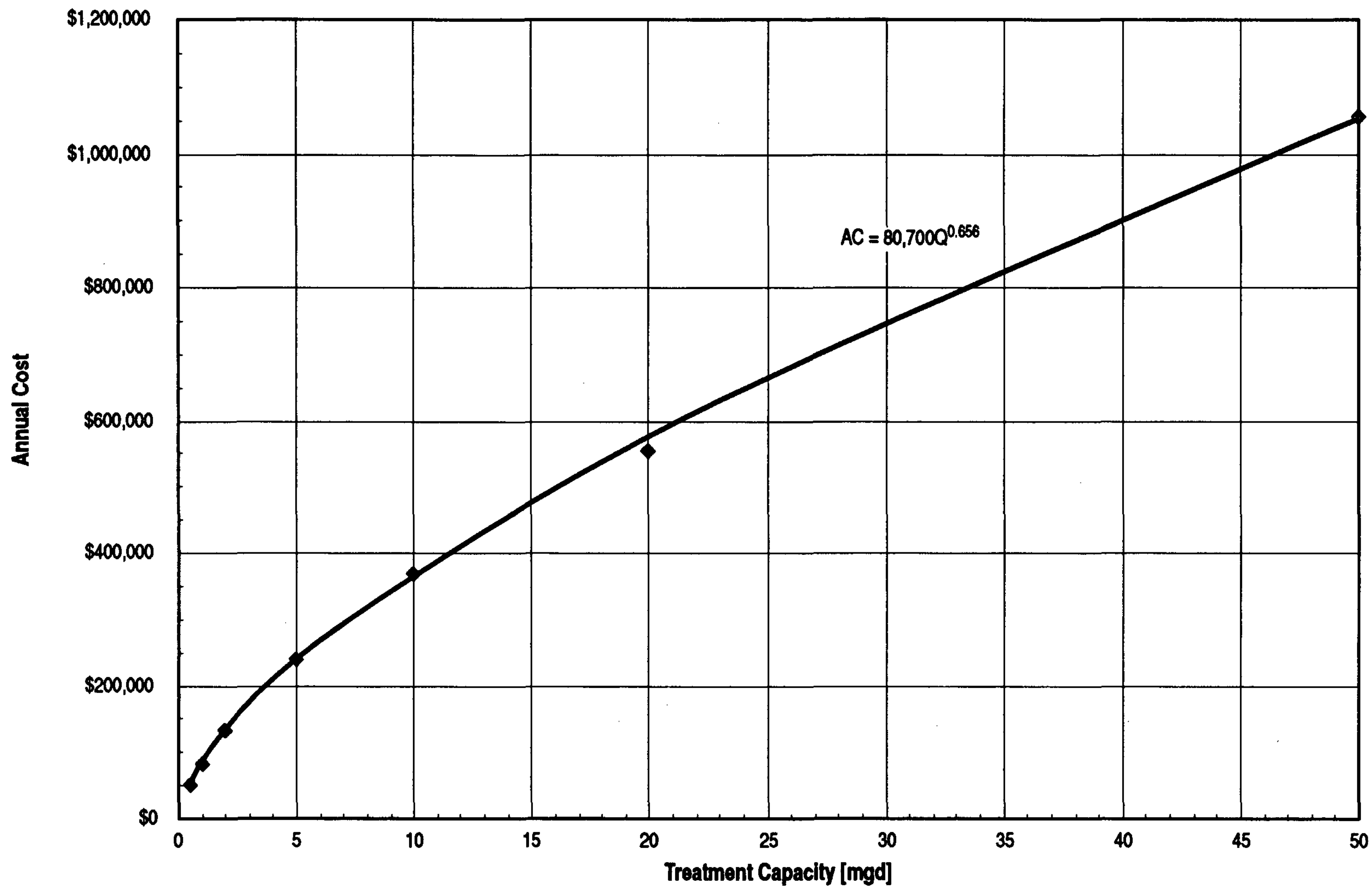


Figure 24. Ozonation with Chlorination annual cost versus treatment capacity.

- Land acquisition cost of 25 percent of the land parcel cost was included in the total capital cost (SJRWMD, 1996).
- Non-construction capital cost allowance of 45 percent included to cover engineering, permitting, administration, and contingency (SJRWMD, 1996).
- Costs presented as 1996 dollars, with a time value of money at 7 percent
- Capital recovery factors used to convert capital costs:
  - CRF (I = 7%, n = 20) = 0.09439
  - CRF (i = 7%, n = 40) = 0.07501
- Equivalent annual costs calculated using a weighted recovery factor. Weighted CRF calculated assuming:
  - 33.3 percent, 20-year life; 66.7 percent, 40-year life

Water Purchase

Water may be purchased from surrounding utilities to meet peak demands. A general cost comparison cannot be provided for this option because of its site-specific nature. The wholesale rate of water will vary depending upon the regional location, the volume purchased, and whether purchases are during peak demand periods or off-peak periods. The transmission costs (transmission pipeline and number of pump stations) will be affected by the distance between the utilities. Therefore, determination of comparative costs for this option are beyond the scope of this document.

REGULATORY FACTORS

Several federal, state and local regulations govern the implementation of ASR in Florida. Table 11 lists the primary statutes and corresponding administrative regulations for each program (USEPA, FDEP, SFWMD, 1993). In Florida, two state agencies and, indirectly, the federal EPA have specific control over water use and injection. General definitions relevant to the regulations are provided followed by a description of each agency's duties. Recharge water quality, and permit requirements for the potable and agricultural scenarios addressed in this document are also discussed.

This regulatory framework was developed pursuant to the 1974 Safe Drinking Water Act (SDWA), which was designed to prevent the contamination of the nation's ground water resources. ASR technology has evolved since that time. Although ASR storage of treated drinking water is permittable under this Act, the requirements of the Act are unnecessarily restrictive regarding ASR storage of other high-quality water that may not meet all federal standards but would not cause significant degradation of public health, ground water quality, or the environment. Efforts are underway in Florida to address these regulatory issues, thereby facilitating more effective management of Florida's seasonally abundant, high-quality surface water, raw ground water, and reclaimed water.

The following subsection presents a current assessment of an evolving regulatory process. Indicative of a core issue in current regulations is the implied basic assumption that ASR wells are synonymous with injection wells, which are used for disposal of public and industrial wastewater effluent. Although this is not the case, the regulations begin from this fundamental premise.

GENERAL DEFINITIONS

The following definitions are relevant for several terms used in the ASR permitting regulations:

Class V: Defined in both federal and state regulations as any injection well not classified as a Class I, II, III, or IV well. Often, but not always, Class V wells inject into or above underground sources of drinking water (USDW) (Chapter 40 *C.F.R.* 144.6).

Table 11. Regulatory Programs Relating to ASR

Program	Regulations
1. Underground Injection Control (FDEP)	Chapter 62-4, *F.A.C.*- Permits Chapter 62-528, *F.A.C.* - UIC Chapter 62-520, *F.A.C.* - Ground Water Classes, Standards and Exemptions Chapter 62-522, *F.A.C.* - Ground Water Permitting and Monitoring Requirements Chapter 62-550, *F.A.C.* - Drinking Water Standards, Monitoring and Reporting Chapter 62-600, *F.A.C.* - Domestic Wastewater Facilities (reclaimed/reuse water)
2. Aquifer Exemptions/State Water Quality Criteria Exemptions (FDEP)	Chapter 62-528.300(3) *F.A.C.* - UIC Program: Identification of and Criteria for Exempted Aquifers Chapter 62-528.300(7) *F.A.C.* - UIC Program: Confidential Information
3. Water Management District Programs	Chapter 40C-2, *F.A.C.* - Permitting Consumptive Uses of Water Chapter 40C-3, *F.A.C.* - Water Wells Chapter 40C-5, *F.A.C.* - Artificial Recharge
4. Federal Regulations for Aquifer Exemptions	Chapter 40 *C.F.R.* 141.11 to 16 - National Primary Drinking Water Regulations Chapter 40 *C.F.R.* 143.3 - National Secondary Drinking Water Regulations Chapter 40 *C.F.R.* 144.7 - UIC Program: Identification of USDWs and Exempted Aquifers Chapter 40 *C.F.R.* 146.4 - UIC Program: Criteria and Standards: Criteria for Aquifer Exemptions 403.859(7) *F.S.* - Environmental Common: Prohibited Acts
5. Other Programs	Other federal, state, and local regulations may apply depending on the specific circumstances and location of the proposed ASR well.

F.A.C. - Florida Administrative Code
C.F.R. - Code of Federal Regulations
F.S. - Florida Statutes

Group 3: Wells that are part of domestic wastewater treatment systems, including septic system wells receiving domestic wastewater other than those specifically excluded in Rule 62-528.120(4)(b), *F.A.C.* (Chapter 62-528.600(2)(c)).

Group 7: Wells associated with an aquifer storage recovery system (Chapter 62-528.600(2)(q)).

USDW: An aquifer or a portion of an aquifer that supplies a public water system (PWS) or has the potential to supply a PWS, contains less than 10,000 mg/L TDS, and is not an exempted aquifer (Chapter 40 *C.F.R.* 144.3).

Underground Injection Control (UIC): A program designed to protect the quality of the State's USDWs and to prevent degradation of the quality of other aquifers adjacent to the injection zone that may be used for other purposes. This purpose is achieved through rules that govern the construction and operation of injection wells in such a way that the injected fluid remains in the injection zone and that unapproved interchange of water between aquifers is prevented (Chapter 62-528, *F.A.C.*).

WATER MANAGEMENT DISTRICTS

Water management districts are responsible for consumptive use permitting (CUP) of the ground water withdrawal, diversion, impoundment, or use of water by utilities or industry with an average annual withdrawal of 100,000 gpd or more. Purposes of the CUP are to:

- Provide the permittee with a level of certainty regarding the availability of water for a reasonable beneficial use.
- Protect the resource from adverse impact resulting from over-development of the source.
- Protect the rights of other existing legal users.

A CUP is required for aquifer testing and operation of the completed system prior to initiating pumpage for storage or recovery. In addition to the CUP, the water management districts may issue well construction permits for Class V injection wells and associated monitoring wells. These permits are issued under district administrative rules that govern well construction and are separate from the UIC program administered by FDEP.

A zero-CUP (0-CUP) is used by the water management districts as a permitting tool to allow ASR record keeping. A 0-CUP assumes that the water injected into the ASR well will be removed, creating a balance between recharge and recovery volumes, thus zero withdrawal. The ASR wells are permitted separately from the regular wellfields, which only withdraw water for eventual public consumption.

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

FDEP is responsible for permitting all wells that inject water into any aquifer and protecting all aquifers that have the potential of becoming a drinking water source. This is referred to as the UIC program. All state UIC permits are issued by the FDEP District offices. However, permit applications are reviewed by both the FDEP District and Tallahassee staff and, in many cases, may be reviewed by the five-member UIC Technical Advisory Committee (TAC).

For the UIC, injection wells are categorized by class and group. A Class V, Group 7 (or Group 3 for reclaimed water) construction permit must be obtained from the FDEP prior to constructing an ASR well. This permit is used to authorize the construction and initial testing of an ASR well. Depending on whether an aquifer exemption is needed, this process could take from 3 months to several years. When the ASR well is operated after the initial testing authorized under the construction permit, a Class V, Group 7 (or Group 3 for reclaimed water) operation permit must be obtained. The review process is similar to the construction permit application review.

FDEP has historically required that the point of compliance for measuring recharge water quality is at the wellhead. In recent months, FDEP has suggested that, for some ASR applications and sites, the point of compliance could possibly be measured at the edge of a zone of discharge (ZOD) around the ASR well. This would be consistent with a similar concept applied to land application systems for wastewater disposal and for discharges to surface water. In particular, the ZOD would be applicable for coliform bacteria, which occur naturally and are known to die rapidly during ASR storage in brackish aquifers. Whether through changes in policy, rules, or legislation, it is expected that this change will occur and will facilitate ASR operations within Florida.

ENVIRONMENTAL PROTECTION AGENCY

The U.S. Environmental Protection Agency (EPA) has participated in the review of ASR permit applications as a member of the UIC TAC. EPA's main role in future ASR projects will be review of aquifer exemption petitions submitted by FDEP.

An exemption is regulatory permission to exceed specific components of an existing regulation. Exemptions are not permits; therefore, no time limit exists. Two types of exemption currently exist:

- Water quality—permission to exceed one or more minor constituents of the non-federal primary or secondary drinking water standards; the receiving aquifer is still classified as G-II or G-III. The recharge water must meet Federal PDWS and SDWS, non-federal PDWS and SDWS or ambient water quality, and minimum criteria. These exemptions are issued by FDEP and typically are applied to raw ground water and reclaimed water ASR systems.
- Aquifer—receiving aquifer classification lowered, typically from a USDW (G-II) to a non-USDW (G-III), removing the protection regulations from that portion of the aquifer.

Aquifer exemptions are not needed for treated water ASR systems because the injected water is better quality than the native water and meets all federal drinking water quality standards. Where high-quality surface water is used as the source water for the ASR system, the source water may exceed some minor PDWS criteria and still be of substantially better quality than the native water and the stored water may be used for irrigation or aquifer management instead of drinking water.

An aquifer exemption is generally needed for the following reasons:

- If injected fluid is placed in a zone below a USDW and inadequate confinement exists below the USDW, the USDW water could be affected by the upward movement of the injected fluid.
- Injected fluid cannot meet federal PDWS.
- Injected fluid or formation fluid causes an exceedance of PDWS in a portion of the aquifer with TDS less than 10,000 mg/L.

Two aquifer exemptions currently exist:

- Minor - required if affected aquifer zones have a TDS concentration between 3,000 and 10,000 mg/L. FDEP is the lead agency approver; Region IV EPA may deny or ignore exemption request. To date, only two minor exemptions have been issued in Florida.
- Major - required if affected aquifer zones have TDS concentration less than 3,000 mg/L. EPA lead agency reviewer; approval or denial is made by the agency's administrator and a notice is placed in Federal Register. To date, no major exemption has been issued in Florida or elsewhere.

In recent months, EPA has addressed the need to reinterpret UIC regulations to better accommodate raw surface water ASR systems in Florida. FDEP has agreed to a protocol under which EPA will consider issuing a parameter-specific aquifer exemption on a site-specific basis. Because the point of compliance is not specified in EPA regulations, EPA will consider the ZOD prepared by FDEP in its decision on whether to approve a major or minor aquifer exemption for each constituent. This is a new procedure that must be tested by submitting a permit application. It offers the potential for accommodating regional ASR systems in Florida that would store high-quality, seasonally available surface water. This could provide several benefits for water uses within the SJRWMD.

RECHARGE WATER CRITERIA

The recharge water to be injected through a Class V well into an aquifer must meet certain criteria. As mentioned previously, a treated water ASR well will, in most circumstances, comply with all of these requirements. Class V wells are allowed to recharge into or above a USDW with vertical and lateral movement of injected water. A Class I well is required to inject below a USDW without vertical movement of injected water. Most ASR wells recharge into a USDW zone, although some ASRs could store water below a USDW, as a Class I well is required to do. However, the classification for an ASR well should always be as a Class V well, even when it is recharging water below a USDW. This designation of Class V allows lateral and vertical movement of the recharge water in the target zone; thus, a Class V well has fewer constraints than for a Class I well. The following are requirements for a Class V ASR well recharge water, as measured at the point of compliance:

1. ASR storage zone with TDS less than or equal to 10,000 mg/L

   a. At an ASR well:

      - Effluent standards (Rule 62-600.540(2))
      - PDWS
      - Non-federal primary drinking water standards or ambient water quality for the constituents contained in the non-federal primary water quality standards (whichever is poorer)
      - Secondary drinking water standards or ambient water quality for the constituents contained in the secondary water quality standards (whichever is poorer)
      - Minimum criteria ("free-froms" policy from the FDEP)

   b. In any location where effluent will migrate:

      - PDWS
      - Non-federal primary drinking water standards or ambient water quality for the constituents contained in the non-federal primary water quality standards (whichever is poorer)
      - Secondary drinking water standards or ambient water quality for the constituents contained in the secondary water quality standards (whichever is poorer)
      - Minimum criteria ("free-froms" policy from FDEP)

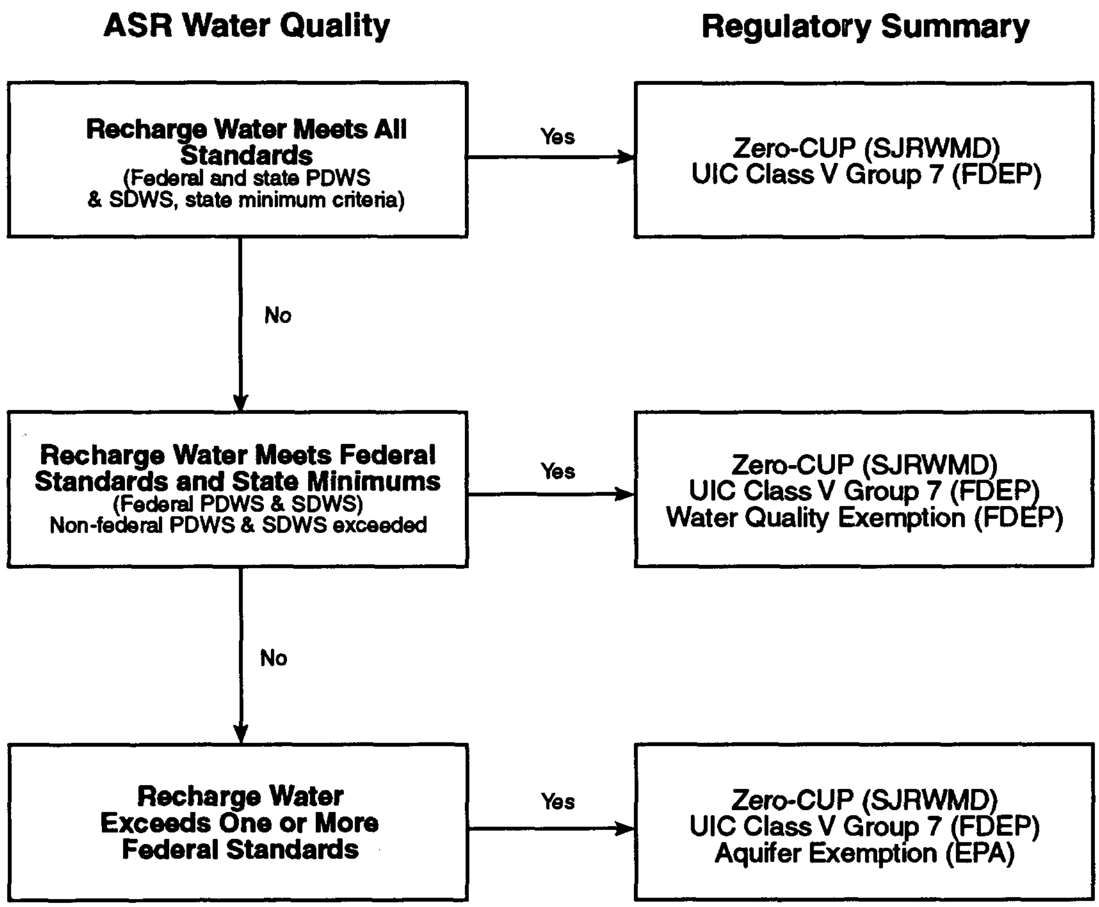
2. Injection zone in Floridan aquifer with TDS greater than or equal to 500 mg/L

   a. A statutory ban for all facilities not approved or conceptually approved on or before June 1, 1983 (403.859 (7) *F.S.*)

An ASR system can be used for various water storage scenarios. The recharge water can be treated ground or surface water or raw ground or surface water before treatment. ASR can be used for potable or agriculture supplies. Table 12 lists the most probable scenarios for ASR system use, along with the associated regulatory permits and constraints. The process, shown in Figure 25, is simplified as a flow chart for use as a decision tool.

