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PUBLIC UTILITIES BOARD

Step 1 Report

FEASIBILITY INVESTIGATION

Aquifer Storage and Recovery System

Submitted to
Brownsville Public Utilities Board
Brownsville, Texas

By
CH2M HILL

January 1996

STATE OF TEXAS
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January 25, 1996

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Mr. Kelvin S. Hinrichs, P.E., Manager
Water/Wastewater Engineering
Brownsville Public Utilities Board
1425 Robinhood Drive
P. O. Box 3270
Brownsville, TX 78520-3270

Dear Mr. Hinrichs:

Subject: Aquifer Storage Recovery Feasibility Investigation

CH2M HILL is pleased to transmit to you 10 copies of our final report for the first phase of the aquifer storage recovery feasibility investigation. We have incorporated the comments received from the Texas Water Development Board (TWDB) into the report.

We have also provide copies of the report to the following people:

Randy Williams Texas Water Development Board 1700 North Congress Avenue Austin, TX 78711-3231	3 Copies
Bill Norris NRS Consulting Engineers 1222 E. Tyler, Suite C Harlingen, TX 78551	1 Copy

It has been a pleasure working with you and John during this initial phase. We look forward to the continuation of this important project.

Sincerely,

CH2M HILL

AL for J Michael Anglea

J. Michael Anglea, P.E.
Vice President and Project Manager

DEN/5449.DOC
Enclosure
c: John Bruciak/PUB
Kevin Bral/CH2M HILL
Randy Williams/TWDB
Bill Norris/NRS

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Executive Summary

Aquifer Storage Recovery (ASR) is a water management technique in which large volumes of treated water can be stored underground in aquifers. The technique is particularly useful to utilities that experience conditions of excess water supplies during certain times and water shortfalls during others. Using ASR, a utility can produce and store water when it is available for later use during high demands.

The results of this investigation suggest that ASR may be a feasible alternative for the City of Brownsville Public Utilities Board (PUB) to meet future water demands. It may be possible for an ASR facility to work with the PUB's recently expanded water treatment facilities, existing water rights, and recently acquired Permit 1838, to meet projected mid-level water demands through the year 2012. Without the ASR alternative, projected water demands exceed supplies by the year 2003, and demands exceed treatment capacity by the year 2005. It is recommended that the PUB proceed with the next phase of the ASR investigation and work with the Texas Water Development Board (TWDB) to construct test borings/wells at selected sites.

The PUB operates a water supply system that serves the City of Brownsville, Texas, and surrounding areas. The Rio Grande river is utilized as a raw water source. The PUB system currently serves residential, commercial, industrial, and wholesale customers. In 1994, the PUB potable water system produced an average of more than 18 million gallons of potable water per day. The City of Brownsville is experiencing a growing population and the associated increase in water demands on their system. Current firm water rights and contracts for the Rio Grande water are only expected to provide sufficient raw water flows until the year 2003. Water treatment facilities are also projected to require additional expansion by the year 2005.

The PUB has recently obtained Water Use Permit 1838 which allows the PUB to pump additional raw water during times when the Rio Grande flows equal or exceed 25 cubic feet per second (cfs). The permit allows the use of up to 40,000 acre-feet of excess Rio Grande water annually that would normally flow into the Gulf of Mexico. The amount of water available each year will depend on actual river flows. Based on historical conditions, it is expected about 17,000 acre-feet per year would be available.

Raw water available under Permit 1838 during high river flows may not correspond to periods of high water needs. In order to provide the most effective use of this water, large volume storage is required. In this way, water could be diverted under Permit 1838 and stored until needed.

Aquifer Storage Recovery provides a method to store water obtained and treated under Permit 1838. Water for storage would be diverted during the low demand months (November through about May), and treated using water treatment plant (WTP) capacity in excess of current demands. Depending on the water demands and availability of the Permit 1838 water, it is feasible that 6,000 acre-feet or more of treated water could be stored during a given year. Recovery of this stored water during the peak demand season would serve two purposes. First, the recovered water would reduce the use of the PUB firm water rights during that year. Secondly, the recovered water would supplement WTP flows during peak demand months and allow the upgraded WTPs to meet maximum day demands in excess of their capacities.

A preliminary balance of water supply, ASR operations, and water demands indicate the ASR operation would benefit the PUB system operation most effectively if integrated thoroughly with the Permit 1838 water. This entails not only using the Permit 1838 water for injection but also for direct treatment and distribution when possible. This type of operation involves some risk without the ASR component because of the need to release Falcon Reservoir water in advance. With an ASR system, the risk is greatly reduced. If insufficient water is requested from Falcon Reservoir, and the Permit 1838 water is not available, water stored in the ASR system can provide the required flows. These three components working together should be capable of meeting PUB's projected water demands through about the year 2012 and possibly beyond.

In order for an ASR facility to be feasible for the PUB, a suitable storage aquifer must exist. Because of the poor water quality exhibited by the Brownsville area groundwater, little exploration has been done in the past and existing information is somewhat limited. Additional information is needed to fully assess the ASR operations.

The hydrogeologic information available identifies three potential aquifer zones beneath Brownsville that may be suitable for aquifer storage. These are identified as the Gravel, the Intermediate, and the Lower Zones. The Gravel Zone exists at depths of approximately 150 to 225 feet, the Intermediate Zone from 200 to 400 feet, and the Lower Zone from about 400 feet to well over 1,500 feet. Water quality of the Gravel and Intermediate Zones are estimated to be similar with total dissolved solids (TDS) concentrations ranging from 2,500 to 12,000 mg/l. Water quality in the Lower Zone may exceed 20,000 mg/l TDS.

The expected capacities of individual wells completed in the potential ASR zones were estimated based on the available information. The information suggests that wells completed into the Gravel or Lower Zones may provide individual capacities of 700 gpm to 1000 gpm. Wells completed into the Intermediate Zone would probably result in lower capacities.

A test drilling program is required to define the hydrogeologic conditions underlying the Brownsville area and further assess the ability of an aquifer zone to store and recover treated water. However, it appears promising that an appropriate ASR zone exists to provide some level of large volume storage for the Permit 1838 water.

The PUB water system is expected to benefit from two ASR applications. First the PUB is projected to require additional raw water supplies by the year 2003 as raw water demand is projected to exceed its firm water rights by that year. One use of ASR for the PUB is to store water available from Permit 1838 for use later in the year. Water obtained under this permit could be treated and stored, and later used to supplement the PUB's firm water rights. A water balance constructed using projected monthly demands, WTP maximum capacity at 40 million gallons per day (mgd), annual firm raw water rights of 33,973 acre-ft, and Permit 1838 water indicate that the PUB system could probably operate through the year 2012 using a fully applied ASR facility in conjunction with Permit 1838 water.

The second benefit of ASR for the PUB will be the ability of an ASR system to meet peak demands on water treatment facilities. The PUB WTPs are being expanded to a combined maximum capacity of 40 mgd. Projected demands on the PUB system indicate the maximum day demand will exceed the WTPs' capacity during the year 2005. A properly operating ASR system could provide recovered water during these maximum day demands and allow the PUB system to safely meet demands in excess of 40 mgd. The water balance conducted indicates that during the year 2012 the maximum day demand is over 49 mgd and this demand can be met through a combination of ASR recovery and WTP operation.

The ASR system that appears to be best suited for the PUB will be a system of wells and piping that operates at average injection and recovery rates of 10 mgd and 12 mgd, respectively. The system will be capable of handling maximum rates higher than this in order to take advantage of the Permit 1838 water which may only be available in large quantities for short periods of time. The maximum rates for injection and recovery of the conceptual ASR system are approximately 15 mgd and 19 mgd, respectively.

The conceptual system may operate most effectively if located in approximately five locations in Brownsville. Two of the locations could be WTP No. 1 and No. 2. At each of the WTPs, 5 or 6 ASR wells could possibly be located. The other 3 locations could be at PUB elevated storage tanks. At each of the elevated storage tanks, 1 or 2 ASR wells could be located. The preliminary estimated cost in 1995 dollars for developing this system as described to potentially meet water demands through the year 2012 is approximately $ 10.8 million.

Section 1
Introduction

Overview

The City of Brownsville Public Utilities Board (PUB) operates a water supply system that serves the City of Brownsville, Texas, and surrounding areas. The Rio Grande river is utilized as a raw water source and the PUB system currently serves residential, commercial, industrial, and wholesale customers. This includes approximately 105,200 people through more than 26,200 potable water connections. In 1994, the PUB potable system produced an average of more than 18 million gallons of potable water per day.

The City of Brownsville is experiencing a growing population and the associated increase in water demands on their system. Projected water demands forecast continuing growth through the period to 2014, with 48,373 connections estimated. However, depending on whether the low, mid, or high water demand forecast is considered, current firm water rights and contracts for the Rio Grande water are only expected to provide sufficient flows for another 7 to 13 years. Additionally, an existing water contract with the Brownsville Irrigation and Drainage District (BIDD) will expire in 1998. The PUB is hopeful this contract will be extended, but if it is not, a water shortfall could occur in Brownsville by 1999.

As a result of the increase in potable water use and the potential for a water shortfall, the investigation of additional strategies for providing future water to the PUB customers has been initiated. One of these strategies is a water management technique known as Aquifer Storage Recovery (ASR). The ASR concept works by storing large volumes of water through wells constructed underground in existing water bearing geologic formations known as aquifers. Water is typically produced for storage during times of the year when excess supply or water treatment capacity is available. Then when water demands are high and supplies cannot keep up with demands, the stored water is recovered from wells and used to satisfy these demands. The ASR concept works well when an abundance of water is available for a limited time that can be stored for later use. Experience with ASR systems for other utilities has also shown that ASR systems can typically be implemented for substantially less cost than the more conventional alternatives to meeting peak water demands.

This report on the feasibility of ASR for the PUB represents the first phase of the ASR investigation. The work to prepare this report relied on existing information including water use records, existing demand projections, geologic reports, verbal communication, and other associated information. The results of the investigation show that ASR may be a viable option for the PUB to meet future water demands. However, this conclusion is based on several assumptions which must be verified through field testing. The subsequent sections of this report describe conceptually how ASR could serve the PUB, steps necessary to confirm the proposed operation, and approximate costs for implementation.

Report Organization

The following report was prepared as a series of Technical Memorandums that each address the required topics to determine ASR feasibility and conceptual applications. These memorandums are included in the appendices to this report. The report sections that follow summarize the more detailed memorandums and focus these results toward ASR feasibility and applications for the PUB. The technical memorandums included in the appendices are listed as follows:

- ASR Feasibility Investigation Surface Water Assessment
- Geology and Ground-Water Conditions Near Brownsville, Texas
- Geochemical Evaluation - Brownsville ASR Project
- ASR Applications
- Temporary UIC and Surface Water Permit Application

Section 2
Water Demand and Water Availability Overview

Existing Water System

The City of Brownsville PUB obtains raw water for treatment from the Rio Grande river which flows along the western edge of the City. Water is pumped from the river into an approximate 27 million gallon raw water surface storage reservoir, and from there to two water treatment plants (WTPs). The WTPs are designated WTP No. 1 and No. 2, and each has a current treatment capacity of about 10 mgd. Both plants are currently being upgraded to higher capacity which is scheduled to be completed at the end of this year. At that time, each WTP will have a treatment capacity of 20 mgd, for a combined total treated water production capacity of 40 mgd.

Water Treatment Plant No. 1 is located adjacent to the Rio Grande River and WTP No. 2 is located near the northeast corner of the City. Facility locations are presented in Figure 2.1.

Raw Water Availability

Raw water obtained from the Rio Grande is pumped by the PUB under existing water rights, one contract for water purchase and one agreement for raw water exchange toward treatment charges. These supply sources are listed below:

Water Source	Acre-Feet
Rio Grande Water Rights	27,935
BIDD Contract	5,000
El Jardin Agreement	1,038
Total	**33,973**

In addition to the above firm commitments for water rights, the PUB holds Permit 1838 which authorizes the PUB to divert up to 40,000 acre-feet annually of excess Rio Grande water from the Brownsville Navigation District. The diversion is allowed when the flow of the Rio Grande at the Lower Brownsville Gauging Station is at least 25 cubic feet per second (cfs). It has been estimated from an analysis of river flow patterns that an average of 17,000 acre-feet of water should be available to the PUB per year from Permit 1838.

The PUB water rights for 33,973 acre-feet are considered a firm water right and should be available for use each year (as long as the contracts and agreements are in force). To obtain water for use under these rights, the PUB requests the Rio Grande Watermaster to release water from Falcon Reservoir. Water released from Falcon takes seven days to reach Brownsville, therefore requests are made weekly based on expected water use for the following week.

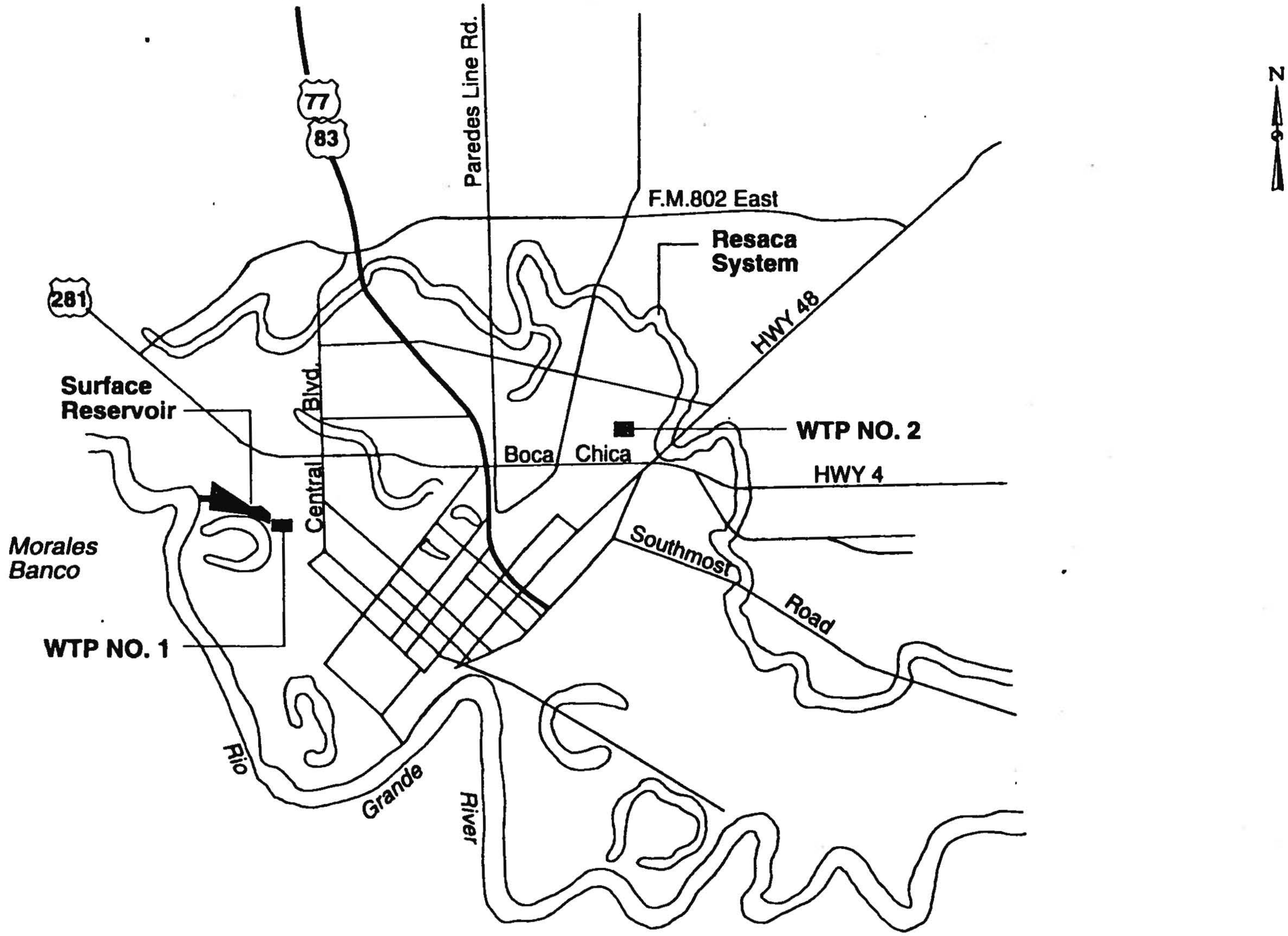

Figure 2-1
Facility Locations
City of Brownsville, Texas

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Water available under Permit 1838 is available at the time that river flows are equal to or in excess of 25 cfs. These conditions can occur for several reasons, some of which may be due to other users not fully utilizing their respective release, excess rainfall, or other reasons which cause the flows in the river to be higher than expected. Water obtained under Permit 1838 must be taken from the river at the time it is available.

The PUB currently operates the water system by ordering water released from Falcon Reservoir each week based on the expected conditions the following week. Each release is charged against the water right account and as long as the account is large enough to charge throughout the year, adequate water is available. As discussed further in the following subsection, water demands are projected to exceed the PUB's firm water rights. At this time, the PUB will have to make use of the water available under Permit 1838. However, although on average this permit provides an appreciable volume of water, the water is not guaranteed to be available precisely when it is needed. Additional complications arise if the Permit 1838 water will be used early in the year to offset or delay the use of the firm water rights. Because the PUB must request release of its firm water right one week before it is needed, there is some uncertainty in relying on the Permit 1838 water to be available one week from requesting a reduced release from Falcon. Once the PUB requests a release from Falcon, the water right account is charged whether the release is pumped from the river by PUB or not.

It is clear that the Permit 1838 water will play a key role in the future water supply of Brownsville and that this water is an important acquisition by the PUB. In order to maximize the effective use of this water, a substantial storage facility is needed. This way, when the Permit 1838 water is available, it can be pumped from the river, treated, and stored. Once the water was stored, it could be called upon for use as needed, and ordering releases from Falcon Reservoir would be much simpler to plan.

Current and Projected Water Demands

Water demands on the PUB system consist of both raw water and treated water demands. Raw water is used directly for irrigation purposes and for power plant cooling water. Over the past 5 years, average annual raw water demands have averaged 21 percent of the water pumped from the river. Treated water demands have encompassed the remaining 79 percent.

Water demands on the PUB water system have been increasing over the past several years. Demand projections estimated by the PUB forecast this increasing trend will continue through the forecast period. Current and mid-level projected annual average water demands for the PUB system are presented in Figure 2.2. The information shown in Figure 2.2 indicates that mid-level projected raw water demands will exceed supply in the year 2003.

Demand variation over a given year plays an important role in water system development and operation. Water production has to keep pace with the varying demands which require water facilities to operate at rates much higher and lower than the average annual water demands. Over the past 5 years, the maximum water production over one day for the PUB water system averaged 1.6 times the annual average treated water demand. In 1994, this maximum day rate was 28.5 mgd and the average annual treated water demand was 18.0 mgd.

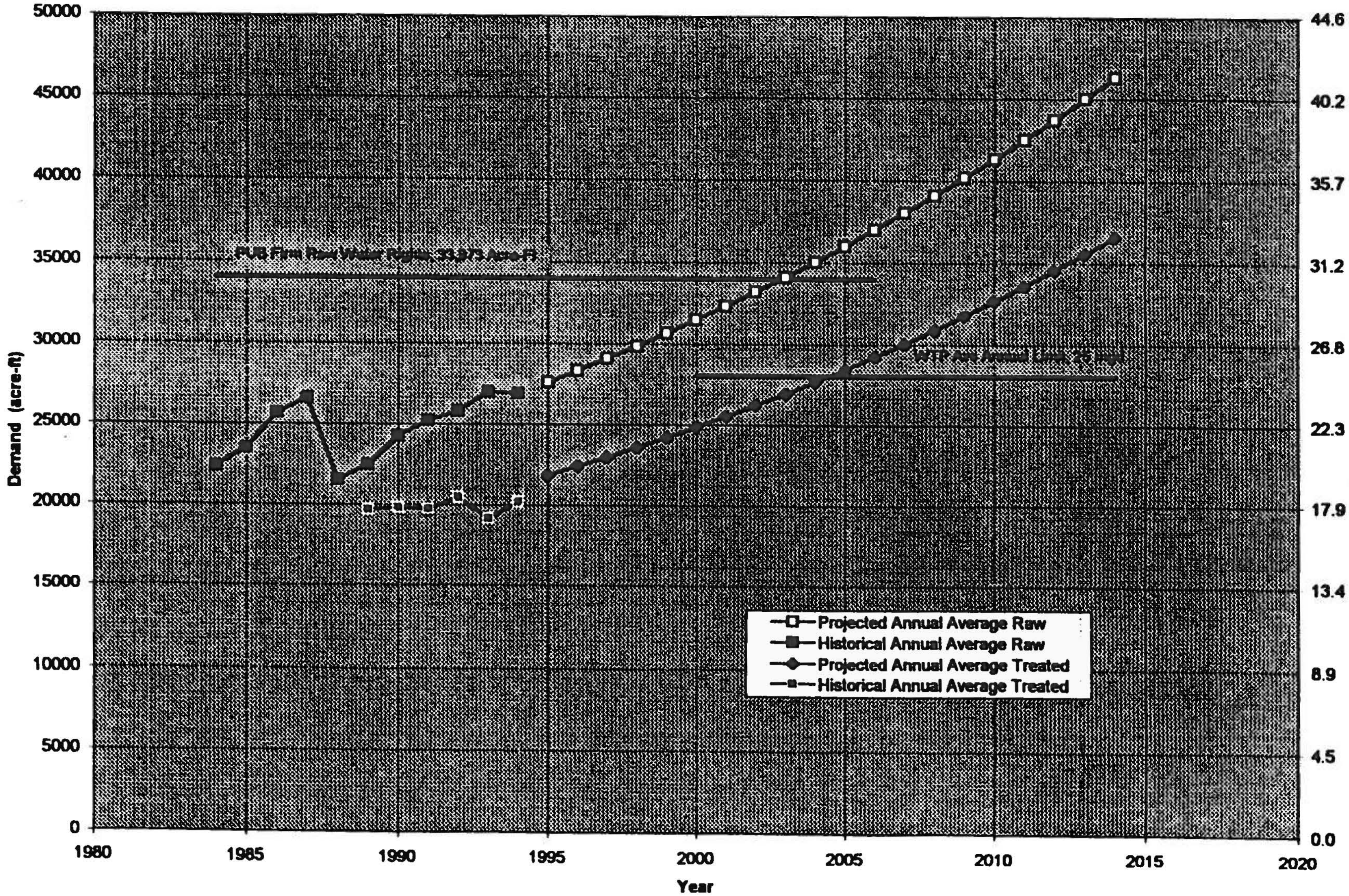


Figure 2.2 Average Annual Water Demands

The significance of the maximum day water demand is apparent when size of treatment facilities is considered. Treatment facilities are typically designed to produce water at the required maximum day demand rate. During the high demand summer months, the WTP operates at the highest rates of the year. In Brownsville's situation, the total treatment capacity will soon be 40 mgd which will be required when the average annual day demand reaches about 25 mgd. Considering the demand projections presented in Figure 2.2, additional treatment plant capacity will again be required in the year 2005. Annual demand variations for the PUB system are illustrated in Figure 2.3.