Table 12. Regulation Permits and Constraints for Implementing ASR

ASR Implementation	Regulation Permits and Constraints
Potable ASR	
Treated ground water or stormwater stored in ASR	SJRWMD: 0-CUP, well construction permit FDEP: Class V injection, Group 7 well construction and operation permit Constraints: Treated water must meet PDWS and SDWS
Potable or Agricultural ASR	
Raw ground water or stormwater stored in ASR	SJRWMD: 0-CUP, well construction permit FDEP: Class V injection, Group 7 well construction and operation permit Constraints: If raw water exceeds PDWS or SDWS, water quality exemption required. Also, need to resolve regulatory constraints to make feasible. Although exceeding coliform levels is not a health risk since coliforms cannot survive underground for more than 3 days, stormwater is likely to exceed this PDWS.



Note: Recharge water can be either treated or raw

Figure 25. Current regulatory requirements

CONCLUSIONS

ASR is becoming an integral part of water supply and resource management throughout Florida. As population increases, so does the demand on ground water as the main source of water supply. Thus, more emphasis will be placed on alternate water sources (surface and reuse water) to offset the ground water withdrawal. ASR practicability extends to other areas of resource management, such as regional aquifer recharge with surface water to augment distant future water supplies, wetland management, drainage control, and others.

PUBLIC PERCEPTION

As innovative methods of treating, storing, and using various types of water emerge, obstacles in public perception and regulation must be overcome. Public perception may be the first obstacle during initial design and permitting. To date, no Florida ASR system permit has been challenged by the public in such a way as to restrict or delay permitting. However, considerable sensitivity exists regarding any existing or proposed activity related to injection wells. Basic education about ASR systems can greatly lessen the potential for such challenges and achieve public approval. The second obstacle is regulatory. Before ASR, regulations were passed to control industrial wastewater injection and to protect drinking water supplies from this waste. The regulations are now realizing the possibility of storing relatively clean water into USDWs and recovering that water for public consumption. Until recently, the strict protection of drinking water supplies has made it difficult for ASR implementation. This marks the start of adjusting injection regulations to treat ASR systems as existing separately from waste injection wells.

REGULATORY RECOMMENDATIONS

Rule revisions to Chapter 62-528 *F.A.C.*-UIC have been suggested to the FDEP that would allow a refined permitting process and regulation for ASR systems, including those for owners who recharge high-quality, non-potable water. The following rule modifications were provided to FDEP by CH2M HILL (Pyne, 1994) in hopes of adopting distinct rules for ASR technology in order to separate it from existing injection well constraints that impede ASR implementation:

- Remove the requirement for a renewable operating permit for ASR wells that store treated drinking water.

- For ASR wells that store high-quality water that does not fully meet all PDWS, the existing regulations provide a process for issuance of a major or minor aquifer exemption. The aquifer exemption is not really a suitable objective, since it removes protection of the high-quality stored water from potential contamination by other adjacent water users. As a result, the existing regulatory process may have the effect of stunting logical extension of ASR technology from current storage of treated water to future storage of high-quality, but non-potable, water from various sources. An alternative to the existing UIC process, or an alternative track within the UIC process, which applies to ASR wells that store high-quality water that does not quite meet all PDWS, is needed.

- Consolidate ASR permitting regulations in a subsection of Chapter 62-528 *F.A.C.* pertaining to Class V, Group 7 wells. Divide this subsection into three parts: a) recharge with water that meets PDWS and SDWS; b) recharge with high-quality water that does not quite meet PDWS and SDWS due to exceedance of a selected list of benign parameters such as sodium, chloride, TDS, color, turbidity, corrosivity, and coliforms, and c) recharge with water that is poorer in quality than category b).

- For recharge waters that meet all DWS, regulations would delineate procedures and standards appropriate for such wells. Reflecting the substantially lower degree of risk, such requirements would not include typical Class I well requirements such as mechanical integrity testing 0.5-inch minimum casing thickness and extensive geophysical logging. The requirements would be more closely aligned with requirements for typical municipal production wells.

- For high-quality recharge water that does not quite meet all DWS, the regulations would provide for a permitting track that does not require a UIC aquifer exemption for each site. The preferred approach is a regional water quality exemption, regional USDW variance, or a regional, or site-specific ZOD.

As discussed previously, EPA and FDEP have recently agreed on a protocol that incorporates a ZOD. Action by the SJRWMD, other WMDs, and ASR users is needed to confirm the viability of this new protocol by submitting permit applications for storing raw ground water and surface water, where applicable. Additional effort should be considered to achieve Congressional action that would direct EPA to implement a change in the UIC program that would delegate permitting of ASR wells to the individual states.

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Appendix A
ASR Feasibility Screening Tool

ASR FEASIBILITY SCREENING TOOL

The ASR Feasibility Screening Tool can be used to determine the applicability of ASR to a potable use or agricultural irrigation problem. The tool aids in determining the feasibility of the ASR system concept. The following numbered sections correspond to the ranking sections presented in the TM, *Aquifer Storage and Recovery, Alternative Water Supply Strategies in the St. John's River Water Management District*, which provides information on each parameter.

OVERVIEW OF SCREENING TOOL COMPONENTS

Once the technical feasibility of ASR has been established in Parts A and B of the screening tool, costs (Part C) and regulatory issues (Part D) are addressed. Part C provides a log for planning cost comparisons, and Part D lists questions regarding current permitting requirements.

In Part A, the demand rates, supply and demand volumes, and storage requirements are required to identify a specific need or problem to be addressed.

In Part B, a score is determined for the hydrogeologic, design and operational factors. The rank determined for each section (storage zone confinement, storage zone transmissivity, aquifer gradient and direction, recharge water quality, native water quality, physical, geochemical, and design interactions, and interfering use impacts) is entered by placing the score obtained in the appropriately labeled factor column, on the same line as the numbers (1 through 5) provided in the score column provided on the Technical Feasibility Score Report, provided at the end of this tool. For parameter ranks of 1 through 3, there is high possibility that (additional) field investigation is needed to better understand the impact of the particular factor.

Each section has a score weight factor on the bottom row, which is incorporated to prioritize the most critical factors of the ASR feasibility study. The most important ASR factors have a larger weight factor, compared to the other factors. The obtained score is multiplied the associated weight factor, and the final score is placed in the box below. If a low rank is achieved in any of these highly weighted sections, then the ASR feasibility will be reduced significantly. The low-weighted sections could have a low rank and ASR could still be highly feasible. Some of these low-ranked sections could possibly be corrected or minimized with additional information, treatment technology advancements, or imposed local regulations. After being multiplied by their corresponding weighting factors, the scores are added and the final feasibility score is placed into the double-lined box. The results are interpreted as shown in Table A1 below:

Table A-1. ASR Feasibility Score for Hydrogeologic, Design, and Operational Factors

Score	Feasibility Level	Type of Study Recommended
180 - 225	High Confidence	General—confirm assumptions
100 - 179	Moderate Confidence	Focused—investigate specific factors
45 - 99	Limited Confidence	Detailed—evaluate impact of critical factors

The graphical relationship of the final score to an imaginary "caution factor" is provided as Figure A-1 at the end of this tool. This chart implies that the more a score deviates from the best score obtainable, the more caution is needed in the final decision about ASR feasibility to match with the specific needs of the utility considering this option. At the lowest score possible, ASR has a limited feasibility as a storage option which means it may not satisfy 100 percent of the utilities needs immediately, but it could still be the best available option. This figure correlates with the ranges specified in Table A1 for high confidence, moderate confidence, and limited confidence for ASR feasibility.

Part C provides a log for comparative costs and Part D provides a checklist and a regulatory flow chart for ASR permitting. All of the score and summary sheets, figures and charts are provided at the end of this scoring section to aid in organization.

ASR FEASIBILITY RANKING REPORT

As each section is reviewed, a score is determined that best represents the site-specific characteristics. At the end of the ranking process, each score is weighted as to its degree of importance and a final score is calculated. The magnitude of this score identifies a relative ASR feasibility for the site.

Part A. Facility Planning Factors

Step 1. List the Average Daily Demand.

For Potable Use, if the ADD is greater than 1 mgd, proceed to Step 2. If the ADD is less than 1 mgd, another solution should be evaluated. For Agricultural Use, proceed to Step 2.

Step 2. List the Total Supply and Demand Volumes for the Planning Period.

If the total supply volume is larger than the total demand volume, proceed to Step 3. If the demand is larger than the supply, investigate other supply increase and demand reduction solutions.

Step 3. List Storage Need Volumes Calculated as a Long-Term Volume, a Seasonal Volume, a Short-Term Volume, or Other.

If the total volume is greater than 5 MG, proceed to Part B, below. If the total volume is less than 5 MG, investigate other storage options.

Part B. Hydrogeologic, Design, and Operation Factors

Step 1. Storage Zone Confinement

Use Table A-2 to rank the hydraulic conductivity and thickness of the vertical flow restrictive units (aquitard) above and below the storage zone. This data can be gathered from local wells in the same zone or from regional published information. Table 3 in the TM presents an example ranking based on a 100-feet thick confining unit, which shows how Figure A-2 is used to determine the ranking.

Table A-2. Storage Zone Confinement Ranking

Rank	Aquitard Hydraulic Conductivity	Aquitard Thickness
1		
2 (default)		
3		
4		
5		

Step 2. Storage Zone Transmissivity

Use Table A-3 to rank the target storage zone transmissivity. This data can be gathered from local wells in the same zone or from regional published information. Figure A-3 should be used in conjunction with Table A-3 to determine the ranking.

Table A-3. Storage Zone Transmissivity Ranking

Rank	Transmissivity Criterion (gpd/ft)		Applicability
	Potable Water	Untreated Surface Water	
1	Less than 8,000	Less than 80,000	Limited
2	8,000 to 15,000	80,000 to 250,000	
3	15,001 to 40,000	250,001 to 400,000	
4	40,001 to 50,000	400,001 to 500,000	
5	50,001 to 80,000	500,001 to 1,000,000	Optimal
4	80,001 to 120,000	1,000,001 to 1,150,000	
3	120,001 to 200,000	1,150,001 to 1,400,000	
2	200,001 to 400,000	1,400,001 to 2,000,000	
1	Greater than 400,000	Greater than 2,000,000	Limited

Step 3. Aquifer Gradient and Direction

Rank the local aquifer gradient and direction. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table A-4.

Table A-4. Local Aquifer Gradient/Direction Ranking

Rank	Aquifer Gradient (in same recharge zone)	Direction Criterion
1	Many strong influences exist	Extreme artificial gradient, reevaluate location of ASR system
2	Several strong influences	Exaggerated gradient, investigation needed
3 Default	Multiple minor influences exist	Affected gradient worth investigating
4	Single minor influence or abnormal natural gradient	Minor investigation or existing data search
5	No influence	No influence

Step 4. Recharge Water Quality

Rank the recharge water quality using chloride or TDS concentrations of the water to be stored in the ASR zone. For potable water, this data can be obtained from the records of the WTP that will be supplying the source water. For raw water, this can be determined from published records or databases. If this information is not available, use the default value shown in Table A-5.

Table A-5. Recharge Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Compliance with SDW Standards
1	Greater than 200	or	Greater than 450	Just within SDW standards
2	200 to 171		450 to 351	
3	170 to 101		350 to 201	Moderately meets SDW standards
4	100 to 50		200 to 100	
5	Less than 50		Less than 100	Well within SDW standards

Step 5. Native Water Quality

Rank the native water quality based on the chloride or TDS information of the native water in the target ASR zone. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table A-6.

Table A-6. Native Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Water Quality
1	Greater than 6,000	or	Greater than 10,000	Very brackish
2	6,000 to 3,001		10,000 to 5,001	
3	3,000 to 801		5,000 to 1,301	Slightly brackish
4	800 to 400		1,300 to 700	
5	Less than 400		Less than 700	Near fresh water

Step 6. Physical, Geochemical, and Design Interactions

Rank the potential for physical, geochemical or design interactions. This rank is based on the sum of the ranks from the sub-categories shown in the table below. If this information is not available, use the default value shown in Table A-7.

Table A-7. Overall Physical, Geochemical and Design Interaction Ranking for SJRWMD

Sub-Category	Rank	Recharge Water and Criterion	Selected Rank
Physical Interactions from Suspended Solids			
TSS	1	TSS>2.0 mg/L	
	2	2.0 mg/L>TSS>0.05 mg/L (default)	
	3	TSS<0.05 mg/L	
Biological Growth and Geochemical Interactions			
pH	1	7.8<pH< 8.6 (default)	
	2	pH>8.6	
	3	pH<7.8	
Total Phosphorous	1	P>0.1 mg/L	
	2	0.1 mg/L>P>0.05 mg/L (default)	
	3	P<0.05 mg/L	
Nitrate as N	1	N>1 mg/L	
	2	1 mg/L>N>0.5 mg/L (default)	
	3	N<0.5 mg/L	
Dissolved Organic Carbon (DOC)	1	DOC>5 mg/L	
	2	5 mg/L>DOC>2.5 mg/L (default)	
	3	DOC <2.5 mg/L	
Total Iron (Fe)	1	Fe>1 mg/L	
	2	1 mg/L>Fe>0.3 mg/L (default)	
	3	Fe<0.3 mg/L	
Dissolved Oxygen (DO) of Recharge Water	1	DO>3 mg/L	
	2	3 mg/L>DO>1.5 mg/L (default)	
	3	DO<1.5 mg/L	
Point Totals			
Overall Interfering Uses and Impacts Rank (Using rank and point totals listed below)			

Note: Use the default value if data for any parameter is unavailable. Determine the overall rank from the following point totals:

Rank	Physical, geochemical, and design criteria (total of above points)	
1	7-10 points	Higher potential for plugging
2	11-12 points	
3	13-16 points	Moderate potential for plugging
4	17-18 points	
5	19-21 points	Low potential for plugging

Step 7. Interfering Uses and Impacts

Rank the interfering uses and impacts which can exist or have the possibility to exist in the vicinity of a proposed ASR site. Information can be gathered from visual surveys, aerial photographs, topographic maps, and public records/information. This rank is determined from the sum of two sub-ranks shown in Table A-8. If this information is not available, use the default value shown.

Table A-8. Interfering Uses and Impacts Ranking

Sub-Category	Rank and Criterion		Selected Rank
Interfering Uses			
Distance to Domestic Wells	1 2 3	0.10 mile<Wells<0.25 mile 0.26 mile<Wells<5 miles (default) Wells>5 miles	
Interfering Impacts			
Distance to Contamination Source	1 2 3	0.10 mile<Source<0.25 mile 0.26 mile<Source<1 mile (default) Source>1 mile	
Point Total			
Overall Interfering Uses and Impacts Rank (Using rank and point totals listed below)			

Overall Interfering Uses and Impacts Rank determined from the following point totals:

Rank	Interfering Use and/or Impact Criteria (possibility of impact)	
1	2 points	High use or impact
2	3 points	
3	4 points	Moderate use or impact
4	5 points	
5	6 points	Low use or impact

Part C: Cost Comparison Summary

The annual cost figures (Figures A-4 through A-10) were developed as a means of comparing alternative water storage and treatment options. Use the tables to complete the Cost Comparison Summary Sheet provided on the following page. On this sheet, a comparison is made between ASR, other storage options and plant upgrades, which will provide the needed water for immediate peak demand or future demands.