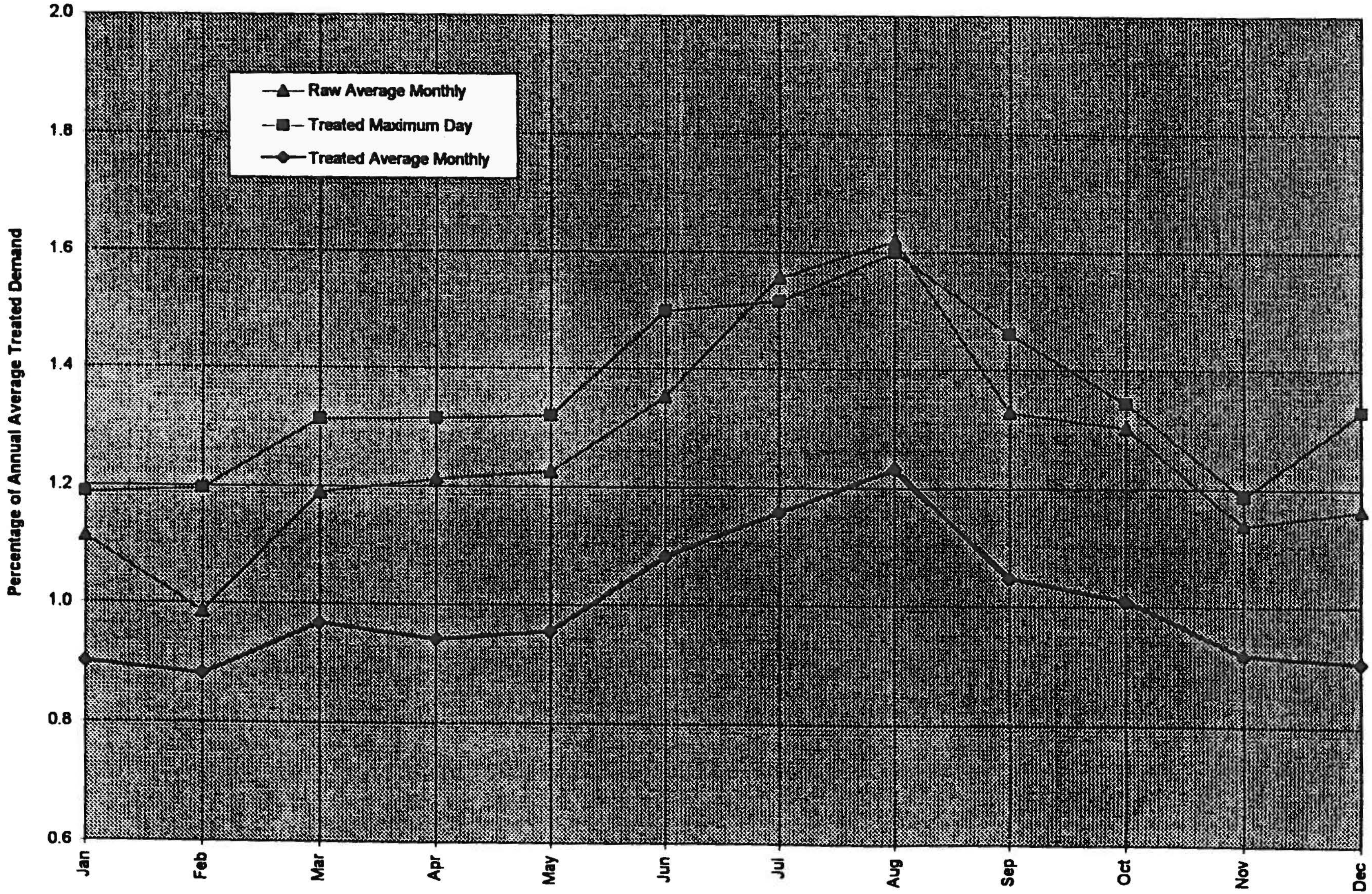
As shown in Figure 2.3, the highest water demands on the PUB system typically occur during the month of August. As stated earlier, during this month the maximum day demand averages 1.6 times the average annual demand and the WTPs typically operate at their highest rate. Demands are seen to decrease during the winter months and typically remain below the annual average during the months of November through May.

General ASR Applications

Aquifer Storage Recovery (ASR) is a technique for storing large volumes of water when it is available in excess. Considering the PUB system operation, two situations exist that would allow the storage of excess water. The first is the Permit 1838 water which is available when flows in the Rio Grande equal or exceed 25 cfs. This water is available under short notice, and is not guaranteed to be available when it is most needed during either high demands, or late in the year when the PUB firm water rights have been completely used. Storage of this water when available for later use would increase the efficiency of PUB's water use.

The other situation where excess water could be available for storage is during the low demand months of a given year. The PUB water treatment plants are designed to produce water at a high rate such that the maximum day demand can be satisfied during the year. For many of the other months, the WTPs are operating at a rate much below the rate at which the plants were designed. If the WTPs were operated at a rate somewhat higher than required to meet the average water demand, the excess produced water could be diverted to storage. During the months of June through September, or October, the stored water could be used to supplement WTP flows and meet the high summer demands. This type of operation would allow the PUB to meet maximum day demands in excess of the plant capacity. Maximum day capacity would then be 40 mgd plus the rate at which water could be removed from storage. This type of operation could provide several additional years of life to the PUB treatment system, delaying the need for further WTP expansion.

Aquifer Storage Recovery systems have been implemented for several utilities to work with both of the above situations. An ASR system stores water by pumping treated water into underground aquifers through wells. Because aquifers are typically very extensive, large volumes of storage are possible. It is typical to pump water into an ASR system for several months and later recover the same water for a similar time period. The rates at which water can be stored and recovered from an aquifer depend on the capacities and number of the ASR wells. The length of time water can be left in storage varies and is dependent on the native quality of the aquifer, aquifer properties, and regional groundwater



Source: Water Demand Records 1989 through 1994

Figure 2.3 PUB Typical Demand Yearly Variation

movement. Most ASR facilities have demonstrated successful storage durations of several months to several years.

The conceptual ASR application that appears beneficial to the PUB is to store treated water in the brackish aquifer beneath or in the vicinity of the existing WTPs. Depending on the results of a prototype test program, it should also be desirable to provide ASR storage in the north and/or west parts of the existing service area. These future areas would be preferably located at PUB elevated storage tanks. The reasoning for these suggested areas is discussed in more detail in Section 3, General Hydrogeology.

Water for storage would be Permit 1838 water that is diverted during the low demand months (November through about May), and treated using WTP capacity in excess of current demands. Depending on the water demands and availability of the Permit 1838 water, it is feasible that 6,000 acre-feet or more treated water could be stored during this time. Recovery of this stored water during the peak demand season would serve two purposes. First, the recovered water would reduce the use of the PUB firm water rights during that year. Secondly, the recovered water would supplement WTP flows during peak demand months and allow the upgraded WTPs to meet maximum day demands in excess of their capacities.

A preliminary analysis indicates that an ASR wellfield with a capacity to pump about 20 mgd for short time periods could provide the above requirements. Water produced for storage could probably be injected into the ASR wells at combined rates of about 10 to 15 mgd, and recovered at rates of about 15 to 20 mgd. Depending on the year's actual water supply and demands, around 6,000 acre-feet of water could be stored and recovered.

A preliminary balance of water supply, ASR operations, and water demands indicate the ASR operation would benefit the PUB system operation most effectively if integrated thoroughly with the Permit 1838 water. This entails not only using the Permit 1838 water for injection but also for direct treatment and distribution when possible. Although this type of operation involves some risk without the ASR component, with an ASR system the risk is greatly reduced. If insufficient water is requested from Falcon Reservoir, and the Permit 1838 water is not available, water stored in the ASR system can provide the required flows. These three components working together should be capable of meeting PUB's projected water demands through about the year 2011 and possibly beyond.

Section 3
General Hydrogeology

Hydrogeologic Zones of Interest

The Brownsville area lies in the area of the Gulf Coastal Plain which is characterized by flat, low-lying topography that slopes toward the Gulf of Mexico. The geologic materials present in the area consist of recent alluvium from the Rio Grande river, underlain by Pleistocene and Pliocene gravel, sand, silt, clay deposits. These deposits belong to the Beaumont and Lissie Formations, the Uvalde Gravel, and the Goliad Formation.

For the purposes of identifying applicable hydrogeologic zones for ASR applications, only about the upper 1500 feet of sediments were considered. Through this depth range, the geologic units were divided into three potential hydrogeologic zones. These are the Gravel, the Intermediate, and the Lower Zones.

The Gravel Zone exists within the alluvial deposits and consists of unconsolidated gravels with interbedded fine sands. The Gravel Zone usually occurs between the depths of approximately 150 to 225 feet below ground surface, and ranges from zero to about 50 feet in thickness. The Gravel Zone is erratic in occurrence and may not be encountered in all locations. Based on previous drilling work in and around the study area, the Gravel Zone may only be encountered at about 50 percent of the sites investigated. Where the Gravel Zone is not encountered, the zone typically consists of very fine to medium sands with some clay and silt.

Of the three zones, the hydraulic conductivity and transmissivity of the Gravel Zone is the best defined. The Gravel Zone is the shallowest hydrogeologic unit with the best water quality and yield and therefore is the most explored unit. In areas where tests have been conducted, hydraulic conductivities range from about 50 gpd/ft^2 to about 4,000 gpd/ft^2. Transmissivities range from about 4,000 gpd/ft to about 80,000 gpd/ft. Depth to static water levels in the Gravel Zone are reported shallow ranging from about 10 to 30 feet below land surface.

The Intermediate Zone is composed of geologic materials below the Gravel Zone. This zone is usually above the older Pleistocene deposits and typically consists of interbedded fine to medium sand, silt, clay, and sometimes minor amounts of gravel. In some areas, this zone may be composed of Pleistocene material. The Intermediate Zone generally extends from about 200 to 400 feet below ground surface. Very little information exists on this zone and its typical thickness is not well known. The zone is considered to exist from the base of the Gravel Zone to the top of the Lower Zone and may average about 200 feet in thickness.

The hydraulic characteristics of the Intermediate Zone are not well documented and no pumping test data was found. However, review of the limited available geophysical logs and specific capacity information indicate hydraulic conductivities around 150 gpd/ft^2 may be representative of fine to medium grained sands in this zone. This may place transmissivities at around 10,000 gpd/ft if wells were completed in the sands. If gravels are found in this zone, hydraulic conductivities may equal those of the Gravel Zone. Little information is available on the depth to water in this zone but the information reviewed indicates this zone approximates the depth to water in the Gravel Zone.

The Lower Zone exists from the base of the Intermediate Zone to well past 1500 feet, the lower limit for this investigation. This zone consists of the Beaumont and Lissie formations, the Uvalde Gravel, and the Goliad Formation. The sediments are interbedded layers and lenses of gravel, sand, silt, and clay.

No site-specific hydraulic information is available for the Lower Zone as this zone contains poor water quality and has not been investigated for groundwater production. However, based on pumping tests conducted in this zone in Willacy and Hidalgo Counties, hydraulic conductivity may range from 80 to 150 gpd/ft^2. Transmissivities may be on the order of 40,000 gpd/ft if enough of this material is screened. No site-specific information was available on the depth to water in this zone, but considering regional information, water levels are thought to be less than 30 feet below ground surface.

Water Quality

Water quality in the Brownsville area is generally mineralized and varies with location and depth. The freshest groundwater occurs to the northwest of Brownsville in the Gravel Zone. Mineralization increases to the east and south, and increases with depth. Total dissolved solids (TDS) in the Gravel Zone beneath Brownsville range from 2,500 mg/l to over 12,000 mg/l. Groundwater samples obtained from exploratory wells near WTP No. 1 and No. 2 during the 1970s reported TDS concentrations of 3,130 mg/l and 9,070 mg/l, respectively.

Water quality in the Intermediate Zone is not well known. Based on the limited data, it is suspected that the water quality in the Intermediate Zone is similar to that in the overlying Gravel Zone, but somewhat more mineralized. Water quality in the Lower Zone is also not well known. Based on the limited data, water quality in the Lower Zone may exceed 20,000 mg/l in TDS.

ASR Considerations

The information presented above and in Appendix 2 of this report summarize the existing information regarding the hydrogeology of the Brownsville area. Because of the poor water quality exhibited by the area's native groundwater, little exploration was previously conducted and the existing information is sparse. However, the ASR concept has been successfully implemented in areas with mineralized groundwater conditions and it is not unusual to find limited existing data on these types of areas.

ASR facilities operate by storing fresh water in existing aquifers. When the native water in the aquifer is of poor quality, the ASR wells must be designed to displace the native water during injection so as to result in a minimum amount of mixing between the native and injected waters. Considering unconsolidated aquifers such as in Brownsville, this has been most effective in either very uniform aquifers, or in relatively thin permeable units confined above and below by clays. From the information reviewed for this area, it appears promising that a confined permeable unit may be located in either of the three hydrogeologic zones identified.

The future ASR facility for Brownsville must be capable of storing water available through Permit 1838, which will comprise a relatively large volume of water over a relatively short period of time. In the previous section, an ASR recovery capacity of 19 mgd was estimated to help the PUB meet water demands through the year 2012. In order to maximize the ASR benefit for the PUB and reduce capital costs, an ASR storage zone that will support wells with higher capacities should be considered. The above hydrogeologic information suggests that either the Gravel Zone or the Lower Zone could support wells with individual capacities of around 700 gpm to 1000 gpm, where the Intermediate Zone would probably result in lower capacities.

An important consideration for an ASR system is the native water quality which exists in the aquifer. Storage of fresh water in poor quality aquifers always results in some degree of mixing between the native and stored waters. Typically, water initially recovered from an ASR well exhibits quality similar or almost identical to that injected. At some point during recovery, which is dependent chiefly on aquifer behavior, mixing with the native water is usually observed and the percentage of native water in the recovered water increases as recovery continues. It is important to note that native water mixing with the stored water typically decreases with successive ASR cycles and that in most operating ASR facilities the degree of mixing observed does not render the recovered water non-potable. However, because mixing of the waters does occur, the selection of the storage zone depth and location with the best native water quality needs to be considered.

It is also important to consider that although groundwater in aquifers moves generally very slowly, it still does move. Water stored in an ASR well moves out in the aquifer radially away from the well during injection. This creates a fresh water lens around the ASR well. Upon recovery of this water by pumping the well, the lens of fresh water moves back along the same path toward and out of the well through the well pump. Regional groundwater flow velocities work to move the stored fresh water lens and, if high enough, or if storage time is sufficiently long, will tend to move the lens laterally such that only a portion of it is recoverable.

A range of information relative to groundwater velocity has been presented for the Brownsville area based on the same data considered for this report. This information can be interpreted to indicate groundwater velocities are very high and fresh water storage would quickly move out of the area, or that fresh water storage could work quite well in the area. There is not enough reliable information on the potentiometric surface in the area to accurately confirm either interpretation. It would also be very costly and time consuming to install the required monitoring wells to define this further.

Many anomalies exist in the water level data that was reviewed for this work and certain data points do not appear to fit an explainable pattern. The existing data is limited to only a few points and only a couple of these points are in the study area. It is possible that errors exist in some of these measurements or in other measurements. It is certain that more work is needed in this area and reliable predictions on groundwater velocities cannot be made with the available information.

Section 4
ASR Conceptual Applications

General ASR Applications

Aquifer Storage Recovery (ASR) systems can be applied to water utilities in many different ways. Potential applications include the storage of raw, treated, and reclaimed water. Storage zones vary from very brackish aquifers containing sea water to fresh aquifers that have been depleted over many years of over pumping. The concept can be applied to many situations requiring large volume water storage where: 1) the existing water is suitable for storage, and 2) a suitable aquifer exists.

Raw water ASR applications may serve a utility or agricultural practice where a supply of raw water varies seasonally in quantity or quality, such as seen in many rivers. During high river flows, water can be diverted and stored to be used later during low flow periods. This is similar to the situation seen in Brownsville where water available from Permit 1838 is available during high river flows. Raw water storage in ASR wells for the PUB would be an attractive alternative if it could be done cost effectively.

The PUB raw water is seen to be very high in turbidity and high in dissolved minerals. The high turbidity poses a problem because injection of water into wells with high particle content plugs most aquifers very quickly. Additionally, geochemical work conducted on PUB raw water indicates the raw water is at or near equilibrium with respect to calcium-carbonate and calcium-sulfate. Small increases in pH that may occur during aquifer storage may cause mineral precipitation. Potential precipitation of minerals combined with the high turbidity levels indicate raw water storage would require at least some pretreatment before ASR storage. For these reasons raw water storage for the PUB does not appear to be a cost effective alternative.

Many existing ASR facilities utilize fresh water storage in brackish aquifers. Typically, the utilities experience a seasonal water demand that is high during the summer months and low during the winter. Additionally, if the utilities are experiencing growth in water demands, they are faced with expanding their water supply facilities to meet the high summertime demands. For this situation, ASR storage can potentially reduce the need to expand supply facilities by providing seasonal and possibly long-term storage of treated water. Water is typically injected into the brackish aquifer during the winter for later use during the summer. In most cases the recovered water can be used directly with only disinfection, thereby, supplementing the treatment plant flows. In these applications, the application of an ASR system can be used to meet growing peak demands and reduce the need for plant expansion. Typically, ASR systems can be implemented for much less cost than a plant expansion to meet the same peak demand.

It is also possible to utilize an ASR system to provide storage of treated water supplies for longer durations than over one annual season. The storage volume of typical aquifers is very large and compared to typical utility use may be considered almost unlimited in many locations. Utilities facing growing water demands and long-term supply shortfalls have considered long-term water banking in overdrafted aquifers to save water for future years. This is common in some western states, California in particular, where overdrafted groundwater basins can be replenished through groundwater recharge. An ASR system has also been implemented in Kerrville, Texas, to maintain an adequate volume of available groundwater in the aquifer for future drought years.

Many of the ASR applications involving long-term storage of water in aquifers are systems recharging freshwater aquifers. In these systems, the important criteria are the aquifer water levels and the recharge being structured to replenish aquifer volumes, as demonstrated by the water levels. It is not as critical that the water recovered be the same water that was injected because all the water is essentially fresh.

Long-term storage of treated water can also work in brackish or poor quality aquifers such as the PUB system. Additional criteria must be considered for these systems because of the undesirable nature of the native groundwater. It will be important that the systems can recover essentially the same water that was injected, or at least with a minimum amount of native water mixing.

Mixing of injected water with native water is evidenced by the recovered water containing certain levels of the dissolved constituents that were present in the native water. For the PUB, this would be high levels of certain ions such as chloride and sulfate. The mixing referred to during ASR storage can occur through several mechanisms. Three of significance are: 1) The injection process, where treated water is pushed through the aquifer matrix and rinses off the aquifer grains, 2) Through diffusion and/or density stratification while the injected water is idle in the aquifer and the edges of the injected water are in contact with the native water, and 3) Through movement of the stored water away from the ASR well due to regional groundwater movement.

The first mechanism contributing to mixing is aquifer specific and typically improves with several ASR cycles. The effect of several ASR cycles provides a flushing mechanism over the aquifer grains which reduces the mixing effect with system use. The second mechanism is a function of the aquifer, the time the injected water spends stored in the aquifer, and the difference in quality between the injected and native water. The third mechanism is a function of the hydrogeology of the area and can be an important controlling factor in the long-term storage of the injected water.

At this point, it is not possible to determine a realistic length of time treated water could be stored in the aquifers underlying Brownsville. The available information regarding the hydrogeologic conditions is based on very limited data and is subject to interpretation. Some of the data indicates the groundwater velocities may be high in certain aquifer zones and, if true, may limit the effective length of time for underground storage in these zones. For other zones, data is not available to estimate groundwater velocity. In order to determine a useable storage time in Brownsville area aquifers, a test program will be required and actual field testing of the effects of time on the stored water will have to be conducted.

Conceptual ASR Application For Brownsville

The PUB water system is expected to benefit from two of the above ASR applications. First the PUB is projected to require additional raw water supplies by the year 2003 because raw water demand is projected to exceed its firm water rights by that year. The PUB, however, can obtain raw water through its Permit 1838 which allows the PUB to divert additional water from the Rio Grande when river flows equal or exceed 25 cfs.

One use of ASR for the PUB is to store treated water available from Permit 1838 for use later in the year. Water obtained under this permit could be treated and stored, and later used to supplement the PUB's firm water rights. A water balance constructed using projected monthly demands, WTP capacity at 40 mgd, annual firm raw water rights of 33,973 acre-feet, and Permit 1838 water indicate that the PUB system could probably operate through the year 2012 using a fully applied ASR facility in conjunction with Permit 1838 water.

The second benefit of ASR for the PUB will be the ability of an ASR system to meet peak demands on water treatment facilities. The PUB WTPs are being expanded to a combined maximum capacity of 40 mgd. Projected demands on the PUB system indicate the maximum day demand will exceed the WTPs' capacity during the year 2005. A properly operating ASR system could provide recovered water during these maximum day demands and allow the PUB system to safely meet demands in excess of 40 mgd. The water balance conducted indicates that during the year 2012 the maximum day demand is over 49 mgd and this demand is met through a combination of ASR recovery and WTP operation.