Part D: Regulatory Summary

Part D presents the regulatory requirements for the different types of water quality. Place an "X" under the category of *YES* or *NO* to best describe the quality of the water to be stored. Figure A-11 provides the regulatory permits or exemptions needed for the different water quality groups.

Feasibility Screening Report
Parts A and B

Facility Designation ______________________ Water Source ______________ Date ______________

Facility Director ______________________ Intended Use ______________

Water Management District St. Johns River Water Management District Date ______________

District Officer ______________________

PART A FACILITY PLANNING FACTORS

1	Average Daily Demand (End of Planning Period):	______ MGD	Is ADD Greater Than 1 mgd?	______ YES	______ NO
2	a. Total Supply Volume for Planning Period:	______ MG	Is the Supply Volume Greater Than Demand Volume?	______ YES	______ NO
	b. Total Demand Volume for Planning Period:	______ MG			
3	List Storage Need Volumes Calculated:		Are any of the Volumes Greater Than 5 MG ?	______ YES	______ NO
	a. Long Term Volume:	______ MG			
	b. Seasonal Volume (For Quantity and Quality):	______ MG			
	c. Short Term Volume:	______ MG			
	d. Other (Emergency, Plant Operations, etc):	______ MG			
	e. Total a. through d., above	______ MG			

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

	ASR Hydrogeologic, Design and Operation Factor Scores							
	1	2	3	4	5	6	7	
Section Points	Storage Zone Confinement	Storage Zone Transmissivity	Local Aquifer Gradient/Direction	Recharge Water Quality	Native Water Quality	Physical, Geochemical Interactions	Interfering Uses and/or Impacts	
5								High Feasibility Zone
4								High Feasibility Zone
3								Further Investigations Needed Zone
2								Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	
Score								Total Score

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts C and D

Facility Designation ______________________________ Date ____________

Facility Director ______________________________

Water Management District St. Johns River Water Management District Date ____________

District Officer ______________________________

PART C COST COMPARISON SUMMARY

Cost Comparison for Storage Options

Storage Need (SN): ____________ MG Peak Factor (PF): ____________ Recovery Duration (RD): ____________ ASR Recovery Rate $\frac{PF \cdot SN}{RD}$ = ____________ mgd

Equivalent Annual Costs

Tank $ ____________ *(Figure A-5)*

Reservoir $ ____________ *(Figure A-6)*

ASR $ ____________ *(Figure A-4)*

Cost Comparison for Management Options

Plant Rate Increase: ____________ mgd

Equivalent Annual Costs

Plant Upgrades	Base Cost	Option 1	Option 2	Option 3	Option 4
Lime Softening and					
Sulfide Reduction by	Tray Aeration *(Figure A-8)*				
	Packing Tower *(Figure A-9)*				
	Ozonation *(Figure A-10)*				
TOTAL					

Equivalent Annual Cost for Options

Plant Upgrade $ ____________ (total cost from option selected from the table above)

ASR $ ____________ (annual cost from cost comparison for storage options) *(Figure A-4)*

PART D REGULATORY SUMMARY

	YES	NO	
Injected water meets all standards	____	____	(refer to Figure A2 for regulatory requirements)
Injected water meets federal standards and state minimums	____	____	(refer to Figure A2 for regulatory requirements)
Injected water exceedes one or more federal standards	____	____	(refer to Figure A2 for regulatory requirements)

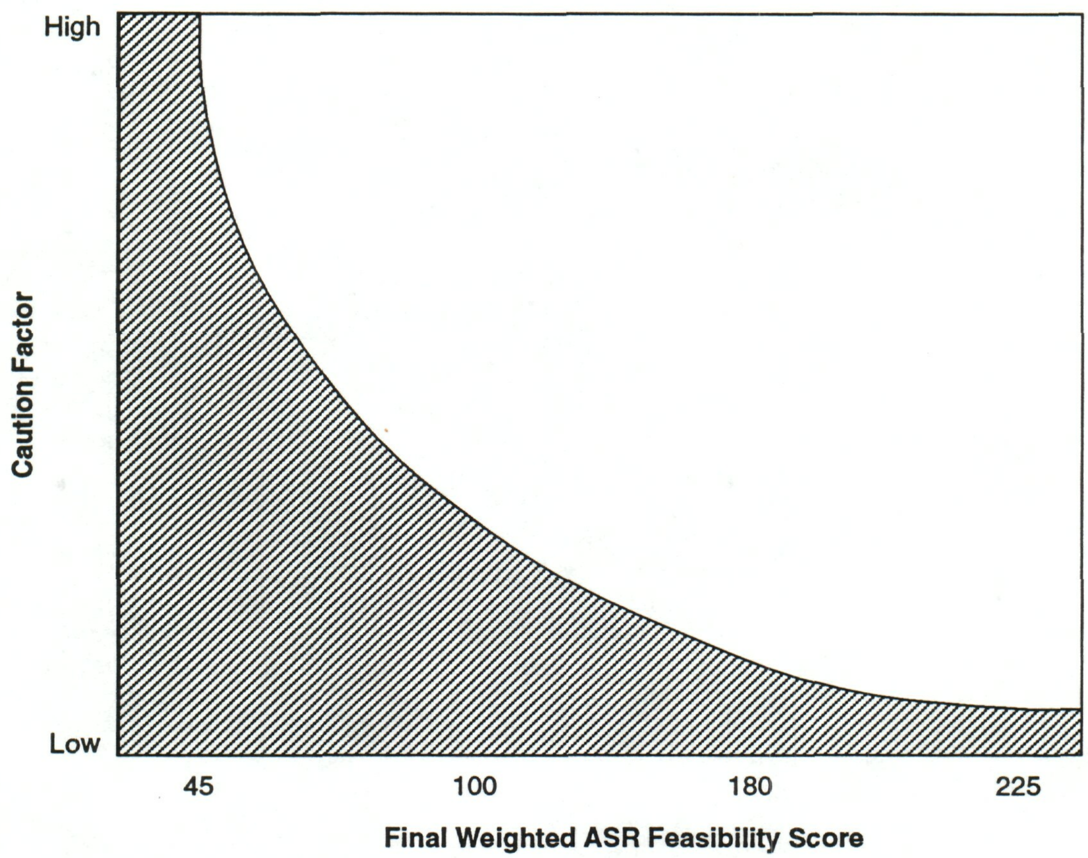

Figure A-1. Final score versus caution factor

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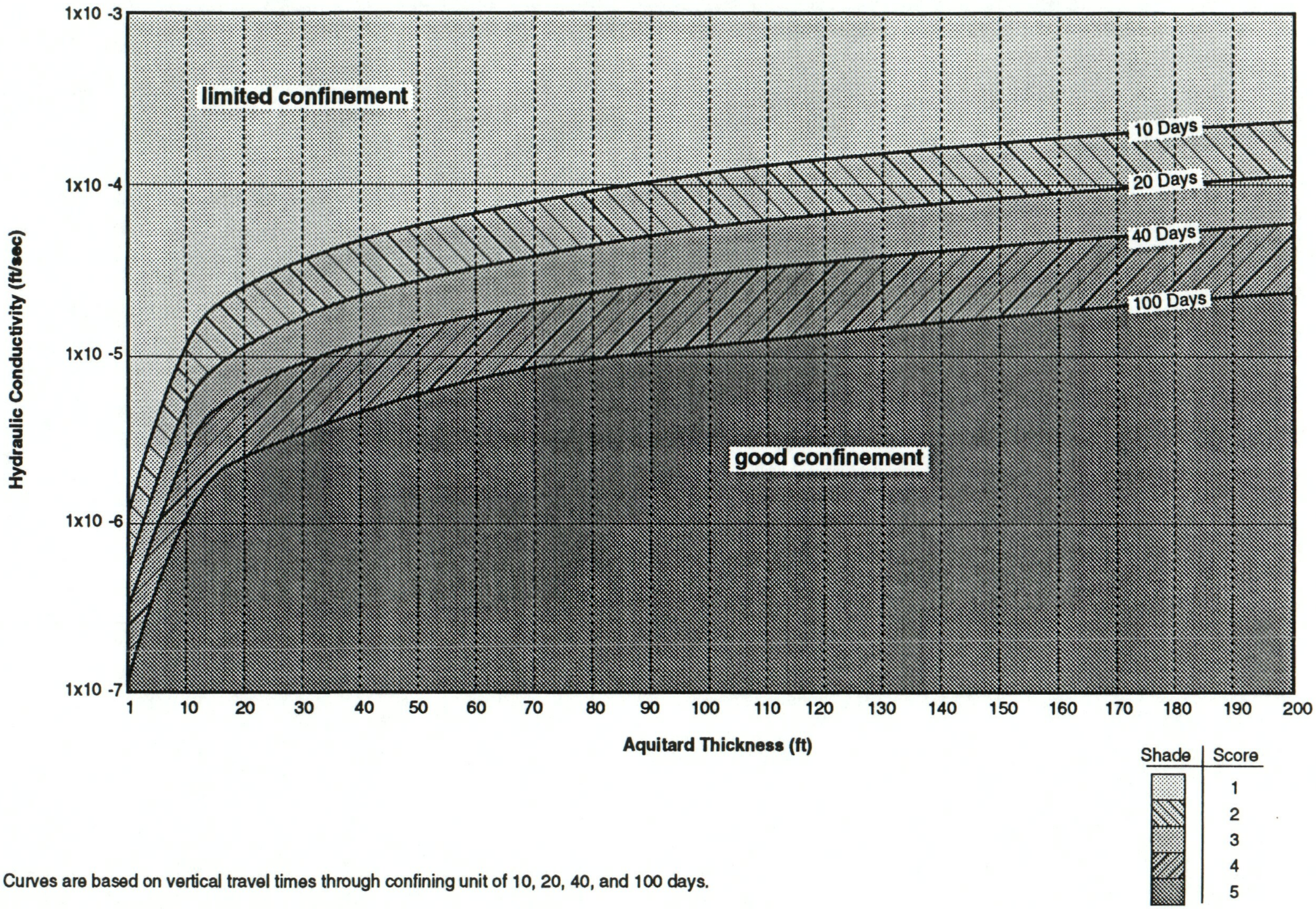

Note: Curves are based on vertical travel times through confining unit of 10, 20, 40, and 100 days.

Figure A-2. Aquitard confinement as a function of thickness and hydraulic conductivity

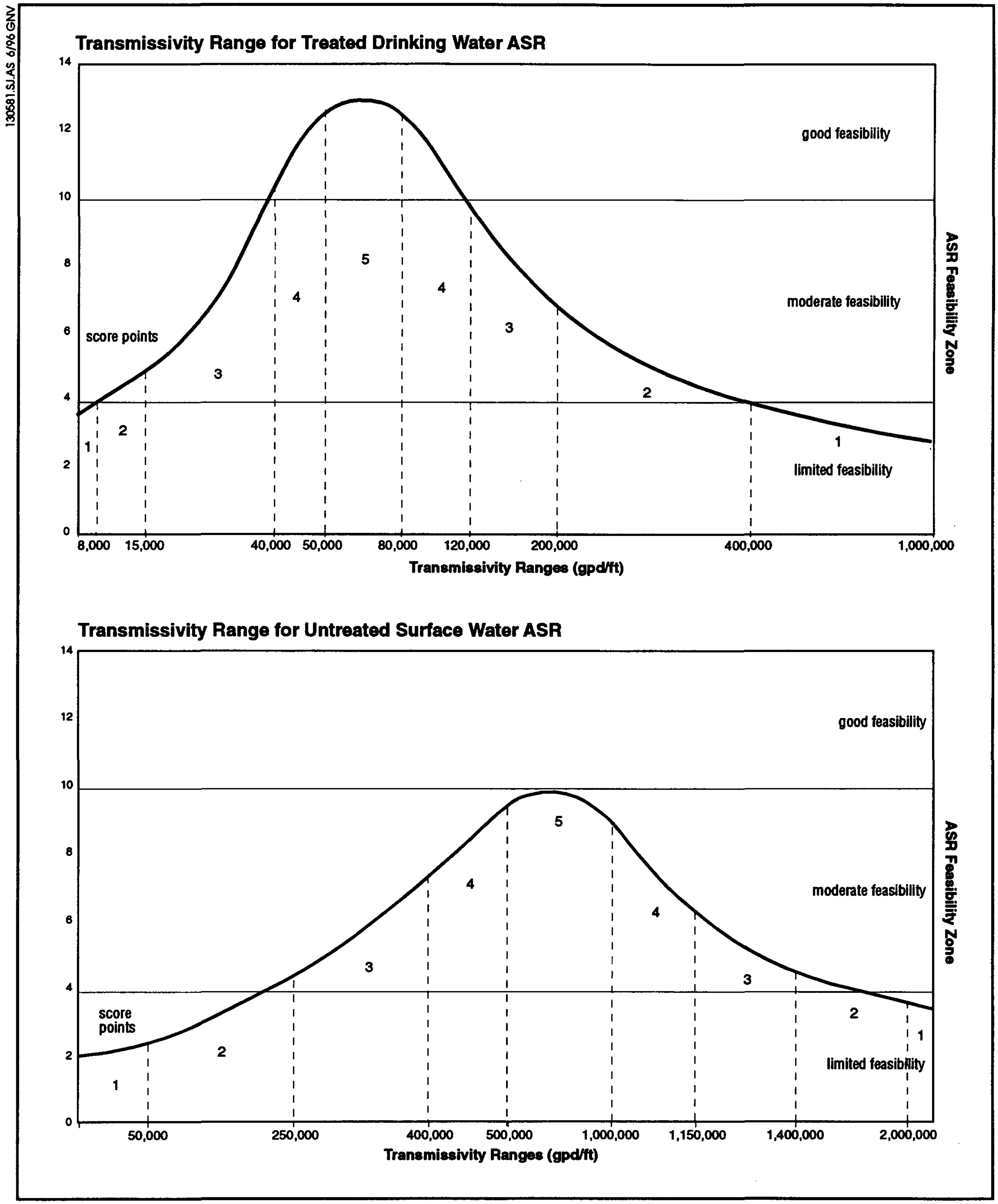

Figure A-3. Storage zone transmissivity range classification

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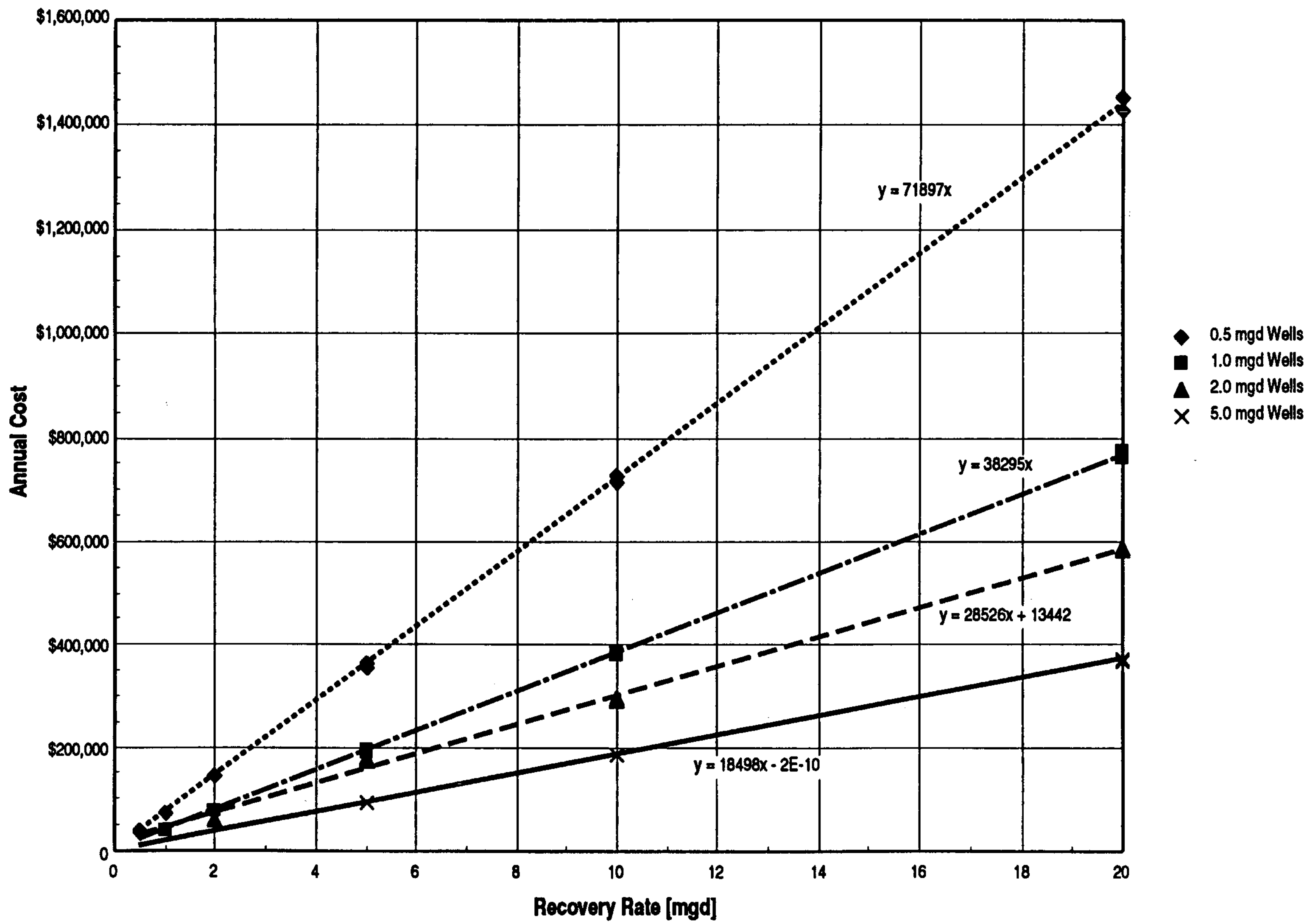

Figure A-4. ASR annual cost versus recovery rate.