The buildout ASR system that was conceptualized herein is based only on existing data and was developed prior to any field testing of the ASR operation. Exploratory drilling, analysis, and ASR testing will be required prior to finalizing this conceptual design and it is possible the design presented herein may change.

The ASR system that, at the present time, appears to be best suited for the PUB will be a system of wells and piping that operates at average injection and recovery rates of 10 mgd and 12 mgd, respectively. The system will be capable of handling maximum rates higher than this in order to take advantage of the Permit 1838 water which may only be available in large quantities for short periods of time. The maximum rates for injection and recovery of the conceptual ASR system are approximately 15 mgd and 19 mgd, respectively.

The conceptual system may operate most effectively if located in approximately five locations in Brownsville. Two of the locations could be WTP No. 1 and No. 2. At each of the WTPs, 5 or 6 ASR wells could be located. The other 3 locations may be PUB elevated storage tanks. At each of the elevated storage tanks, 1 or 2 ASR wells could be located. The conceptual ASR system is listed in more detail in Table 4.1.

Table 4.1 Conceptual ASR System Configuration

WTP No. 1 and WTP No. 2 Sites (each)

Number ASR Wells	6 total, 5 firm
Injection Capacity Each Well	800 gpm / 1.1 mgd
Recovery Capacity Each Well	1,000 gpm / 1.4 mgd
Total Site Firm Injection Capacity	4,000 gpm / 5.7 mgd
Total Site Firm Recovery Capacity	5,000 gpm / 7.1 mgd
Average Injection Operation	2,660 gpm / 3.8 mgd
Average Recovery Operation	3,220 gpm / 4.6 mgd

Capabilities

Treated water injection from WTP
Treated water recovery to WTP clearwell
Alternative treated water recovery to high service piping
Recovery to raw water intake piping
Waste recovery to sanitary sewer

3 Elevated Tank Sites (each)

Number ASR Wells	2 total, 1 firm
Injection Capacity Each Well	800 gpm / 1.1 mgd
Recovery Capacity Each Well	1,000 gpm / 1.4 mgd
Total Site Firm Injection Capacity	800 gpm / 1.1 mgd
Total Site Firm Recovery Capacity	1000 gpm / 1.4 mgd
Average Injection Operation	550 gpm / 0.8 mgd
Average Recovery Operation	650 gpm / 0.9 mgd

Capabilities

Treated water injection from Distribution Piping
Treated water recovery to elevated tank
Waste recovery to sanitary sewer

Total ASR System

Number ASR Wells	18 total, 13 firm
Injection Capacity Each Well	800 gpm / 1.1 mgd
Recovery Capacity Each Well	1000 gpm / 1.4 mgd
Total System Firm Injection Capacity	10,400 gpm / 14.9 mgd
Total Site Firm Recovery Capacity	13,000 gpm / 18.6 mgd
Average Injection Operation	7,000 gpm / 10.0 mgd
Average Recovery Operation	8,400 gpm / 12.0 mgd

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Injection flows to the ASR wells at either of the WTPs would likely be transmitted off the high service discharge piping leaving the WTP. Recovery flows from the ASR wells could be returned to the WTP, either upstream of, or into the clearwell to take advantage of mixing in the tank and existing chlorination facilities. Depending on WTP hydraulics at the time, it could also be possible to pump the ASR recovered water directly into distribution piping off the high service discharge. The ASR facilities at the WTP would also include a recovery return line to pump water back through the treatment process. This line would probably be directed back to the raw water intake piping. Additional piping from the ASR facility to the sanitary sewer or other waste area may be required for more extensive well cleaning or testing. These requirements will be evaluated during initial ASR testing and can not be accurately estimated at this point.

The ASR facility located at the PUB elevated tanks would consist of 1 or 2 ASR wells at each site and would receive injection flows from the distribution system piping near each tank. Recovered flows would be directed back into the tank to again allow the recovered water to blend with the system water at that point. It will be necessary to provide a discharge line to sanitary sewers at each elevated tank ASR system. This piping would be used to discharge initial flush water and water produced during periodic backflush of the wells.

Another advantage for the PUB of developing the ultimate ASR system at several locations is the flexibility in ultimate construction. The PUB would be well advised to develop the ASR system in stages, adding capacity at different locations as needed by existing distribution system hydraulics and other system needs. Following this path, the PUB can work out specific design issues on the first sites, and add sites as needed through the planning period.

Section 5
ASR Recommendations and Proposed Implementation Plan

Summary of Findings

The work conducted under the ASR Investigation indicates that an ASR system could substantially benefit the PUB. An ASR system could provide a means to utilize Permit 1838 water and extend the life of raw water supplies. General water balance calculations conducted in this report indicate this could be through the year 2012. Additionally, the implementation of an ASR system provides the benefit of increasing the ability of the PUB system to meet maximum day treated water demands. During the year 2012, the PUB system with a 40 mgd WTP capacity, working with an ASR system was simulated to meet a maximum day demand of over 49 mgd.

One of the required criteria for an ASR system is the existence of a suitable aquifer for ASR storage. This important part of the investigation was completed based on existing information which is not in abundance for the Brownsville area. Because the groundwater supplies are of poor quality, little previous work has been done to document the hydrogeologic conditions. The information that does exist indicates a suitable storage zone for ASR purposes may exist in one or more of three potential aquifer zones. Each of these zones is thought to have different hydraulic characteristics, water quality, and areal variations. It was not possible to verify which zone may best serve ASR purposes, or if any of the zones will perform as required for the PUB.

However, it is very positive that three potential aquifer zones are present beneath Brownsville. Based on the limited information, it appears that overall adequate aquifer capacity probably exists, the confined nature of the aquifer and shallow water levels are positive aspects for ASR implementation, and interference with existing users should not be an issue.

The hydrogeologic information that is uncertain at this time includes the existence of aquifer capacity at the required locations, for example, the WTPs or elevated tank sites, regional groundwater movement, and levels of stored water mixing and interaction with native groundwater during ASR storage. In order to obtain the above information and therefore determine ASR performance, a test program is required.

Recommendations

Aquifer Storage Recovery could provide several benefits to the PUB at a fairly reasonable cost. The estimated system costs for the conceptual ASR system outlined herein are about $10.8 million. For this investment, the PUB would be able to meet projected demands through about the year 2012. Additionally, the ASR system development includes several sites and a modular approach to development. Depending on the results of the test program and ASR system development, some of these sites may not be needed. ASR system development can be flexible and be adjusted to fit the best application for the PUB.

Because ASR has the potential to be of substantial benefit to the PUB, it is recommended to proceed with the ASR investigation and conduct a test drilling program. The drilling program should be structured to investigate the three potential ASR zones, and to conduct the testing necessary to estimate if adequate ASR storage properties exist any of the zones.

Interest in the ASR concept by the State of Texas has resulted in the Texas Water Development Board (TWDB) offering the state owned drilling rig services for the recommended test drilling program. It is further recommended to continue negotiations with the TWBD for assistance with this program, which will result in substantial drilling cost savings for the PUB.

It is recommended that the test drilling program be generally conducted as follows:

- Finalize agreement with the TWDB for the use of drilling rig, crew, geophysical logger, coring equipment, and other required equipment. Agreement should include the construction and testing of at least two 450-foot borings and one 1,500-foot boring at selected sites. The selected sites will likely include the two WTPs. The 1,500-foot monitoring well will be constructed at the site selected for later ASR prototype construction. Consider if an additional 450-foot monitoring well should be constructed at an elevated storage tank site.

- Select sites for the test drilling at WTP No. 1 and WTP No. 2. It is expected that the site for WTP No. 1 will be about 1,000 feet south of the WTP in the existing park area. The site at WTP No. 2 is expected to be adjacent to the WTP facilities, on the southwest side in the open or grassy area. Final site selection should be made to minimize piping distances for a potential future ASR test facility for sanitary sewer, raw water, and treated water piping.

- Begin test well construction, including geophysical logs on mudded boreholes. Construct two 450 foot monitoring wells first to investigate existence of the Gravel Zone at WTP sites. If the Gravel Zone is unsuitable at either WTP, consider a 450 foot monitoring well at a selected elevated tank site. Construct 1,500 foot monitoring well. Collect geologic cores from promising aquifer zones and conduct geochemical analysis.

- Conduct pumping tests on monitoring wells. Run water quality related geophysical logs. Collect native groundwater samples for laboratory analyses.

The completion of the above test program will provide the PUB information regarding the suitability of the aquifer zones for ASR storage. This will include direct measurements of native aquifer water quality, aquifer hydraulics including determination of recharge and recovery rates, analysis of potential geochemical reactions using obtained aquifer cores and native groundwater, and verification of potentiometric surface levels. The interpretation of these results will further the understanding of ASR feasibility for the PUB and will be used to determine if ASR prototype testing should be conducted at the recommended location.

Appendix 1

PREPARED FOR: Brownsville PUB

PREPARED BY: CH2M HILL

DATE: August 9, 1995

SUBJECT: ASR Feasibility Investigation
Surface Water Assessment

PROJECT: 116700.D0.ZZ

Introduction

The surface water assessment component of this project is divided into five elements:

- Existing Supply System
- Existing and Future Demands
- Surface Water Rights
- Water Quality
- General ASR Application

Existing Supply System

The Brownsville Public Utility Board (PUB) obtains raw water for treatment from the Rio Grande River, adjacent to the City in south Texas. The PUB operates a potable water supply system comprised of raw water pumping and storage facilities, and two water treatment plants. Raw water pumping facilities are located along the Rio Grande River, near PUB Water Treatment Plant (WTP) No. 1. The river pumping station has a maximum capacity of 80.2 million gallons per day (mgd). This water is lifted directly into a surface reservoir with a capacity of about 27 million gallons, and then pumped to the PUB's two water plants. Water Treatment Plant No. 1 is located adjacent to the surface reservoir. Water Treatment Plant No. 2 is located east of the river pumping station, near the northeast end of the City of Brownsville. Raw water is pumped to WTP No. 2 through a 36-inch, 5 mile long pipeline, which is supplemented as needed by the resaca system. The pipeline is now used as the primary means of transmitting raw water to WTP No. 2.

The rate at which water is produced and pumped from the two WTPs to satisfy customer demand is typically referred to in terms of maximum day and average day demands. The maximum day demand as used herein refers to the maximum volume of water produced and pumped from the WTPs over the period of one day during a given month or year. Maximum day demand will generally be presented in this report in the units of million gallons per day (mgd).