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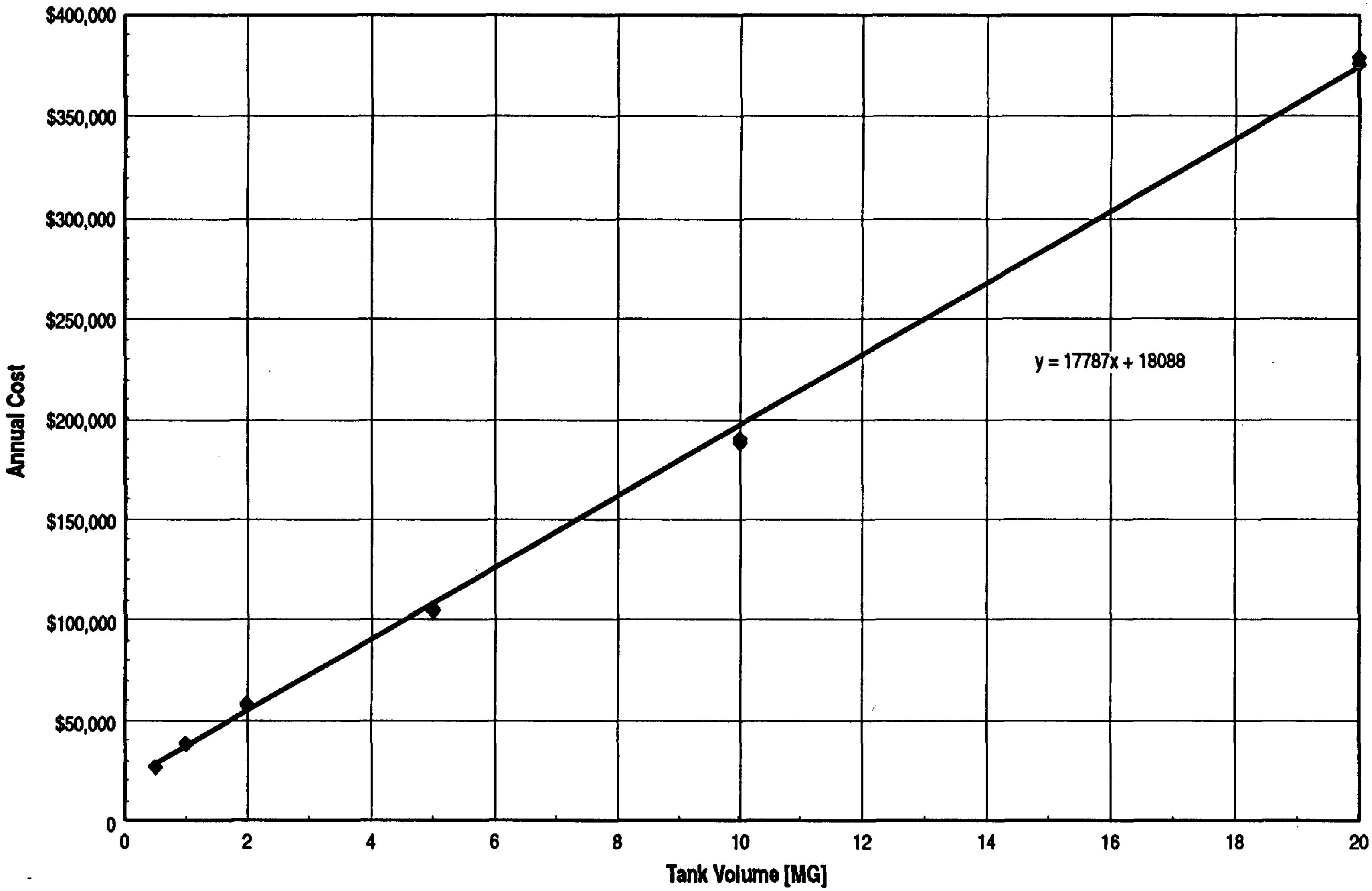

Figure A-5. Storage tanks annual cost versus tank volume.

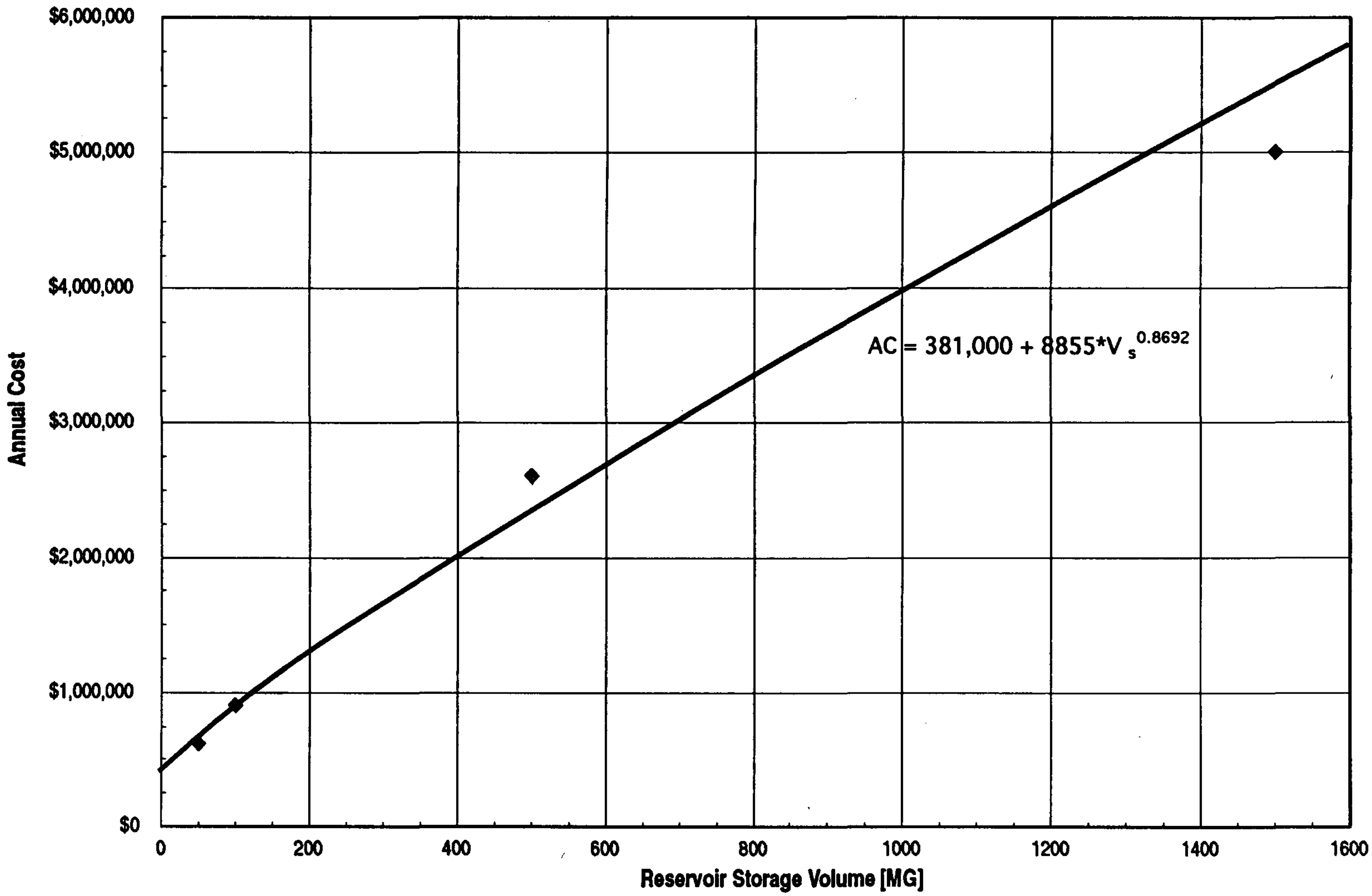

Figure A-6. Storage reservoirs annual cost versus storage volume.

130581.SJ.AS 6/96 GNV

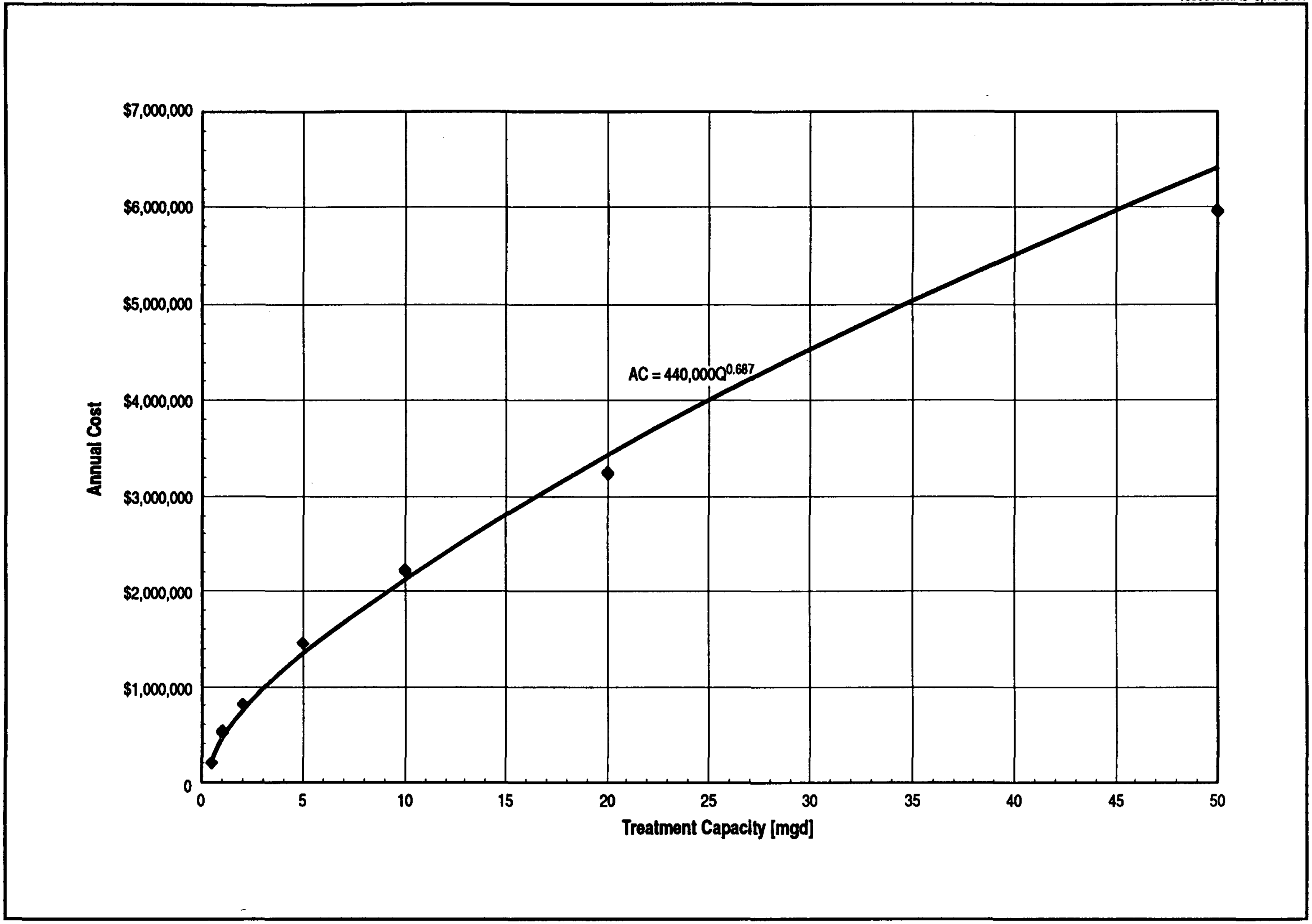

Figure A-7. Lime softening annual cost versus treatment capacity.

130581.SJ.AS 6/96 GNV

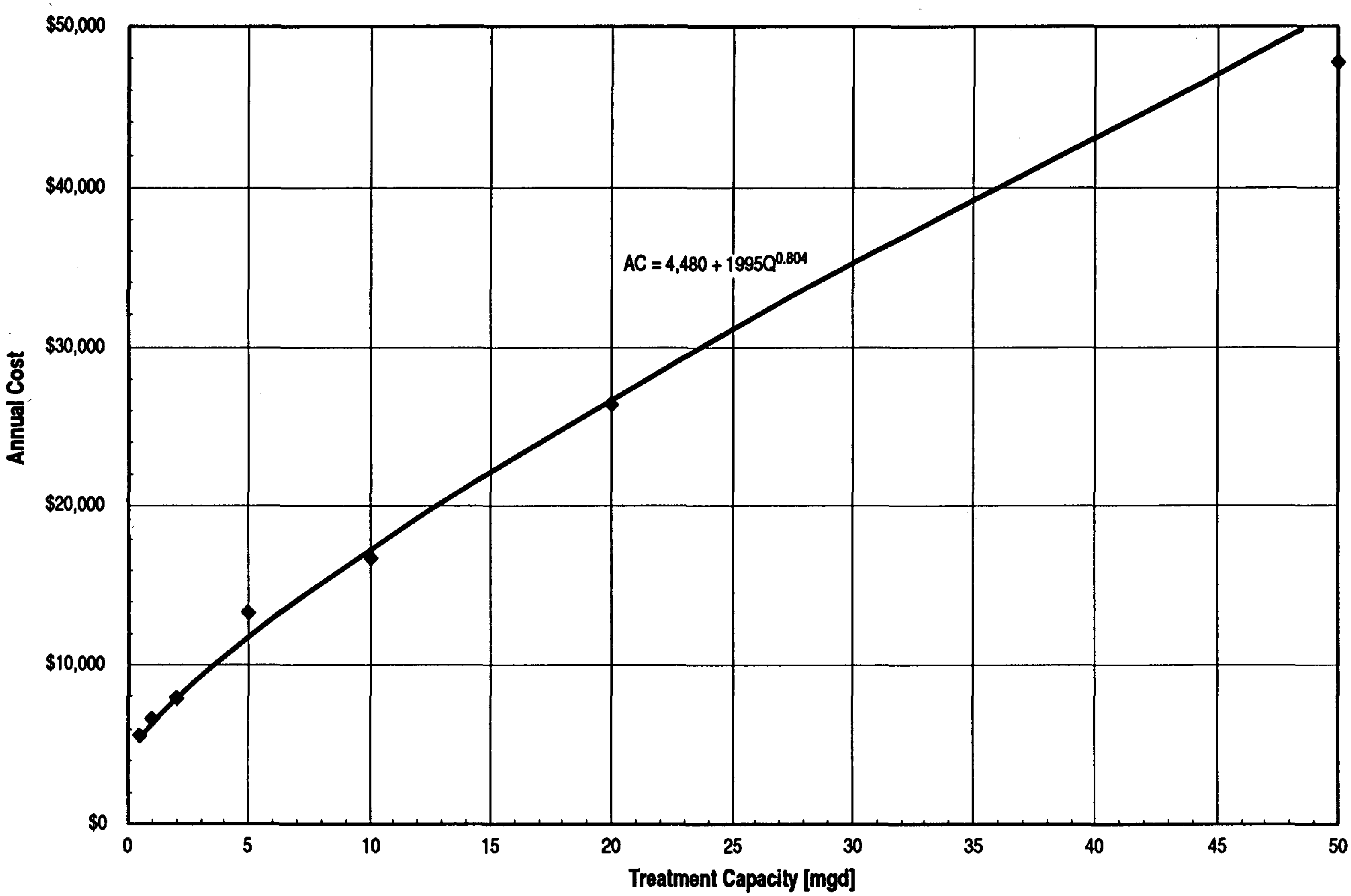

Figure A-8. Tray aeration annual cost versus treatment capacity.

130581.SJ.AS 6/96 GNV

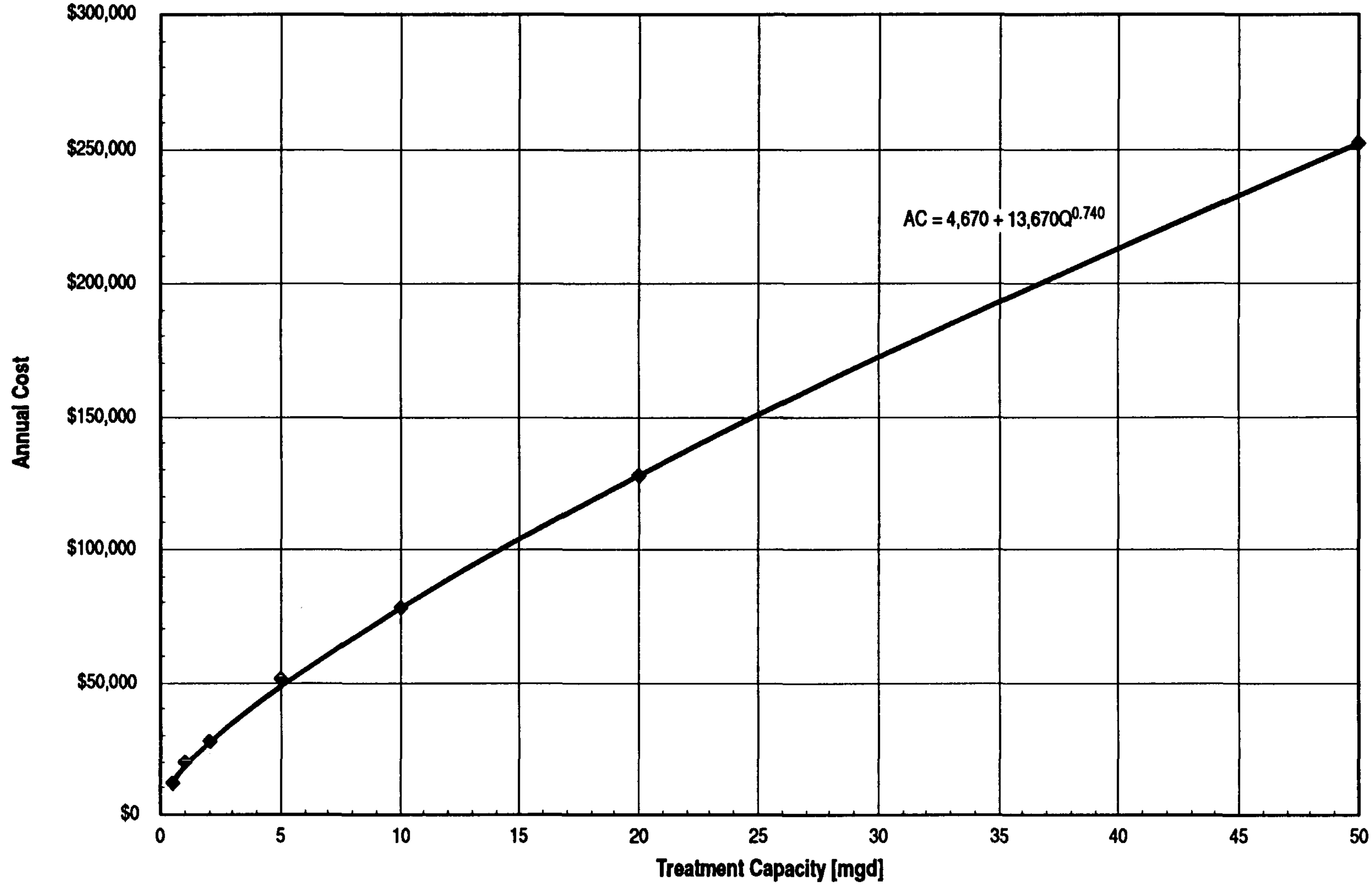

Figure A-9. Packed towers annual cost versus treatment capacity.

130581.SJ.AS 6/96 GNV

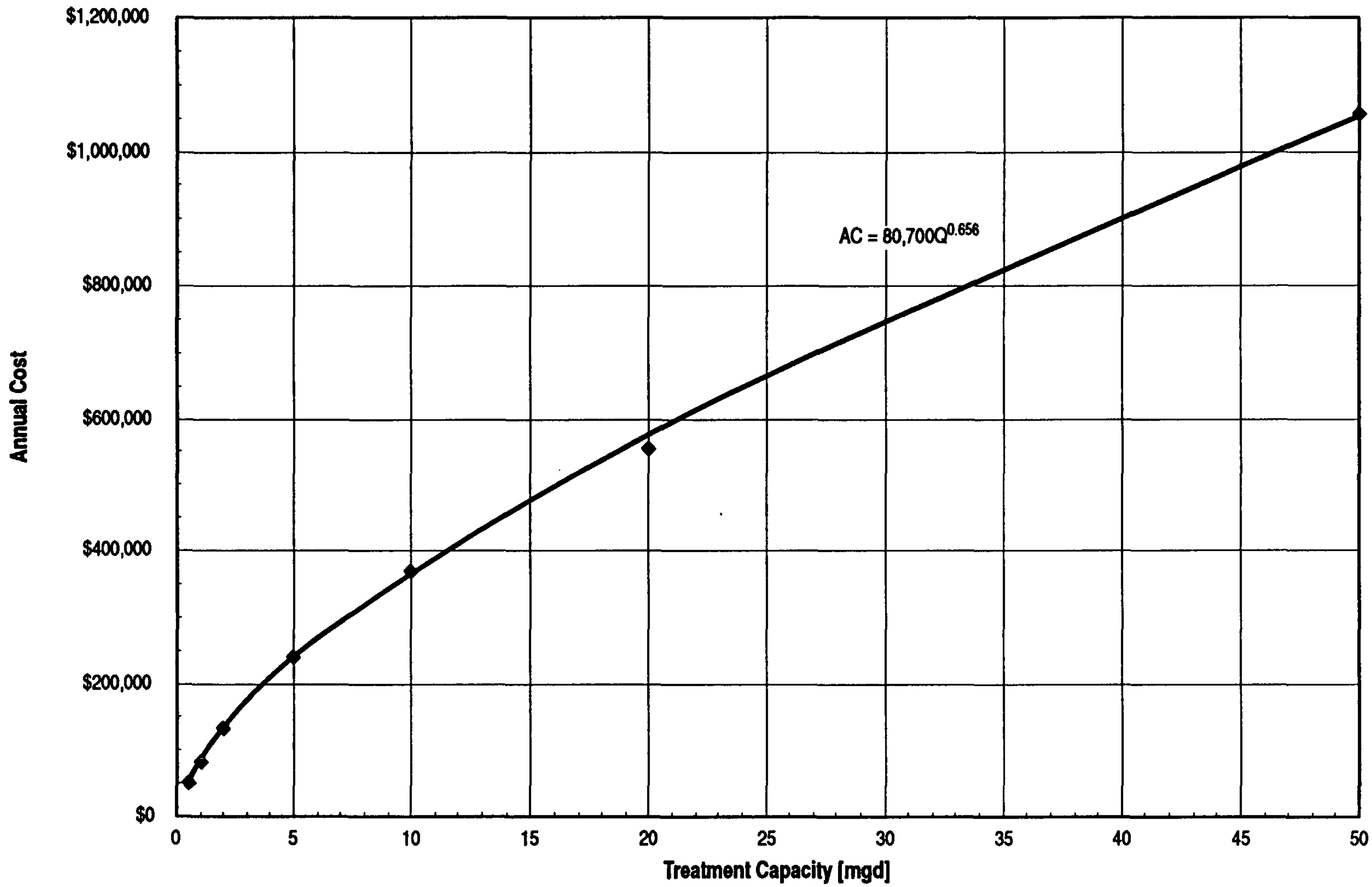

Figure A-10. Ozonation with Chlorination annual cost versus treatment capacity.

130581.SJ.AS 6/96 GNV

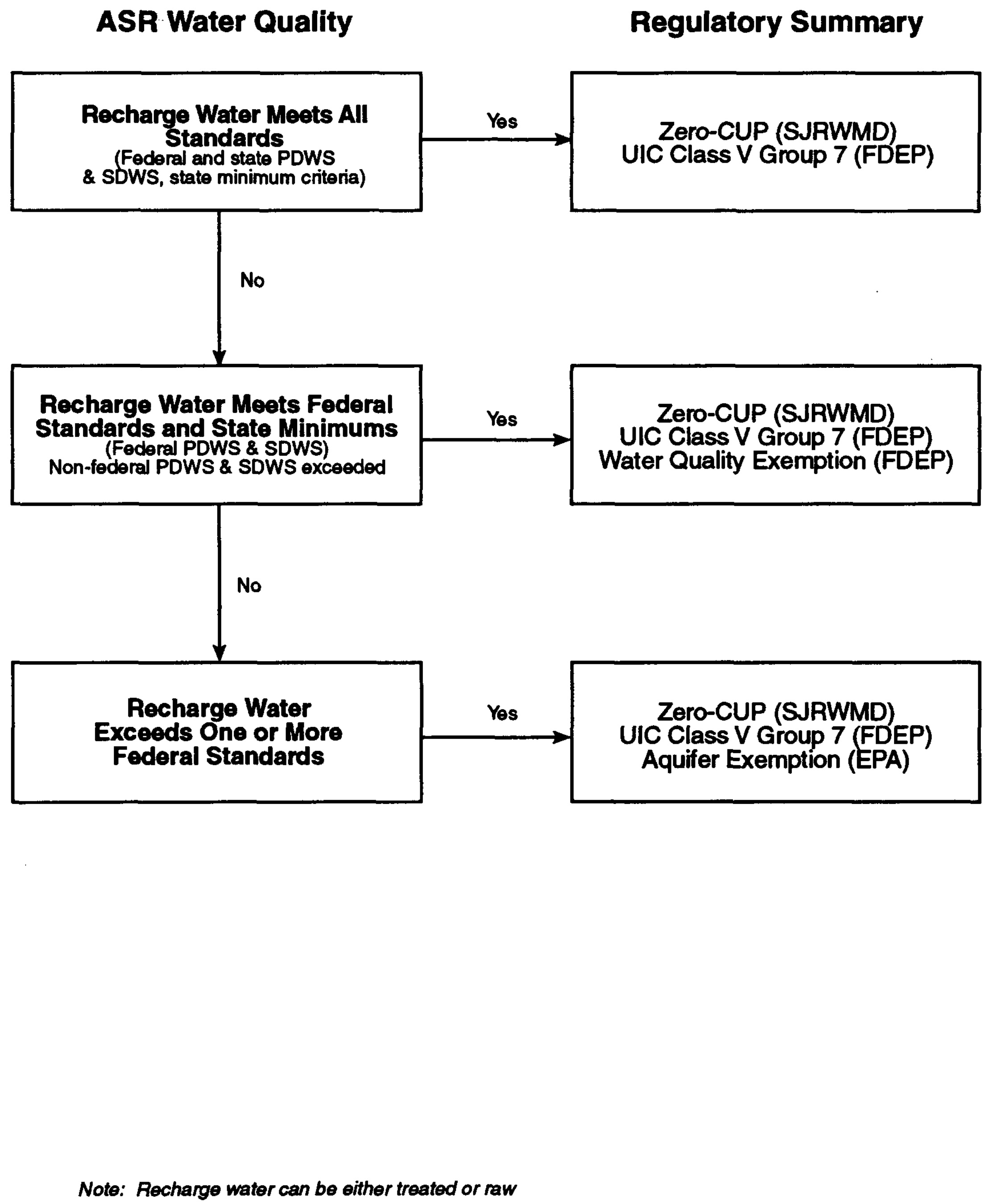

Figure A-11. Current regulatory requirements

Appendix B
ASR Feasibility Screening Tool Examples

Example 1
Fictitious Hastings Water District
(Agricultural Water Use)

EXAMPLE 1 - FICTITIOUS HASTINGS WATER DISTRICT (AGRICULTURAL WATER USE)

Since the predominant application of ASR in Florida has been the storage and recovery of potable water, an actual example of an agricultural use could not be found. The potato farms in Hastings, Florida, represent a significant agricultural ground water use where water quality problems have developed. Over the last 20 years, there has been continued upconing of high salinity water in this agricultural area. This design example looks at using the ASR concept to recharge the aquifer with raw groundwater at key points in order for the individual farmers to continue to use the existing wells.

OVERVIEW OF SCREENING TOOL COMPONENTS

The ASR Feasibility Screening Tool can be used to determine the applicability of ASR to a potable use or agricultural irrigation problem. The tool aids in determining the feasibility of the ASR system concept. The following numbered sections correspond to the ranking sections presented in the TM, *Aquifer Storage and Recovery, Alternative Water Supply Strategies in the St. John's River Water Management District*, which provides information on each parameter.

Once the technical feasibility of ASR has been established in Parts A and B of the screening tool, costs (Part C) and regulatory issues (Part D) are addressed. Part C provides a log for planning cost comparisons, and Part D lists questions regarding current permitting requirements.

In Part A, the demand rates, supply and demand volumes, and storage requirements are required to identify a specific need or problem to be addressed.

In Part B, a score is determined for the hydrogeologic, design and operational factors. The rank determined for each section (storage zone confinement, storage zone transmissivity, aquifer gradient and direction, recharge water quality, native water quality, physical, geochemical, and design interactions, and interfering use impacts) is entered by placing the score obtained in the appropriately labeled factor column, on the same line as the numbers (1 through 5) provided in the score column provided on the Technical Feasibility Score Report, provided at the end of this tool. For parameter ranks of 1 through 3, there is high possibility that (additional) field investigation is needed to better understand the impact of the particular factor.

Each section has a score weight factor on the bottom row, which is incorporated to prioritize the most critical factors of the ASR feasibility study. The most important ASR factors have a larger weight factor, compared to the other factors. The obtained score is multiplied the associated weight factor, and the final score is placed in the box below. If a low rank is achieved in any of these highly weighted sections, then the ASR feasibility will be reduced significantly. The low-weighted sections could have a low rank and ASR could still be highly feasible. Some of these low-ranked sections could possibly be corrected or minimized with additional information, treatment technology advancements, or imposed local regulations. After being multiplied by their corresponding weighting factors, the scores are added and the final feasibility score is placed into the double-lined box. The results are interpreted as shown in Table B1-1 below:

Table B1-1. ASR Feasibility Score for Hydrogeologic, Design, and Operational Factors

Score	Feasibility Level	Type of Study Recommended
180 - 225	High Confidence	General—confirm assumptions
100 - 179	Moderate Confidence	Focused—investigate specific factors
45 - 99	Limited Confidence	Detailed—evaluate impact of critical factors

The graphical relationship of the final score to an imaginary "caution factor" is provided as Figure A-1, in Appendix A. This chart implies that the more a score deviates from the best score obtainable, the more caution is needed in the final decision about ASR feasibility to match with the specific needs of the utility considering this option. At the lowest score possible, ASR has a limited feasibility as a storage option which means it may not satisfy 100 percent of the utilities needs immediately, but it could still be the best available option. This figure correlates with the ranges specified in Table B1-1 for high confidence, moderate confidence, and limited confidence for ASR feasibility.

Part C provides a log for comparative costs and Part D provides a checklist and a regulatory flow chart for ASR permitting. All of the score and summary sheets, figures and charts are provided at the end of this scoring section to aid in organization.

ASR FEASIBILITY RANKING REPORT

As each section is reviewed, a score is determined that best represents the site-specific characteristics. At the end of the ranking process, each score is weighted as to its degree of importance and a final score is calculated. The magnitude of this score identifies a relative ASR feasibility for the site.

Part A. Facility Planning Factors

Step 1. List the Average Daily Demand.

For Potable Use, if the ADD is greater than 1 mgd, proceed to Step 2. If the ADD is less than 1 mgd, another solution should be evaluated. For Agricultural Use, proceed to Step 2.

Hastings Water District is agricultural use, proceed to the next parameter.

[see Part A, Item 1 on scoring report]

Step 2. List the Total Supply and Demand Volumes for the Planning Period.

If the total supply volume is larger than the total demand volume, proceed to Step 3. If the demand is larger than the supply, investigate other supply increase and demand reduction solutions.

Hastings Water District planning period is the average year. Total supply is 6,924 MG; Total demand is 4,527 MG.

[see Part A, Item 2 on scoring report]

Step 3. List Storage Need Volumes Calculated as a Long-Term Volume, a Seasonal Volume, a Short-Term Volume, or Other.

If the total volume is greater than 5 MG, proceed to Part B, below. If the total volume is less than 5 MG, investigate other storage options.

Hastings Water District seasonal storage need identified 1,992 MG (Figure 9 from TM)

[see Part A, Item 3 on scoring report]

Part B. Hydrogeologic, Design, and Operation Factors

Step 1. Storage Zone Confinement

Use Table B1-2 to rank the hydraulic conductivity and thickness of the vertical flow restrictive units (aquitard) above and below the storage zone. This data can be gathered from local wells in the same zone or from regional published information. Table 3 in the TM presents an example ranking based on a 100-feet thick confining unit, which shows how Figure B-3 is used to determine the ranking.

Hastings Water District storage zone confinement is 100 feet thickness of $1x10^{-4}$ ft/sec.

Table B1-2. Storage Zone Confinement Ranking

Rank	Aquitard Hydraulic Conductivity	Aquitard Thickness
1		
2 (default)	$1x10^{-4}$ ft/sec	100 feet
3		
4		
5		

Step 2. Storage Zone Transmissivity

Use Table B1-3 to rank the target storage zone transmissivity. This data can be gathered from local wells in the same zone or from regional published information. Figure B-4 should be used in conjunction with Table B1-3 to determine the ranking.

Hastings Water District transmissivity is mapped by USGS at 60,000 gpd/ft average in this area, therefore, rank is 5.