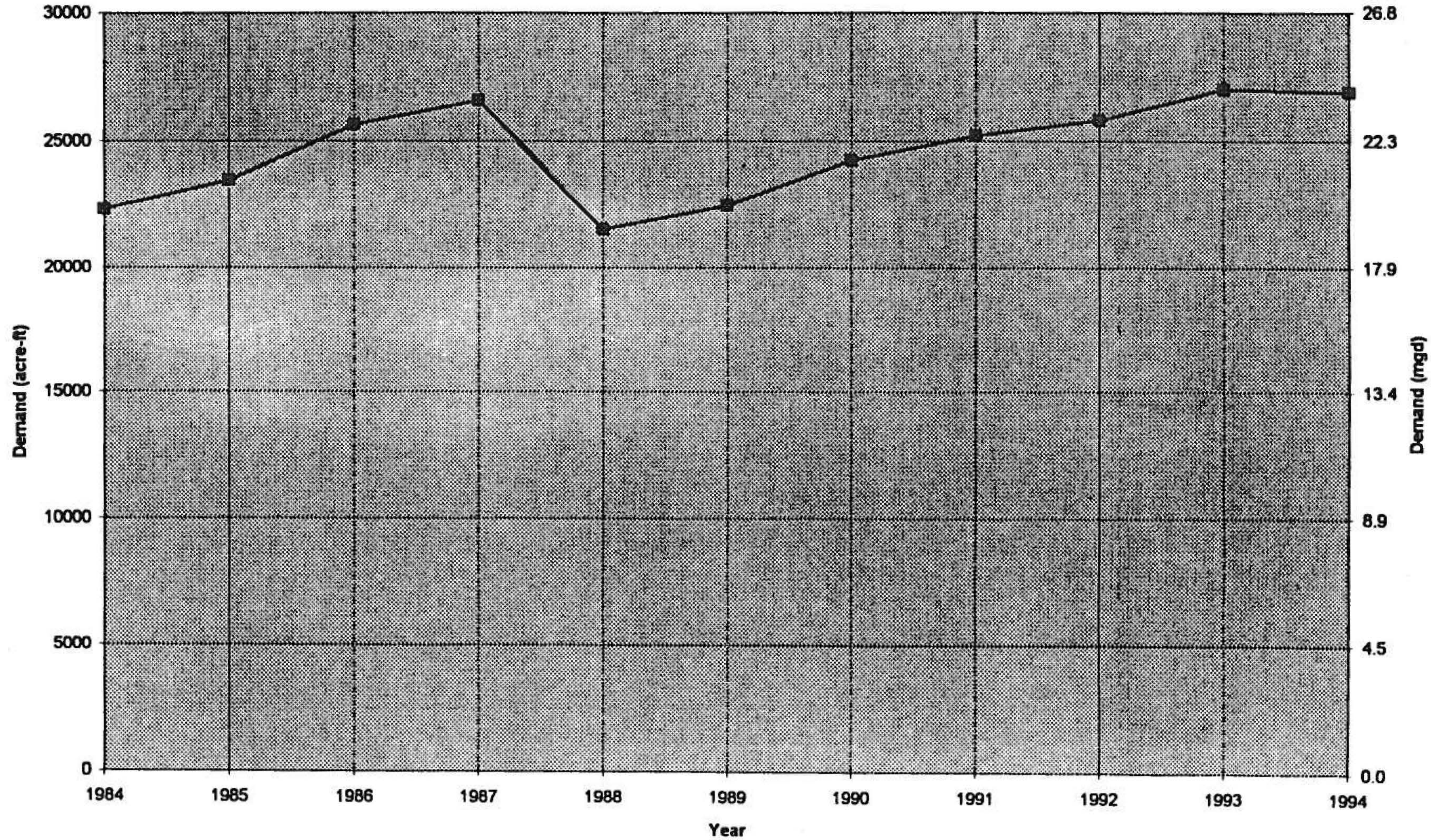

Figure 1 PUB Historic Annual Raw Water Demand

The average day demand referred to in this report is the average production of water from the two WTPs over a given month or year. This demand is typically expressed as a rate in mgd, but can also be expressed as a total volume, in acre-feet for example, over the time period. It is important to note that although water demand can be expressed as rate of water production over a day's time, production rates are seldom this constant. Water production rates vary over a given day to as much as two or more times above or below the maximum day demand for shorter periods. The historical average and maximum day treated water demands over the time period of 1989 through 1994 are presented with the raw water demands for that time period in Figure 2.

The variation in water demand over the course of the year is another important factor in assessing the applicability of ASR in a given water system. The ASR concept utilizes large volume storage of treated water to supplement water supplies. Water system supply and demand variability are used to plan future ASR operation.

Water demands on the PUB's system over the period of 1989 through 1994 were used to estimate the typical variation in water demands over a year. Monthly average and maximum day treated water demands were used to calculate a ratio of monthly demand to average annual raw water demand typical for the time period. Raw water demand was included in the calculation for comparison purposes. The calculated values are shown in Figure 3.

The demand factor shown in Figure 3 is a multiplier that can be used to obtain values for the illustrated water demands. To interpret the figure, multiply the corresponding demand factor times the average annual treated water demand to obtain the required value. For example, if the average annual treated water demand for a given year was 30 mgd, the expected average monthly treated water demand for June would be 30 times about 1.1, or 33 mgd.

The demand pattern shown in Figure 3 indicates typical PUB water demands are highest during the period from June through September. Low demand season typically occurs during the period from November through April. A slight peak in maximum day demand occurs during December, probably due to the Christmas holidays. It is important to note that average raw water demands are typically less than the treated maximum day demands. This indicates the need to either increase the raw water pumpage appreciably during maximum day demand periods, or rely on storage. Because the PUB system does not have an abundance of storage, frequent changes in raw water pumping rates appear to be required. An ASR system could serve to significantly reduce the variability of these pumping rates over the course of a season.

The future demands for raw water have been estimated by the Brownsville PUB in their Water Supply and Conservation Report, which has been accepted by the Texas Water Development Board (TWDB) as satisfying the requirements of a water conservation plan. These projected demands (mid-level) are shown in Figure 4 along with the most recent TWDB demand projections.

The demand projections developed by the PUB and the TWDB are approximately the same for the year 2000, but diverge after this point. The TWDB does not typically project raw