Table B1-3. Storage Zone Transmissivity Ranking

	Transmissivity Criterion (gpd/ft)		
Rank	Potable Water	Untreated Surface Water	Applicability
1	Less than 8,000	Less than 80,000	Limited
2	8,000 to 15,000	80,000 to 250,000	
3	15,001 to 40,000	250,001 to 400,000	
4	40,001 to 50,000	400,001 to 500,000	
5	50,001 to 80,000	500,001 to 1,000,000	Optimal
4	80,001 to 120,000	1,000,001 to 1,150,000	
3	120,001 to 200,000	1,150,001 to 1,400,000	
2	200,001 to 400,000	1,400,001 to 2,000,000	
1	Greater than 400,000	Greater than 2,000,000	Limited

Step 3. Aquifer Gradient and Direction

Rank the local aquifer gradient and direction. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table B1-4.

This parameter was not known for Hastings Water District. Because there may be multiple minor influences in the area, the default rank of 3 was used.

Table B1-4. Local Aquifer Gradient/Direction Ranking

Rank	Aquifer Gradient (in same recharge zone)	Direction Criterion
1	Many strong influences exist	Extreme artificial gradient, reevaluate location of ASR system
2	Several strong influences	Exaggerated gradient, investigation needed
3 (default)	Multiple minor influences exist	Affected gradient worth investigating
4	Single minor influence or abnormal natural gradient	Minor investigation or existing data search
5	No influence	No influence

Step 4. Recharge Water Quality

Rank the recharge water quality using chloride or TDS concentrations of the water to be stored in the ASR zone. For potable water, this data can be obtained from the records of the WTP that will be supplying the source water. For raw water, this can be determined from published records or databases. If this information is not available, use the default value shown in Table B1-5.

Hastings Water District - Cl^- = 225 mg/L from EarthInfo database of quantity and quality of St. Johns River at the Palatka station. The rank is 1.

Table B1-5. Recharge Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Compliance with SDW Standards
1	Greater than 200	or	Greater than 450	Just within SDW standards
2	200 to 171		450 to 351	
3	170 to 101		350 to 201	Moderately meets SDW standards
4	100 to 50		200 to 100	
5	Less than 50		Less than 100	Well within SDW standards

Step 5. Native Water Quality

Rank the native water quality based on the chloride or TDS information of the native water in the target ASR zone. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table B1-6.

Hastings Water District - Chloride = 250 to 1,000 mg/L from USGS Mapping. Rank is 3.

Table B1-6. Native Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Water Quality
1	Greater than 6,000	or	Greater than 10,000	Very brackish
2	6,000 to 3,001		10,000 to 5,001	
3	3,000 to 801		5,000 to 1,301	Slightly brackish
4	800 to 400		1,300 to 700	
5	Less than 400		Less than 700	Near fresh water

Step 6. Physical, Geochemical, and Design Interactions

Rank the potential for physical, geochemical or design interactions. This rank is based on the sum of the ranks from the sub-categories shown in the table below. If this information is not available, use the default value shown in Table B1-7.

Table B1-7. Overall Physical, Geochemical and Design Interaction Ranking for SJRWMD

Sub-Category	Rank	Recharge Water and Criterion	Selected Rank
Physical Interactions from Suspended Solids			
Total Suspended Solids (TSS) **use default**	1 2 3	TSS>2.0 mg/L 2.0 mg/L>TSS>0.05 mg/L (default) TSS<0.05 mg/L	**2**
Biological Growth and Geochemical Interactions			
pH **use default**	1 2 3	7.8<pH< 8.6 (default) pH>8.6 pH<7.8	**1**
Total Phosphorous **use default**	1 2 3	P>0.1 mg/L 0.1 mg/L>P>0.05 mg/L (default) P<0.05 mg/L	**2**
Nitrate as N **use default**	1 2 3	N>1 mg/L 1 mg/L>N>0.5 mg/L (default) N<0.5 mg/L	**2**
Dissolved Organic Carbon (DOC) **use default**	1 2 3	DOC>5 mg/L 5 mg/L>DOC>2.5 mg/L (default) DOC <2.5 mg/L	**2**
Total Iron (Fe) **use default**	1 2 3	Fe>1 mg/L 1 mg/L>Fe>0.3 mg/L (default) Fe<0.3 mg/L	**2**
Dissolved Oxygen (DO) of Recharge Water **use default**	1 2 3	DO>3 mg/L 3 mg/L>DO>1.5 mg/L (default) DO<1.5 mg/L	**2**
Point Totals			**13**
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)			**3**

Note: Use the default value if data for any parameter is unavailable. Determine the overall rank from the following point totals:

Rank	Physical, geochemical, and design criteria (total of above points)	
1	7-10 points	Higher potential for plugging
2	11-12 points	
3	***13-16 points***	***Moderate potential for plugging***
4	17-18 points	
5	19-21 points	Low potential for plugging

Step 7. Interfering Uses and Impacts

Rank the interfering uses and impacts which can exist have the possibility to exist in the vicinity of an proposed ASR site. Information can be gathered from visual surveys, aerial photographs, topography maps, and public records/information from City Hall. This rank is determined from the sum of two sub-ranks shown in Table B1-8. If this information is not available, use the default value shown.

This was an unknown parameter at the time of installation for the Hastings Water District. Because there may be minor interfering uses or impacts in the area, the default rank of 3 was used.

Table B1-8. Interfering Uses and Impacts Ranking

Sub-Category	Rank and Criterion		Selected Rank
Interfering Uses			
Distance to Domestic or Public Supply Wells	1 2 3	0.10 mile<Wells<0.25 mile 0.26 mile<Wells<5 miles (default) Wells>5 miles	**2**
Interfering Impacts			
Distance to Contamination Source	1 2 3	0.10 mile<Source<0.25 mile 0.26 mile<Source<1 mile (default) Source>1 mile	**2**
Point Total			**4**
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)			**3**

Overall Interfering Uses and Impacts Rank determined from the following point totals:

Rank	Interfering Use and/or Impact Criteria (possibility of impact)	
1	2 points	High use/impact
2	3 points	
3	***4 points***	***Moderate use or impact***
4	5 points	
5	6 points	Low use/impact

Part C: Cost Comparison Summary

The annual cost figures (Figures A-4 through A-10) were developed as a means of comparing alternative water storage and treatment options. Use the tables to complete the Cost Comparison Summary Sheet provided on the following page. On this sheet, a comparison is made between ASR, other storage options and plant upgrades, which will provide the needed water for immediate peak demand or future demands.

Hastings Water District - Cost comparisons for this example are not provided.

Part D: Regulatory Summary

Part D presents the regulatory requirements for the different types of water quality. Place an "X" under the category of *YES* or *NO* to best describe the quality of the water to be stored. Figure A-11 provides the regulatory permits or exemptions needed for the different water quality groups.

Hastings Water District - A regulatory summary for this example is provided on the second page of the report sheet.

Feasibility Screening Report
Parts A and B

Facility Designation *Hastings Water District* Water Source *Raw Ground Water* Date *5/9/96*

Facility Director *Example* Intended Use *Agricultural*

Water Management District St. Johns River Water Management District Date ______

District Officer ______

PART A FACILITY PLANNING FACTORS

1	Average Daily Demand (End of Planning Period):	*Agricultural* MGD	Is ADD Greater Than 1 mgd?	*NA* YES	____ NO
2	a. Total Supply Volume for Planning Period:	*6924* MG	Is the Supply Volume Greater Than Demand Volume?	*X* YES	____ NO
	b. Total Demand Volume for Planning Period:	*4527* MG			
3	List Storage Need Volumes Calculated:				
	a. Long Term Volume:	*1992* MG	Are any of the Volumes Greater Than 5 MG ?	*X* YES	____ NO
	b. Seasonal Volume (For Quantity and Quality):	____ MG			
	c. Short Term Volume:	____ MG			
	d. Other (Emergency, Plant Operations, etc):	____ MG			
	e. Total a. through d., above	*1992* MG			

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts	
5		*X*						High Feasibility Zone
4								High Feasibility Zone
3			*X*		*X*	*X*	*X*	Further Investigations Needed Zone
2	*X*							Further Investigations Needed Zone
1				*X*				Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	Total Score
Score	*20*	*50*	*3*	*2*	*30*	*15*	*15*	*135*

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts C and D

Facility Designation *Hastings Water District* Date ______

Facility Director *Example 1*

Water Management District St. Johns River Water Management District Date ______

District Officer ______

PART C COST COMPARISON SUMMARY

Cost Comparison for Storage Options

Storage Need (SN): ______ MG Peak Factor (PF): ______ Recovery Duration (RD): ______ ASR Recovery Rate $\frac{PF \cdot SN}{RD}$ = ______ mgd

Equivalent Annual Costs

Tank $ ______

Reservoir $ ______

ASR $ ______

Cost Comparison for Management Options

Plant Rate Increase: ______ mgd

Equivalent Annual Costs

Plant Upgrades	Base Cost	Option 1	Option 2	Option 3	Option 4
Lime Softening and					
Sulfide Reduction by	Tray Aeration				
	Packing Tower				
	Ozonation				
TOTAL					

Equivalent Annual Cost for Options

Plant Upgrade $ ______ (total cost from option selected from the table above)

ASR $ ______ (annual cost from cost comparison for storage options)

PART D REGULATORY SUMMARY

	YES	NO	
Injected water meets all standards		*X*	(refer to Figure A2 for regulatory requirements)
Injected water meets federal standards and state minimums		*X*	(refer to Figure A2 for regulatory requirements)
Injected water exceedes one or more federal standards	*X*		(refer to Figure A2 for regulatory requirements)

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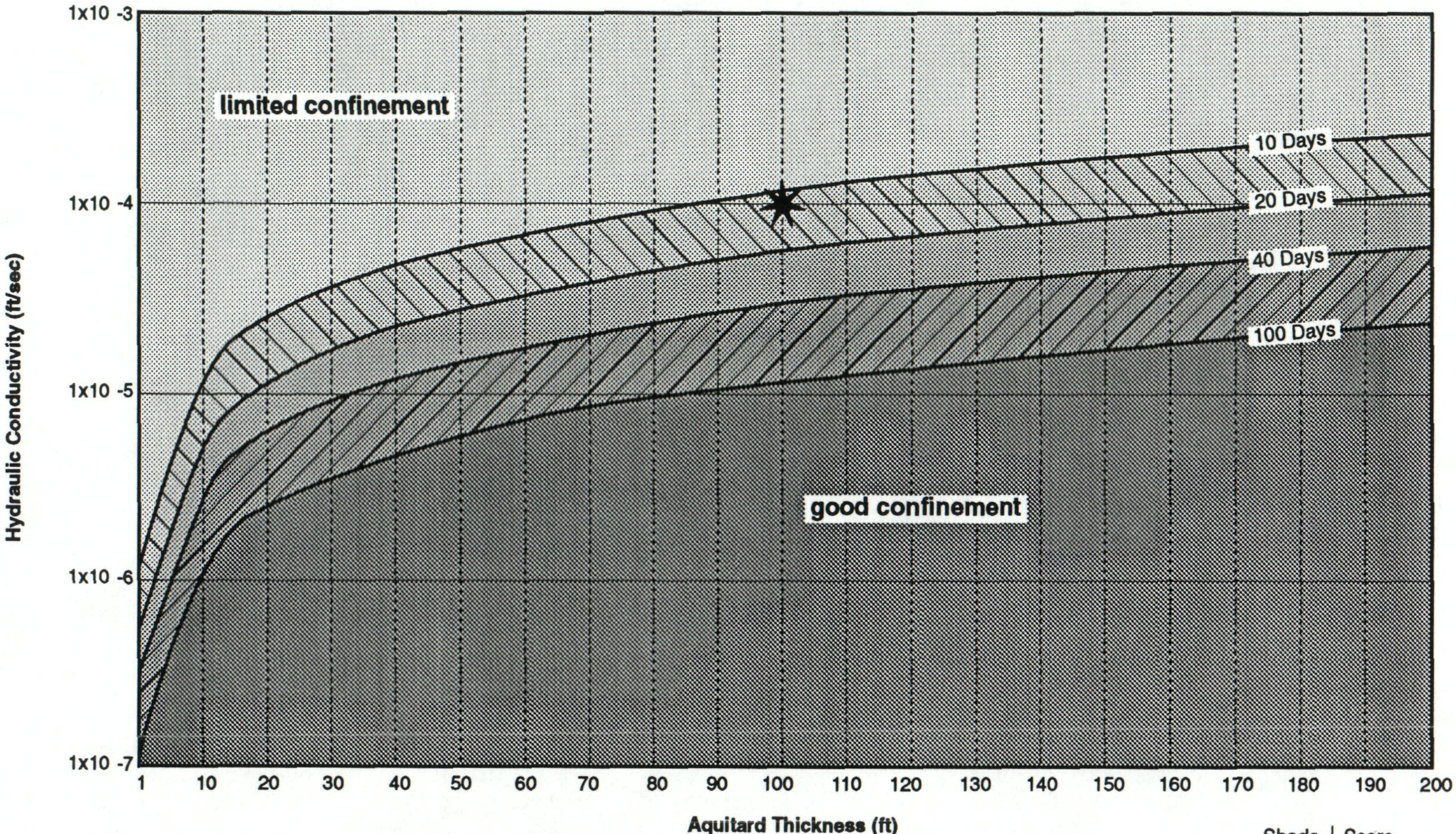
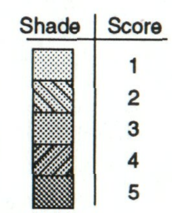




Notes: Curves are based on vertical travel times through confining unit of 10, 20, 40, and 100 days.
✱ 100 ft thickness with $1X10^{-4}$ ft/sec hydraulic conductivity

Figure B-1. Aquitard confinement as a function of thickness and hydraulic conductivity (Hastings Water District, Florida)

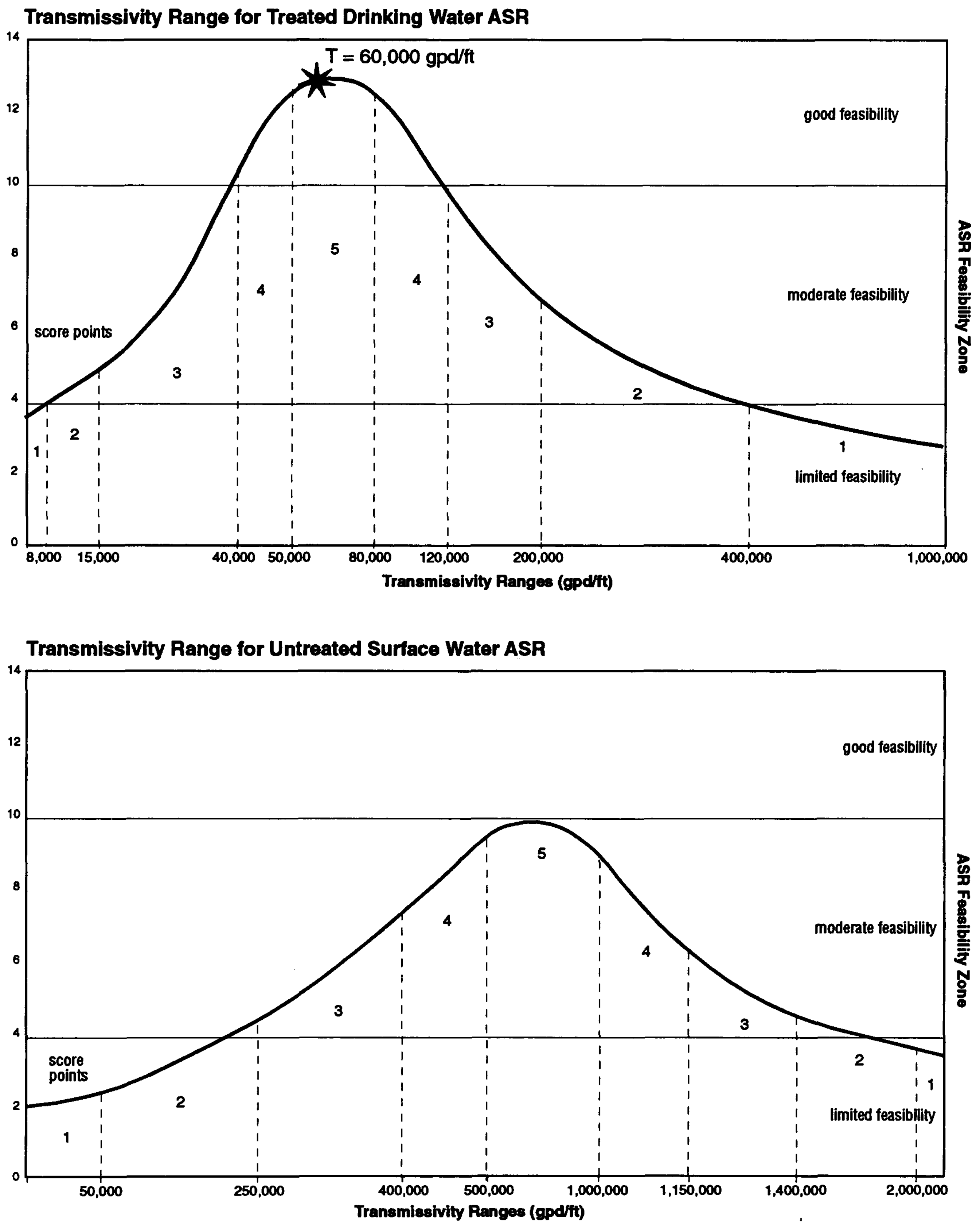


Figure B-2. Storage zone transmissivity range classification (Hastings Water District, Florida)

Example 2
City of Cocoa, Florida
(Potable Water Use)

EXAMPLE 2—CITY OF COCOA (POTABLE WATER USE)

The Dyal Water Treatment Plant is located in Orange County. The service area consists of the city of Cocoa, portions of Brevard County, and water sale to the two military installations. In 1989, Cocoa installed the first of six existing ASR wells. This example uses data available for a 1989 to 2002 planning period and, therefore, predates the ASR. As ASR has been successfully applied at Cocoa, this is a representative example of how the screening tool identifies possible ASR applications, and how to apply the tool to site-specific characteristics. The entire tool is included in the following pages and should be used as an example for scoring a site and using the figures and tables for each factor.