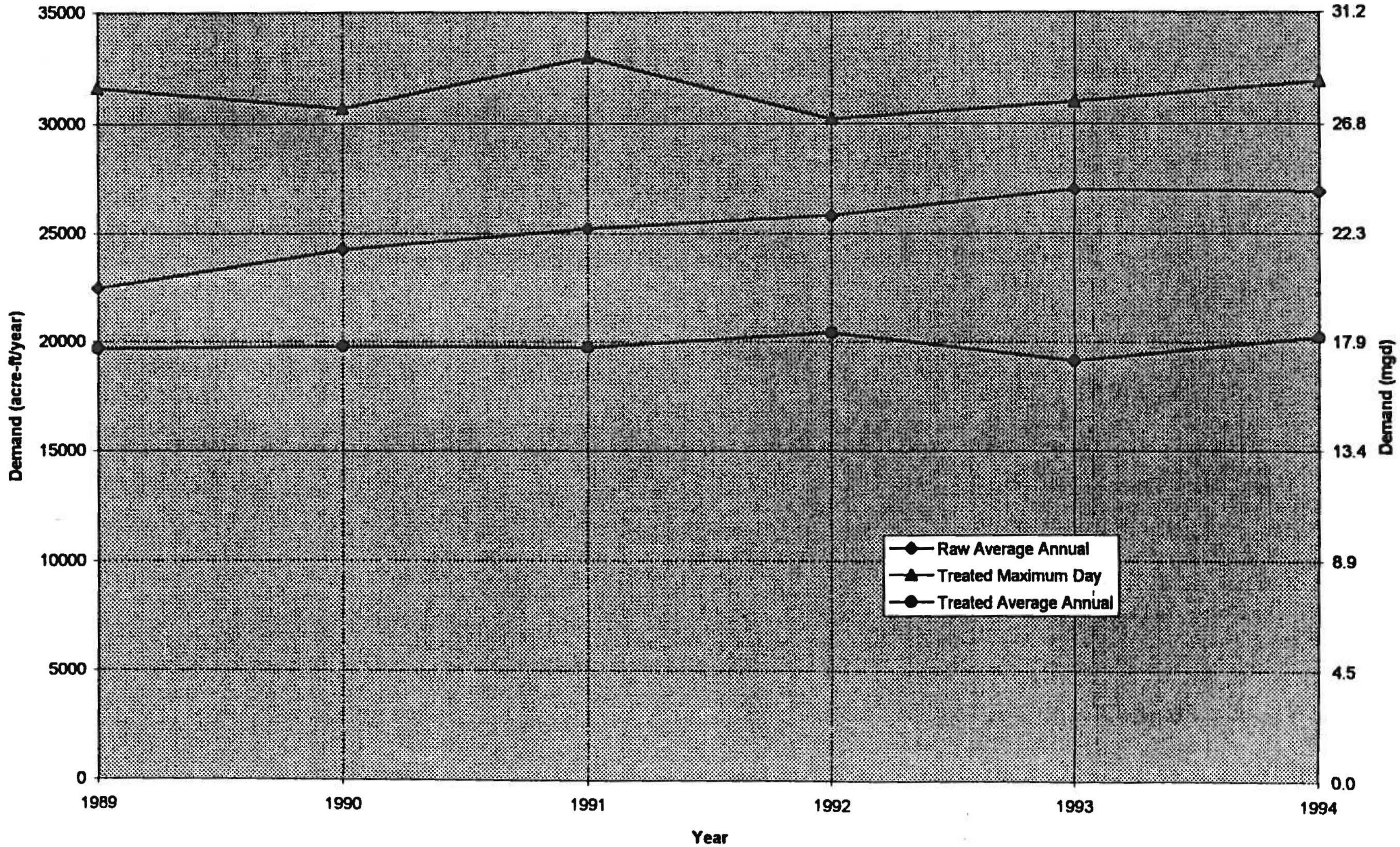

Figure 2 PUB Historic Raw and Treated Water Demand

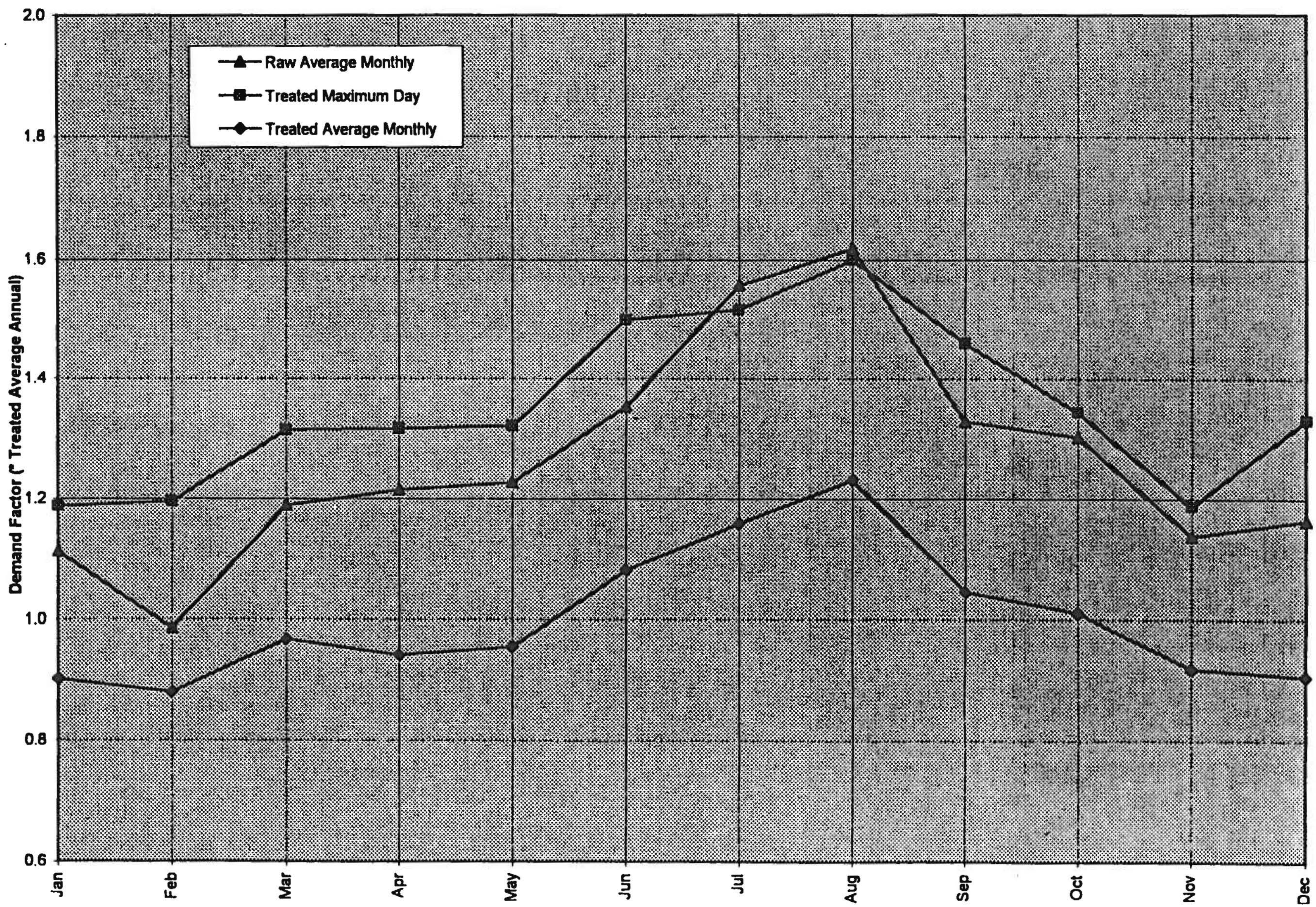

Figure 3 Seasonal Water Demand Variation

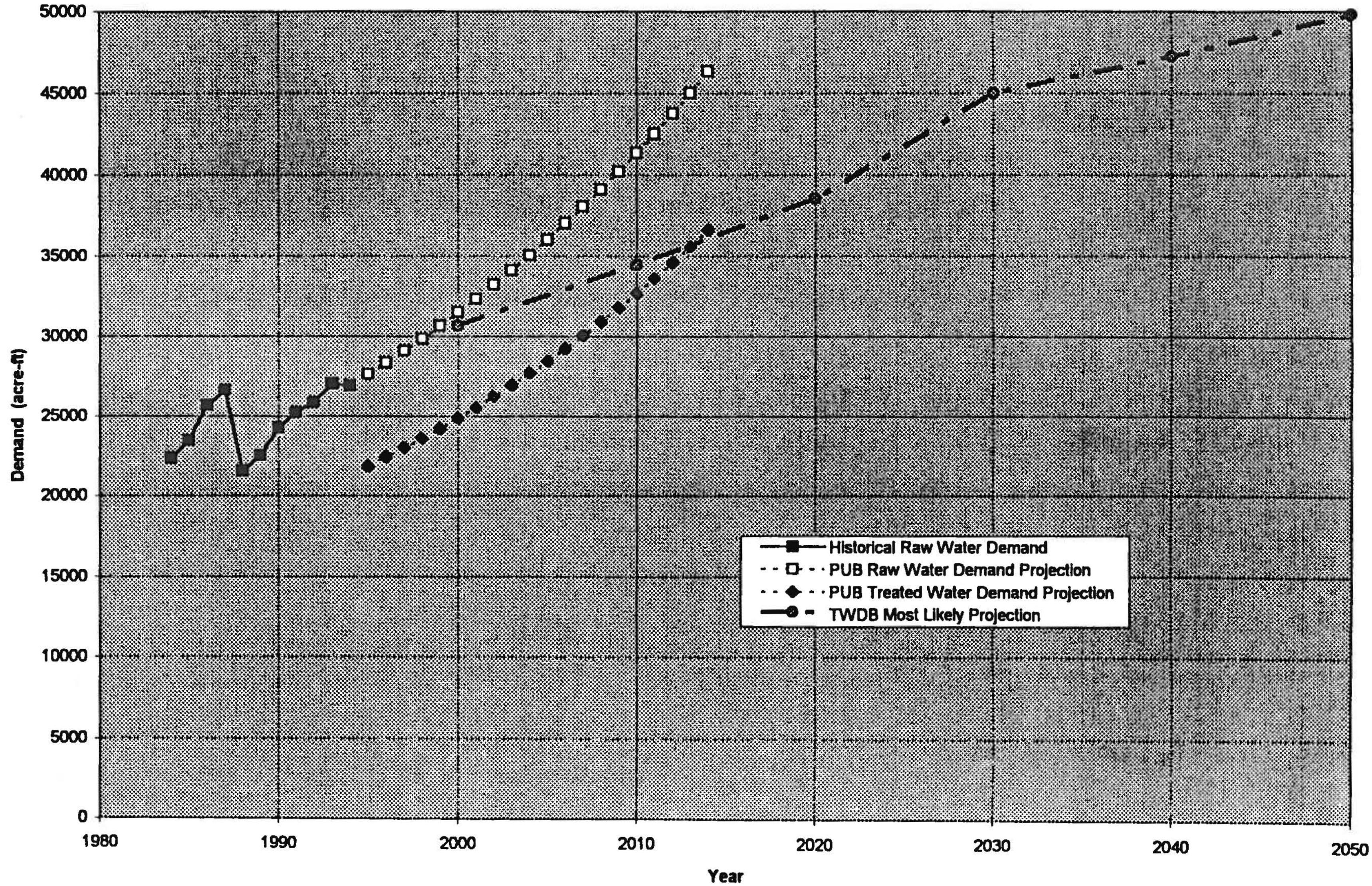

Figure 4 Projected Average Annual Water Demand

water demand but projects municipal demand based on per-capita water use and population projections. Since the Water Supply and Conservation Report of the PUB has been accepted by the TWDB, the PUB estimates of future demand should be used. The PUB estimates power plant, resaca irrigation use and raw water losses will continue at 21 percent, so the treated water demand is calculated at 79 percent of the raw water demand.

Surface Water Rights

Surface water from the Rio Grande is the current source for the City of Brownsville's raw water supply. The amount of raw water available to Brownsville is dictated by the city's water rights from the Rio Grande which were first established in the court case, The State of Texas v. Hidalgo County Water Control and Improvement District No. 18, 443 SW 2d 728 (1969). This case, also known as the Lower Rio Grande Valley Water Case, defines the criteria for the distribution of the United States' share of Rio Grande water to all claimants downstream from Falcon Dam. Besides establishing water distribution criteria, the outcome of this court case provided the initial water rights for the City of Brownsville.

Brownsville's existing raw water supply is comprised of three sources: Rio Grande Water Rights, the Brownsville Irrigation and Drainage District (BIDD) Contract, and the El Jardin Agreement. The second source, the BIDD Contract, was initiated in 1978 and allows PUB to purchase 5,000 acre-feet of raw water per year through 1998. In 1991 an agreement between PUB and the El Jardin Water Supply Corporation was established and required El Jardin to supply PUB with raw water in exchange for credit towards their water treatment charges. The existing raw water supply sources are summarized below in Table 1.

Table 1
Brownsville's Raw Water Supply

Source	Raw Water Available (Acre-Feet)
Rio Grande Water Rights	(Municipal Basis)
Municipal	25,824,236
Industrial	1,220
Irrigation (713 acres Class A)	891
BIDD Contract	5,000
El Jardin Agreement	1,038
Total	**33,973**

During low to average flow occurrences in the Rio Grande, water users in both the United States and Mexico provide requests to the International Boundary and Water Commission (IBWC) for release of stored water from Falcon Reservoir. The United States diverts water from various locations that extend along the lower boundary of the Rio Grande.

The TNRCC administers and processes the United States' requests for releases to meet the municipal, industrial, and agricultural demands of users in the Rio Grande Valley from the conservation pool in Falcon Reservoir through the Rio Grande Watermaster. The Rio Grande Watermaster accumulates the requests and provides a total daily request for water releases from Falcon Reservoir to IBWC who operates the reservoir.

For the users located below Falcon Dam, a series of seven reaches along the river are utilized by the Rio Grande Watermaster to project the time required for the requested diversions to meet their respective locations. Each reach is equivalent to one day of travel time from Falcon Reservoir. Brownsville is in the last reach or seven days travel time from Falcon. In addition, IBWC provides the Watermaster with instantaneous data that corresponds to particular streamflow velocities along the river and the amount of water stored in the Anzalduas Reservoir.

Under the current rules and regulations of the TNRCC, the Rio Grande Watermaster accounts for all diverted water to the United States from the Lower Rio Grande. Based upon existing water rights, individual storage accounts are charged for the actual amount of water diverted from the river. On the other hand, periods of high flow can occur during flood spills, favorable runoff conditions, or releases from upstream reservoirs and are often referred to as "no-charge pumping" periods. The Rio Grande Watermaster determines when a no-charge pumping period can effectively be declared. Based upon its availability, water from the Lower Rio Grande can then be diverted by authorized water rights holders without having their annual water use and storage accounts charged.

As a result of the Lower Rio Grande Valley Water Case, Brownsville's acquired water rights include 21,840 acre-feet for municipal use, 1,220 acre-feet for industrial use, and 713 acres of Class A irrigation rights. The water rights allocated for industrial use are specifically for PUB's Silas Ray Power Plant. Brownsville's irrigation water rights (713 acres) are approximately equivalent to 1,783 acre-feet. Since the Lower Rio Grande Valley Water Case, Brownsville's municipal water rights holdings have increased to 25,824.236 acre-feet. This municipal water rights figure is based upon the Rio Grande Watermaster's (TNRCC) account for the City of Brownsville. Table 2 summarizes the City of Brownsville's current account for municipal water rights that is on file at the Rio Grande Watermaster's office in McAllen.

In addition to these firm commitments for water rights, the PUB holds Permit 1838 which authorizes the PUB to divert up to 40,000 acre-feet annually of excess Rio Grande water from the Brownsville Navigation District. Excess flow is defined in the permit as periods when the flow of the Rio Grande at the Lower Brownsville Gauging Station is at least 25 cubic feet per second (cfs). This water is not guaranteed but is a potentially lucrative source of water available for long term injection in an ASR program. Flow records from the Rio Grande indicate that there are many times when the flow exceeds 25 cfs at this gauging station. According to the PUB Water Supply and Conservation Report, the analysis of historical river patterns indicate an average of 17,000 acre-feet of water should be available per year. Adding the total possible amount under the 1838 permit to the 33,973 acre-feet of firm and contracted water rights results in a maximum of 73,973 acre-feet of water that is potentially available during a given year. But, on average, 50,923 acre-feet are available.