OVERVIEW OF SCREENING TOOL COMPONENTS

The ASR Feasibility Screening Tool can be used to determine the applicability of ASR to a potable use or agricultural irrigation problem. The tool aids in determining the feasibility of the ASR system concept. The following numbered sections correspond to the ranking sections presented in the TM, *Aquifer Storage and Recovery, Alternative Water Supply Strategies in the St. John's River Water Management District*, which provides information on each parameter.

Once the technical feasibility of ASR has been established in Parts A and B of the screening tool, costs (Part C) and regulatory issues (Part D) are addressed. Part C provides a log for planning cost comparisons, and Part D lists questions regarding current permitting requirements.

In Part A, the demand rates, supply and demand volumes, and storage requirements are required to identify a specific need or problem to be addressed.

In Part B, a score is determined for the hydrogeologic, design and operational factors. The rank determined for each section (storage zone confinement, storage zone transmissivity, aquifer gradient and direction, recharge water quality, native water quality, physical, geochemical, and design interactions, and interfering use impacts) is entered by placing the score obtained in the appropriately labeled factor column, on the same line as the numbers (1 through 5) provided in the score column provided on the Technical Feasibility Score Report, provided at the end of this tool. For parameter ranks of 1 through 3, there is high possibility that (additional) field investigation is needed to better understand the impact of the particular factor.

Each section has a score weight factor on the bottom row, which is incorporated to prioritize the most critical factors of the ASR feasibility study. The most important ASR factors have a weight factor larger than the other factors. The obtained score is multiplied the associated weight factor, and the final score is placed in the box below. If a low rank is achieved in any of these highly weighted sections, then the ASR feasibility will be reduced significantly. The low-weighted sections could have a low rank and ASR could still be highly feasible. Some of these low-ranked sections could possibly be corrected or minimized with additional information, treatment technology advancements, or imposed local regulations. After being multiplied by their corresponding weighting factors, the scores are added and the final feasibility score is placed into the double-lined box. The results are interpreted as shown in Table B2-1 below:

Table B2-1. ASR Feasibility Score for Hydrogeologic, Design, and Operational Factors

Score	Feasibility Level	Type of Study Recommended
180 - 225	High Confidence	General—confirm assumptions
100 - 179	Moderate Confidence	Focused—investigate specific factors
45 - 99	Limited Confidence	Detailed—evaluate impact of critical factors

The graphical relationship of the final score to an imaginary "caution factor" is provided as Figure A-1, in Appendix A. This chart implies that the more a score deviates from the best score obtainable, the more caution is needed in the final decision about ASR feasibility to match with the specific needs of the utility considering this option. At the lowest score possible, ASR has a limited feasibility as a storage option which means it may not satisfy 100 percent of the utilities needs immediately, but it could still be the best available option. This figure correlates with the ranges specified in Table B2-1 for high confidence, moderate confidence, and limited confidence for ASR feasibility.

Part C provides a log for comparative costs and Part D provides a checklist and a regulatory flow chart for ASR permitting. The scoring and summary sheets, figures, and charts are at the end of the appendix.

ASR FEASIBILITY RANKING REPORT

As each section is reviewed, a score is determined that best represents the site-specific characteristics. At the end of the ranking process, each score is weighted as to its degree of importance and a final score is calculated. The magnitude of this score identifies a relative ASR feasibility for the site.

Part A. Facility Planning Factors

Step 1. List the Average Daily Demand.

For Potable Use, if the ADD is greater than 1 mgd, proceed to Step 2. If the ADD is less than 1 mgd, another solution should be evaluated. For Agricultural Use, proceed to Step 2.

City of Cocoa ADD = 37.6 mgd in year 2002 (end of planning period)

[see Part A, Item 1 on scoring report]

Step 2. List the Total Supply and Demand Volumes for the Planning Period.

If the total supply volume is larger than the total demand volume, proceed to Step 3. If the demand is larger than the supply, investigate other supply increase and demand reduction solutions.

City of Cocoa planning period of 1989 to 2002. Total supply is 158,410 MG; total demand is 155,170 MG.

[see Part A, Item 2 on scoring report]

Step 3. List Storage Need Volumes Calculated as a Long-Term Volume, a Seasonal Volume, a Short-Term Volume, or Other.

If the total volume is greater than 5 MG, proceed to Part B, below. If the total volume is less than 5 MG, investigate other storage options.

City of Cocoa seasonal storage need identified = 89.9 MG (Figure 12 in TM)

[see Part A, Item 3 on scoring report]

Part B. Hydrogeologic, Design, and Operation Factors

Step 1. Storage Zone Confinement

Use Table B2-2 to rank the hydraulic conductivity and thickness of the vertical flow restrictive units (aquitard) above and below the storage zone. This data can be gathered from local wells in the same zone or from regional published information. Table 3 in the TM presents an example ranking based on a 100-feet thick confining unit, which shows how Figure B-1 is used to determine the ranking.

City of Cocoa storage zone confinement is approximately 100 feet thickness of $1x10^{-5}$ ft/sec.

Table B2-2. Storage Zone Confinement Ranking

Rank	Aquitard Hydraulic Conductivity	Aquitard Thickness
1		
2 (default)		
3		
4		
5	$1x10^{-5}$ ft/sec	100 feet

Step 2. Storage Zone Transmissivity

Use Table B2-3 to rank the target storage zone transmissivity. This data can be gathered from local wells in the same zone or from regional published information. Figure B-2 should be used in conjunction with Table B2-3 to determine the ranking.

City of Cocoa transmissivity is 68,000 gpd/ft to be used for treated drinking water.

Table B2-3. Storage Zone Transmissivity Ranking

Rank	Transmissivity Criterion (gpd/ft)		Applicability
	Potable Water	Untreated Surface Water	
1	Less than 8,000	Less than 80,000	Limited
2	8,000 to 15,000	80,000 to 250,000	
3	15,001 to 40,000	250,001 to 400,000	
4	40,001 to 50,000	400,001 to 500,000	
5	50,001 to 80,000	500,001 to 1,000,000	Optimal
4	80,001 to 120,000	1,000,001 to 1,150,000	
3	120,001 to 200,000	1,150,001 to 1,400,000	
2	200,001 to 400,000	1,400,001 to 2,000,000	
1	Greater than 400,000	Greater than 2,000,000	Limited

Step 3. Local Aquifer Gradient/Direction

Rank the local aquifer gradient and direction. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table B2-4.

This was an unknown parameter at the time of installation for the City of Cocoa. The default rank of 3 was used because there may be multiple minor influences in the area.

Table B2-4. Local Aquifer Gradient/Direction Ranking

Rank	Aquifer Gradient (in same recharge zone)	Direction Criterion
1	Many strong influences exist	Extreme artificial gradient, reevaluate location of ASR system
2	Several strong influences	Exaggerated gradient, investigation needed
3 (default)	Multiple minor influences exist	Affected gradient worth investigating
4	Single minor influence or abnormal natural gradient	Minor investigation or existing data search
5	No influence	No influence

Step 4. Recharge Water Quality

Rank the recharge water quality using chloride or TDS concentrations of the water to be stored in the ASR zone. For potable water, this data can be obtained from the records of the WTP that will be supplying the source water. For raw water, this can be determined from published records or databases. If this information is not available, use the default value shown in Table B2-5.

City of Cocoa (Cl^-) = 151 mg/L for recharge quality to meet drinking water standards, therefore, rank is 3.

Table B2-5. Recharge Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Compliance with SDW Standards
1	Greater than 200	or	Greater than 450	Just within SDW standards
2	200 to 171		450 to 351	
3	170 to 101		350 to 201	Moderately meets SDW standards
4	100 to 50		200 to 100	
5	Less than 50		Less than 100	Well within SDW standards

Step 5. Native Water Quality

Rank the native water quality based on the chloride or TDS information of the native water in the target ASR zone. This data can be gathered from local wells in the same zone or from regional published information. If this information is not available, use the default value shown in Table B2-6.

City of Cocoa chloride = 480 mg/L. Rank is 4.

Table B2-6. Native Water Quality Ranking

Rank	Chloride	(mg/L)	TDS	Water Quality
1	Greater than 6,000	or	Greater than 10,000	Very brackish
2	6,000 to 3,001		10,000 to 5,001	
3	3,000 to 801		5,000 to 1,301	Slightly brackish
4	800 to 400		1,300 to 700	
5	Less than 400		Less than 700	Near fresh water

Step 6. Physical, Geochemical, and Design Interactions

Rank the potential for physical, geochemical or design interactions. This rank is based on the sum of the ranks from the sub-categories shown in the table below. If this information is not available, use the default value shown in Table B2-7.

Table B2-7. Overall Physical, Geochemical and Design Interaction Ranking for SJRWMD

Sub-Category	Rank	Recharge Water and Criterion	Selected Rank
Physical Interactions from Suspended Solids			
Total Suspended Solids (TSS) **use default**	1 2 3	TSS>2.0 mg/L 2.0 mg/L>TSS>0.05 mg/L (default) TSS<0.05 mg/L	**2**
Biological Growth and Geochemical Interactions			
pH **pH= 7.86**	1 2 3	7.8<pH< 8.6 (default) pH>8.6 pH<7.8	**1**
Total Phosphorous **use default**	1 2 3	P>0.1 mg/L 0.1 mg/L>P>0.05 mg/L (default) P<0.05 mg/L	**2**

Sub-Category	Rank	Recharge Water and Criterion	Selected Rank
Nitrate as N **N= 0.54 mg/L**	1 2 3	N>1 mg/L 1 mg/L>N>0.5 mg/L (default) N<0.5 mg/L	**2**
Dissolved Organic Carbon (DOC) **use default**	1 2 3	DOC>5 mg/L 5 mg/L>DOC>2.5 mg/L (default) DOC <2.5 mg/L	**2**
Total Iron (Fe) **Fe = 0.05 mg/L**	1 2 3	Fe>1 mg/L 1 mg/L>Fe>0.3 mg/L (default) Fe<0.3 mg/L	**3**
Dissolved Oxygen (DO) of Recharge Water **use default**	1 2 3	DO>3 mg/L 3 mg/L>DO>1.5 mg/L (default) DO<1.5 mg/L	**2**
Point Totals			**14**
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)			**3**

Note: Use the default value if data for any parameter is unavailable. Determine the overall rank from the following point totals:

Rank	Physical, geochemical, and design criteria (total of above points)	
1	7-10 points	Higher potential for plugging
2	11-12 points	
3	***13-16 points***	***Moderate potential for plugging***
4	17-18 points	
5	19-21 points	Low potential for plugging

Step 7. Interfering Uses and Impacts

Rank the interfering uses and impacts which can exist have the possibility to exist in the vicinity of an proposed ASR site. Information can be gathered from visual surveys, aerial photographs, topography maps, and public records/information from City Hall. This rank is determined from the sum of two sub-ranks shown in Table B2-8. If this information is not available, use the default value shown.

This was an unknown parameter at the time of installation for the City of Cocoa. The default rank of 3 was used because there may be minor interfering uses or impacts in the area.

Table B2-8. Interfering Uses and Impacts Ranking

Sub-Category	Rank and Criterion	Selected Rank
Interfering Uses		
Distance to Domestic or Public Supply Wells	1 0.10 mile<Wells<0.25 mile 2 0.26 mile<Wells<5 miles (default) 3 Wells>5 miles	**2**
Interfering Impacts		
Distance to Contamination Source	1 0.10 mile<Source<0.25 mile 2 0.26 mile<Source<1 mile (default) 3 Source>1 mile	**2**
Point Total		**4**
Overall Interfering Uses and Impacts Rank (using rank corresponding to point totals listed below)		**3**

Overall Interfering Uses and Impacts Rank determined from the following point totals:

Rank	Interfering Use and/or Impact Criteria (possibility of impact)	
1	2 points	High use/impact
2	3 points	
3	***4 points***	***Moderate use or impact***
4	5 points	
5	6 points	Low use/impact

Part C: Cost Comparison Summary

The annual cost figures (Figures A-4 through A-10) were developed as a means of comparing alternative water storage and treatment options. Use the tables to complete the Cost Comparison Summary Sheet provided on the following page. On this sheet, a comparison is made between ASR, other storage options and plant upgrades, which will provide the needed water for immediate peak demand or future demands.

City of Cocoa - Cost comparisons for this example are not provided.

Part D: Regulatory Summary

Part D presents the regulatory requirements for the different types of water quality. Place an "X" under the category of *YES* or *NO* to best describe the quality of the water to be stored. Figure A-11 provides the regulatory permits or exemptions needed for the different water quality groups.

City of Cocoa - A regulatory summary for this example is provided on the second page of the report sheet.

Feasibility Screening Report
Parts A and B

Facility Designation: City of Cocoa WTP | Water Source: Treated Ground Water | Date: 5/9/96

Facility Director: Example 2 | Intended Use: Potable Use

Water Management District: St. Johns River Water Management District | Date: ______

District Officer: ______

PART A FACILITY PLANNING FACTORS

					YES	NO
1	Average Daily Demand (End of Planning Period):	37.6	MGD	Is ADD Greater Than 1 mgd?	X	
2	a. Total Supply Volume for Planning Period:	158,410	MG	Is the Supply Volume Greater Than Demand Volume?	X	
	b. Total Demand Volume for Planning Period:	155,170	MG			
3	List Storage Need Volumes Calculated:			Are any of the Volumes Greater Than 5 MG ?	X	
	a. Long Term Volume:	89.9	MG			
	b. Seasonal Volume (For Quantity and Quality):		MG			
	c. Short Term Volume:		MG			
	d. Other (Emergency, Plant Operations, etc):		MG			
	e. Total a. through d., above	89.9	MG			

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts	
5	5	5						High Feasibility Zone
4					4			High Feasibility Zone
3			3	3		3	3	Further Investigations Needed Zone
2								Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	
Score	50	50	3	6	40	15	15	Total Score: 179

High Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts C and D

Facility Designation *City of Cocoa WTP* Date ______

Facility Director *Example 2*

Water Management District St. Johns River Water Management District Date ______

District Officer ______

PART C COST COMPARISON SUMMARY

Cost Comparison for Storage Options

Storage Need (SN): *9* MG Peak Factor (PF): *1.5* Recovery Duration (RD): *37 Days* ASR Recovery Rate $\frac{PF \cdot SN}{RD}$ = *3.6* mgd

Equivalent Annual Costs

Tank $ *400,000*

Reservoir $ *800,000*

ASR $ *250,000*

Cost Comparison for Management Options

Plant Rate Increase: ______ mgd

Equivalent Annual Costs

Plant Upgrades	Base Cost	Option 1	Option 2	Option 3	Option 4
Lime Softening and	*$1.1 Million*				
Sulfide Reduction by	Tray Aeration				
	Packing Tower				
	Ozonation				
TOTAL	*$1.1 Million*	*NA*	*NA*	*NA*	*NA*

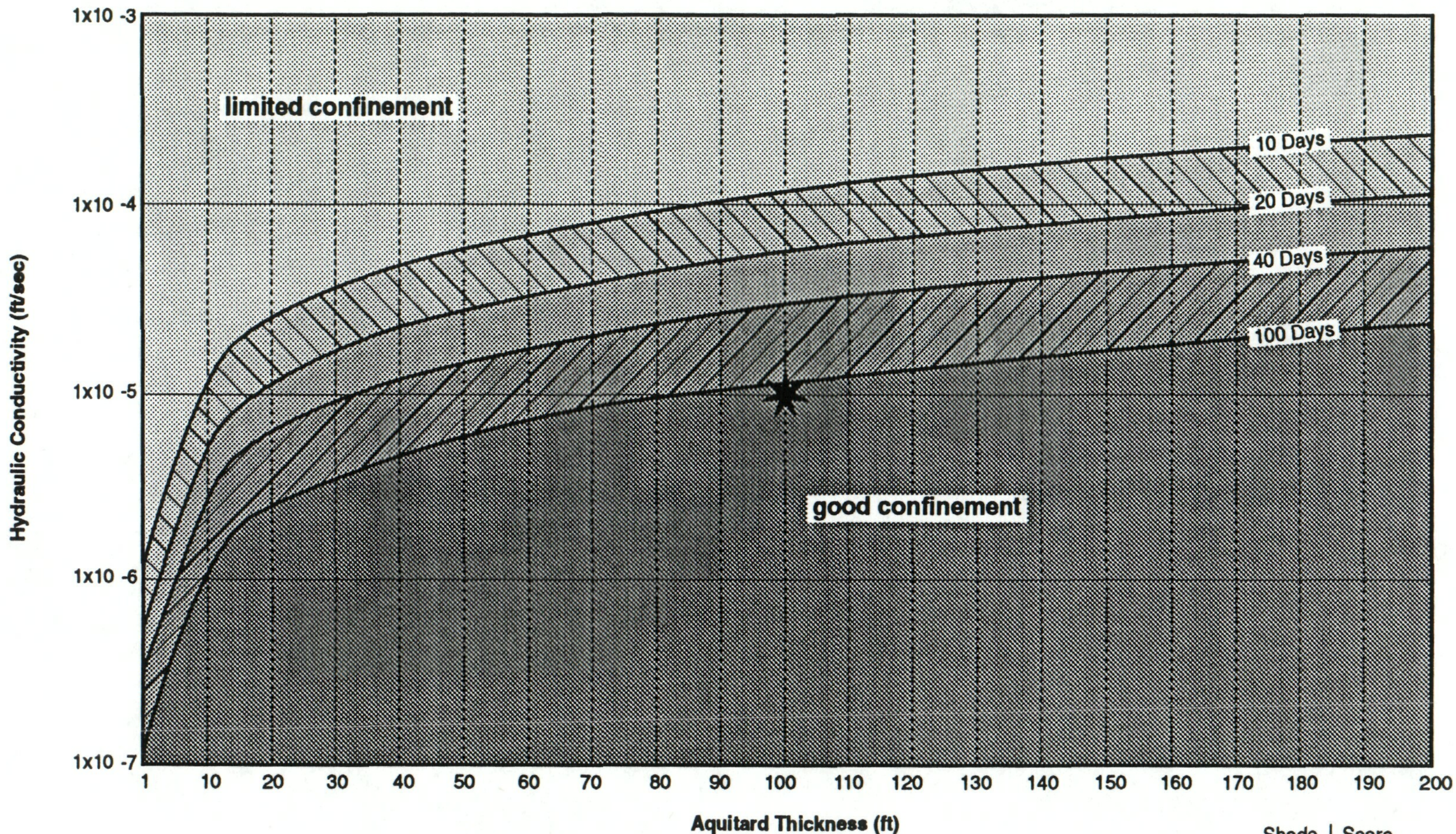
Equivalent Annual Cost for Options

Plant Upgrade $ *1.1 Million* (total cost from option selected from the table above)

ASR $ *250,000* (annual cost from cost comparison for storage options)

PART D REGULATORY SUMMARY

	YES	NO	
Injected water meets all standards	*X*		(refer to Figure A2 for regulatory requirements)
Injected water meets federal standards and state minimums			(refer to Figure A2 for regulatory requirements)
Injected water exceedes one or more federal standards			(refer to Figure A2 for regulatory requirements)



Notes: Curves are based on vertical travel times through confining unit of 10, 20, 40, and 100 days.
✱ 100 ft thickness with $1X10^{-5}$ ft/sec hydraulic conductivity

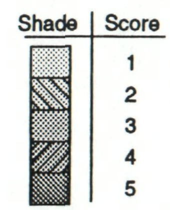


Figure B-3. Aquitard confinement as a function of thickness and hydraulic conductivity (City of Cocoa, Florida)

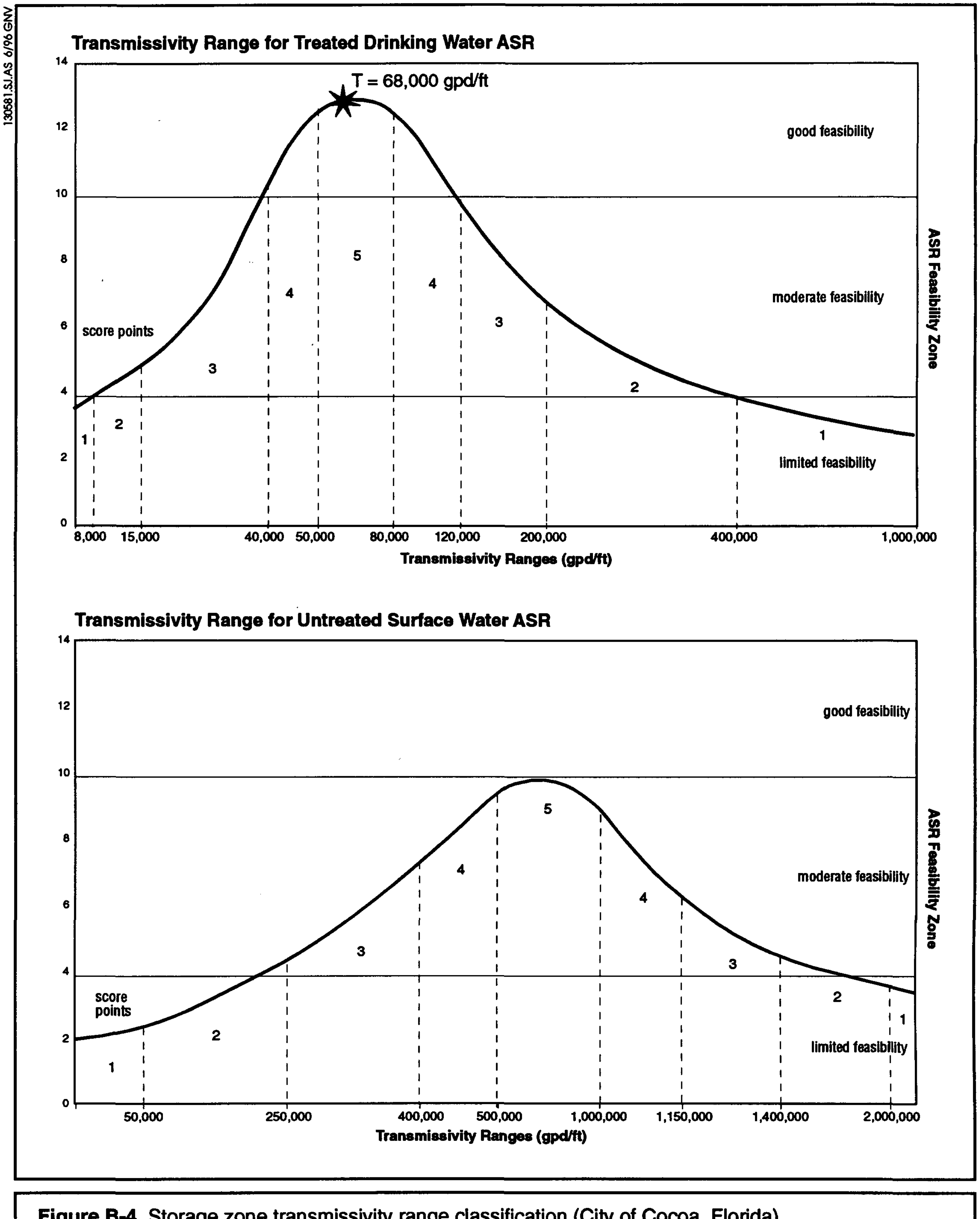


Figure B-4. Storage zone transmissivity range classification (City of Cocoa, Florida)

Appendix C
Existing ASR System Feasibility Screening Summary Reports

Feasibility Screening Report
Parts A and B

Facility Designation Cocoa, Florida — Water Source Treated Ground Water — Date ______

Facility Director Existing System Scoring Study — Intended Use Potable Use

Water Management District St. Johns River Water Management District — Date ______

District Officer ______

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ______ MGD — Is ADD Greater Than 1 mgd? ______ YES ______ NO

2 a. Total Supply Volume for Planning Period: ______ MG
b. Total Demand Volume for Planning Period: ______ MG — Is the Supply Volume Greater Than Demand Volume? ______ YES ______ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ______ MG
b. Seasonal Volume (For Quantity and Quality): ______ MG
c. Short Term Volume: ______ MG
d. Other (Emergency, Plant Operations, etc): ______ MG
e. Total a. through d., above ______ MG

Are any of the Volumes Greater Than 5 MG ? ______ YES ______ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts	
5	5	5						High Feasibility Zone
4					4			High Feasibility Zone
3			3	3		3	3	Further Investigations Needed Zone
2								Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	
Score	50	50	3	6	40	15	15	Total Score 179

High Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation Boynton Beach, Florida — Water Source Treated Ground Water — Date ____________

Facility Director Existing System Scoring Study — Intended Use Potable Use

Water Management District St. Johns River Water Management District — Date ____________

District Officer ____________

PART A FACILITY PLANNING FACTORS

1	Average Daily Demand (End of Planning Period):	________ MGD	Is ADD Greater Than 1 mgd?	____ YES	____ NO
2	a. Total Supply Volume for Planning Period: b. Total Demand Volume for Planning Period:	________ MG ________ MG	Is the Supply Volume Greater Than Demand Volume?	____ YES	____ NO
3	List Storage Need Volumes Calculated: a. Long Term Volume: b. Seasonal Volume (For Quantity and Quality): c. Short Term Volume: d. Other (Emergency, Plant Operations, etc): e. Total a. through d., above	 ________ MG ________ MG ________ MG ________ MG ________ MG	Are any of the Volumes Greater Than 5 MG ?	____ YES	____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

	ASR Hydrogeologic, Design and Operation Factor Scores							
	1	2	3	4	5	6	7	
Section Points	Storage Zone Confinement	Storage Zone Transmissivity	Local Aquifer Gradient/Direction	Recharge Water Quality	Native Water Quality	Physical, Geochemical Interactions	Interfering Uses and/or Impacts	
5		5					5	High Feasibility Zone
4			4	4				High Feasibility Zone
3					3	3		Further Investigations Needed Zone
2	2							Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	
Score	20	50	4	8	30	15	25	Total Score 152

Moderate Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation: Manatee, Florida — Water Source: Treated Surface Water — Date ____________

Facility Director: Existing System Scoring Study — Intended Use: Potable Use

Water Management District: St. Johns River Water Management District — Date ____________

District Officer ____________

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ________ MGD — Is ADD Greater Than 1 mgd? ____ YES ____ NO

2 a. Total Supply Volume for Planning Period: ________ MG
b. Total Demand Volume for Planning Period: ________ MG — Is the Supply Volume Greater Than Demand Volume? ____ YES ____ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ________ MG
b. Seasonal Volume (For Quantity and Quality): ________ MG
c. Short Term Volume: ________ MG
d. Other (Emergency, Plant Operations, etc): ________ MG
e. Total a. through d., above ________ MG

Are any of the Volumes Greater Than 5 MG ? ____ YES ____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts
5			5		5		3
4				4			
3						3	
2	2	2					
1							
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5
Score	20	20	5	8	50	15	25

Rows 5–4: High Feasibility Zone
Rows 3–1: Further Investigations Needed Zone

Total Score: 143

Moderate Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation: Marathon, Florida — Water Source: Treated Ground Water — Date ________

Facility Director: Existing System Scoring Study — Intended Use: Potable Use

Water Management District: St. Johns River Water Management District — Date ________

District Officer ________________

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ________ MGD — Is ADD Greater Than 1 mgd? ____ YES ____ NO

2 a. Total Supply Volume for Planning Period: ________ MG
b. Total Demand Volume for Planning Period: ________ MG — Is the Supply Volume Greater Than Demand Volume? ____ YES ____ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ________ MG
b. Seasonal Volume (For Quantity and Quality): ________ MG
c. Short Term Volume: ________ MG
d. Other (Emergency, Plant Operations, etc): ________ MG
e. Total a. through d., above ________ MG

Are any of the Volumes Greater Than 5 MG ? ____ YES ____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts
5			5	5			5
4							
3		3				3	
2	2						
1					1		
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5
Score	20	30	5	10	10	15	25

Rows 5–4: High Feasibility Zone. Rows 3–1: Further Investigations Needed Zone.

Total Score: 115

Moderate Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation: Palm Bay, Florida — Water Source: Treated Ground Water — Date ______

Facility Director: Existing System Scoring Study — Intended Use: Potable Use

Water Management District: St. Johns River Water Management District — Date ______

District Officer ______

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ______ MGD — Is ADD Greater Than 1 mgd? ______ YES ______ NO

2 a. Total Supply Volume for Planning Period: ______ MG
b. Total Demand Volume for Planning Period: ______ MG
Is the Supply Volume Greater Than Demand Volume? ______ YES ______ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ______ MG
b. Seasonal Volume (For Quantity and Quality): ______ MG
c. Short Term Volume: ______ MG
d. Other (Emergency, Plant Operations, etc): ______ MG
e. Total a. through d., above ______ MG
Are any of the Volumes Greater Than 5 MG ? ______ YES ______ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

	ASR Hydrogeologic, Design and Operation Factor Scores						
	1	2	3	4	5	6	7
Section Points	Storage Zone Confinement	Storage Zone Transmissivity	Local Aquifer Gradient/Direction	Recharge Water Quality	Native Water Quality	Physical, Geochemical Interactions	Interfering Uses and/or Impacts
5	5						5
4					4		
3		3	3			3	
2				2			
1							
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5
Score	50	30	3	4	40	15	25

Points 5–4: High Feasibility Zone
Points 3–1: Further Investigations Needed Zone

Total Score: 167

High Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation: Peace River, Florida
Water Source: Treated Surface Water
Date: ____________

Facility Director: Existing System Scoring Study
Intended Use: Potable Use

Water Management District: St. Johns River Water Management District
Date: ____________

District Officer: ____________

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ________ MGD — Is ADD Greater Than 1 mgd? ____ YES ____ NO

2 a. Total Supply Volume for Planning Period: ________ MG
b. Total Demand Volume for Planning Period: ________ MG — Is the Supply Volume Greater Than Demand Volume? ____ YES ____ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ________ MG
b. Seasonal Volume (For Quantity and Quality): ________ MG
c. Short Term Volume: ________ MG
d. Other (Emergency, Plant Operations, etc): ________ MG
e. Total a. through d., above ________ MG — Are any of the Volumes Greater Than 5 MG ? ____ YES ____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

ASR Hydrogeologic, Design and Operation Factor Scores

Section Points	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts	
5	5				5		5	High Feasibility Zone
4		4	4	4				High Feasibility Zone
3						3		Further Investigations Needed Zone
2								Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	
Score	50	40	4	8	50	15	25	Total Score: 192

High Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

Feasibility Screening Report
Parts A and B

Facility Designation: Highland Ranch, Colorado — Water Source: Treated Surface Water — Date ____________

Facility Director: Existing System Scoring Study — Intended Use: Potable Use

Water Management District: St. Johns River Water Management District — Date ____________

District Officer ____________

PART A FACILITY PLANNING FACTORS

1 Average Daily Demand (End of Planning Period): ________ MGD — Is ADD Greater Than 1 mgd? ____ YES ____ NO

2 a. Total Supply Volume for Planning Period: ________ MG
b. Total Demand Volume for Planning Period: ________ MG — Is the Supply Volume Greater Than Demand Volume? ____ YES ____ NO

3 List Storage Need Volumes Calculated:
a. Long Term Volume: ________ MG
b. Seasonal Volume (For Quantity and Quality): ________ MG
c. Short Term Volume: ________ MG
d. Other (Emergency, Plant Operations, etc): ________ MG
e. Total a. through d., above ________ MG — Are any of the Volumes Greater Than 5 MG ? ____ YES ____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

	ASR Hydrogeologic, Design and Operation Factor Scores							
	1	2	3	4	5	6	7	
Section Points	Storage Zone Confinement	Storage Zone Transmissivity	Local Aquifer Gradient/Direction	Recharge Water Quality	Native Water Quality	Physical, Geochemical Interactions	Interfering Uses and/or Impacts	
5			5	5	5		5	High Feasibility Zone
4								High Feasibility Zone
3						3		Further Investigations Needed Zone
2	2	2						Further Investigations Needed Zone
1								Further Investigations Needed Zone
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5	Total Score
Score	20	20	5	10	50	15	25	145

Moderate Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors

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Feasibility Screening Report
Parts A and B

Facility Designation Seattle, Washington ____ Water Source Treated Surface Water ____ Date ____

Facility Director Existing System Scoring Study ____ Intended Use Potable Use ____

Water Management District St. Johns River Water Management District ____ Date ____

District Officer ____

PART A FACILITY PLANNING FACTORS

1	Average Daily Demand (End of Planning Period):	____ MGD	Is ADD Greater Than 1 mgd?	____ YES	____ NO
2	a. Total Supply Volume for Planning Period: b. Total Demand Volume for Planning Period:	____ MG ____ MG	Is the Supply Volume Greater Than Demand Volume?	____ YES	____ NO
3	List Storage Need Volumes Calculated: a. Long Term Volume: b. Seasonal Volume (For Quantity and Quality): c. Short Term Volume: d. Other (Emergency, Plant Operations, etc): e. Total a. through d., above	____ MG ____ MG ____ MG ____ MG ____ MG	Are any of the Volumes Greater Than 5 MG ?	____ YES	____ NO

PART B HYDROGEOLOGIC, DESIGN, AND OPERATION FACTORS

Section Points	ASR Hydrogeologic, Design and Operation Factor Scores						
	1 Storage Zone Confinement	2 Storage Zone Transmissivity	3 Local Aquifer Gradient/Direction	4 Recharge Water Quality	5 Native Water Quality	6 Physical, Geochemical Interactions	7 Interfering Uses and/or Impacts
5			5	5	5		5
4							
3	3					3	
2		2					
1							
Weight Factor	X 10	X 10	X 1	X 2	X 10	X 5	X 5
Score	30	20	5	10	50	15	25

High Feasibility Zone (points 5–4)

Further Investigations Needed Zone (points 3–1)

Total Score: 155

Moderate Confidence

Score	Feasibility Level	Type of Study Recommended
160-215	High Confidence	General – Confirm Assumptions
100-159	Moderate Confidence	Focused – Investigate Specific Factors
43-99	Low Confidence	Detailed – Evaluate Impact of Critical Factors