The PUB requests water releases from Falcon Reservoir on a weekly basis and usually does this by estimating whether demand is increasing or decreasing and modifies the release rate from the previous week. The PUB uses the regulating reservoir located at WTP No. 1 and the resaca system to handle minor adjustments between the demand and the release rate. The PUB must closely manage its release requests. This is to ensure a sufficient supply of water while, at the same time, avoiding being changed for more water than can be used.

Table 2
Rio Grande Municipal Water Rights for the City of Brownsville

Date	Certificates	Amount of Water (Acre-Feet)
1969	Original Water Right Amount	21,840.00
10/8/88	23 Certificates of Adjudication (COA) Includes: 4 Amigoland Municipal Utility District Certificates #10 - 65 AF #11 - 37 AF #12 - 185 AF #13 - 35 AF Total 322 AF	2,277.946
5/15/90	COA 23-276 (75 AF Class A Irrigation)	37.50
8/28/91	COA 23-143 (50 AF Class B Irrigation)	20.00
4/27/92	COA 23-38 (244.675 AF Class B Irrigation)	97.87
5/26/92	COA 23-139 (125 AF Class B Irrigation)	50.00
12/8/92	COA 23-23 (629.80 AF Class B Irrigation) COA 23-181 (907.50 AF Class B Irrigation) COA 23-528 (430.00 AF Class B Irrigation) COA 23-836 (825.00 AF Class A Irrigation	1,199.42
5/26/95	COA 23-242 (125 AF Class A Irrigation) COA 23-190 (597.50 AF Class B Irrigation)	62.50 239.00
TOTAL		**25,824.236 AF**

Water Quality

The quality of the PUB's raw and treated water was documented through WTP records, State of Texas analyses reports, and through additional treated water sampling for this project. Routine analyses were obtained from the two WTPs that reported daily values of raw and treated water turbidity, alkalinity, and pH from about 1989 through March 1995. Final chloramine residual was also obtained for this time period and chloride values in the treated water from 1989 through June 1993 were obtained. This data is presented as plots in attached Figures 5 through 10.

The State of Texas periodically collects water quality samples for general minerals from the PUB's system for water quality analysis. A partial set of these records was obtained from the PUB and is summarized in Table 3.

To supplement the above water quality analyses, two treated water samples were obtained for complete analyses from WTPs No. 1 and No. 2 on July 31, 1995. The samples were analyzed for major cations and anions, organics, metals, some minor constituents, and selected other parameters. The results of these analyses is presented in the attached laboratory report forms.

The above water quality information indicates the Rio Grande water is generally very turbid and relatively high in dissolved solids. Additionally, substantial changes in the raw water quality occur and these do not appear to follow a set seasonal pattern. The WTPs are very effective in removing turbidity from the raw water, but the treatment process does not address most of the dissolved solids in the raw water. The result is a treated water that is relatively high in dissolved solids.

The implications of this observation, relative to an ASR application, is that little system blending can be counted on during ASR applications. Storage of the treated water in ASR wells will result in storing the treated water in contact with the native brackish groundwater. Recovery of the stored water will result in a blend of the stored water and the native brackish water. The degree of blending is a function of the aquifer properties. Some sites experience very little blending and others experience more. The impact of the PUB treated water being high in dissolved solids before aquifer storage is that use of the water upon recovery will be best if little blending with the native waters occurs. It is very possible that the final ASR facility will be able to operate in this manner. However, only a test program involving a prototype ASR well can determine this.

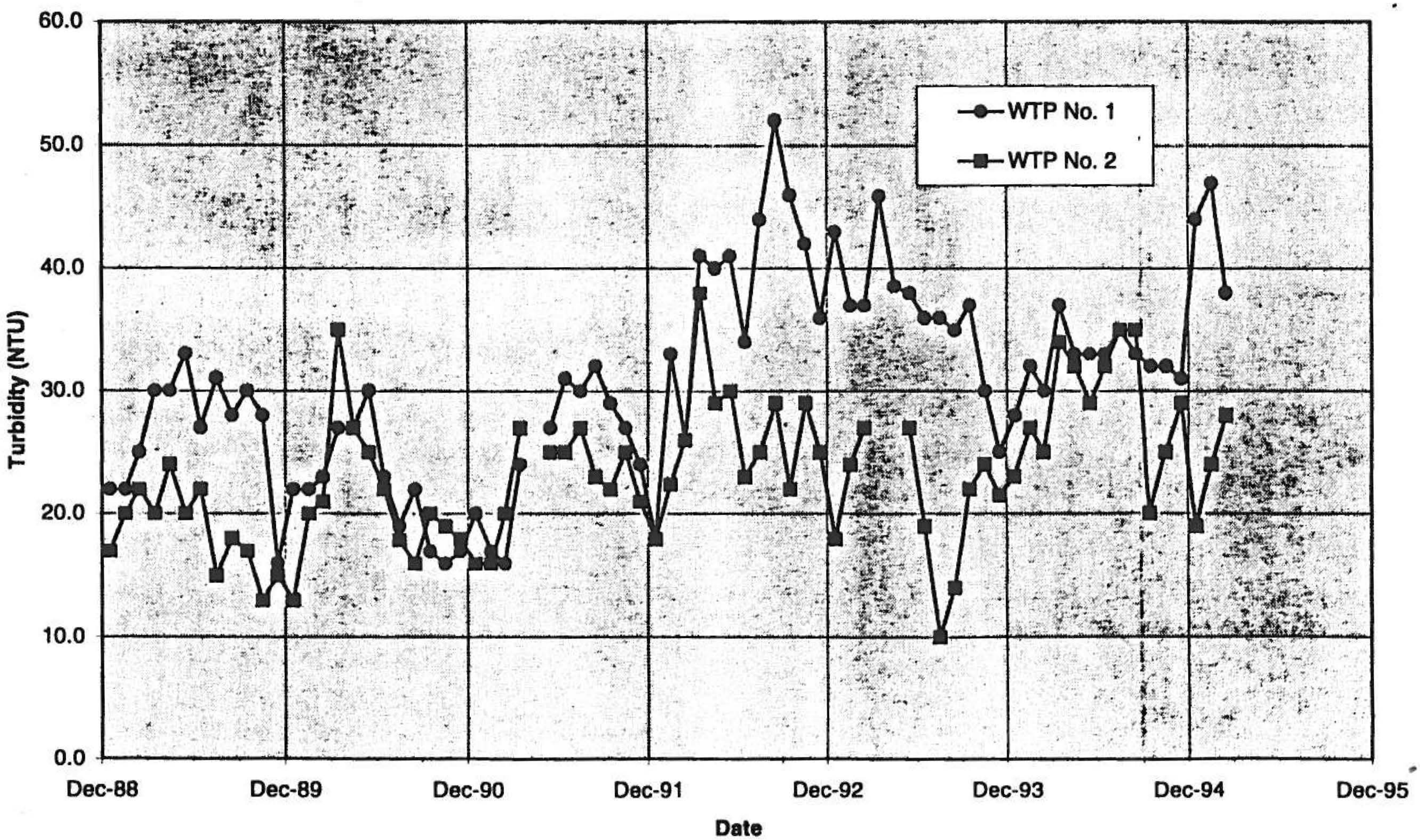

Figure 5 Raw Water Average Monthly Turbidity

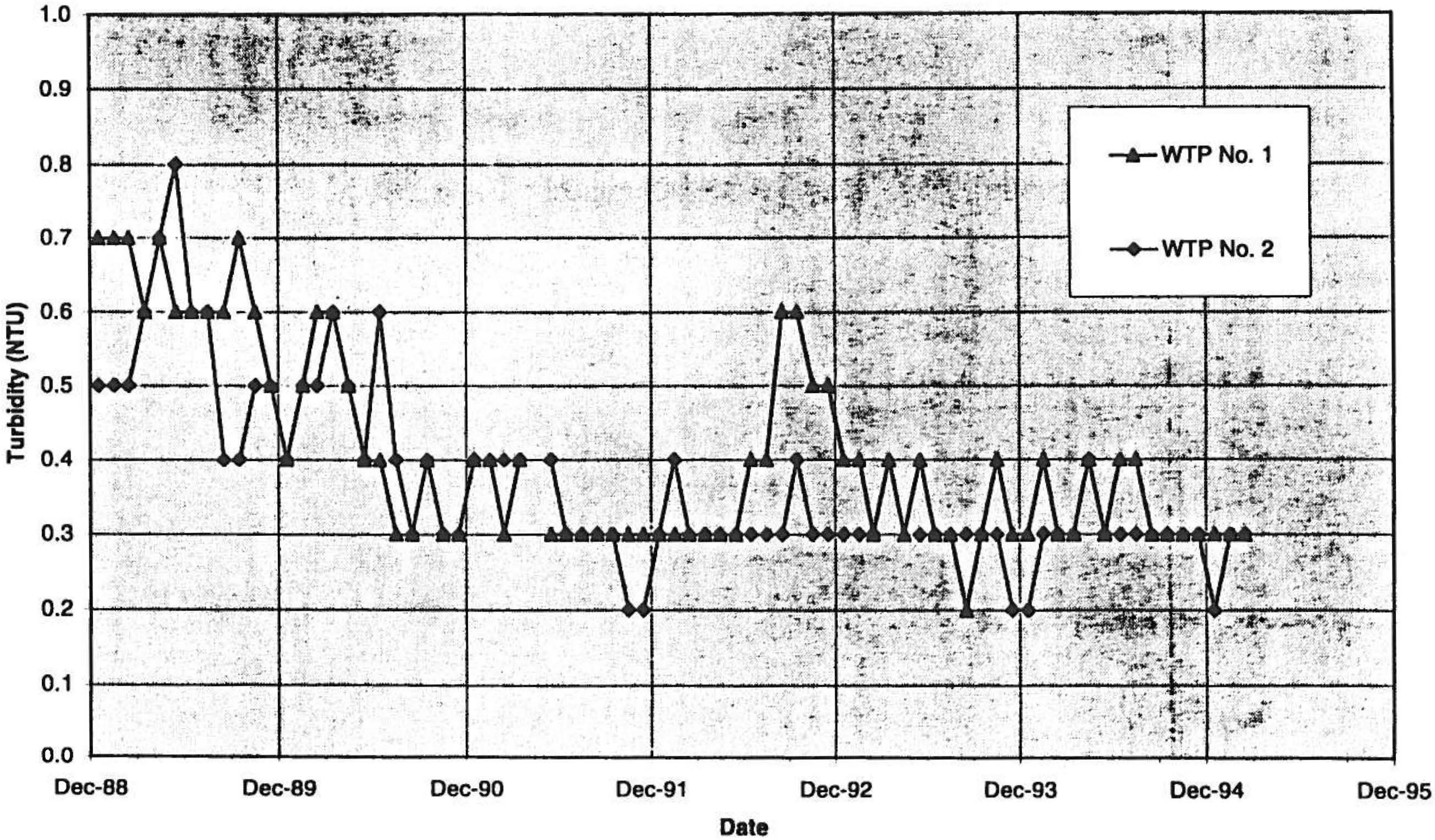

Figure 6 Treated Water Monthly Average Turbidity

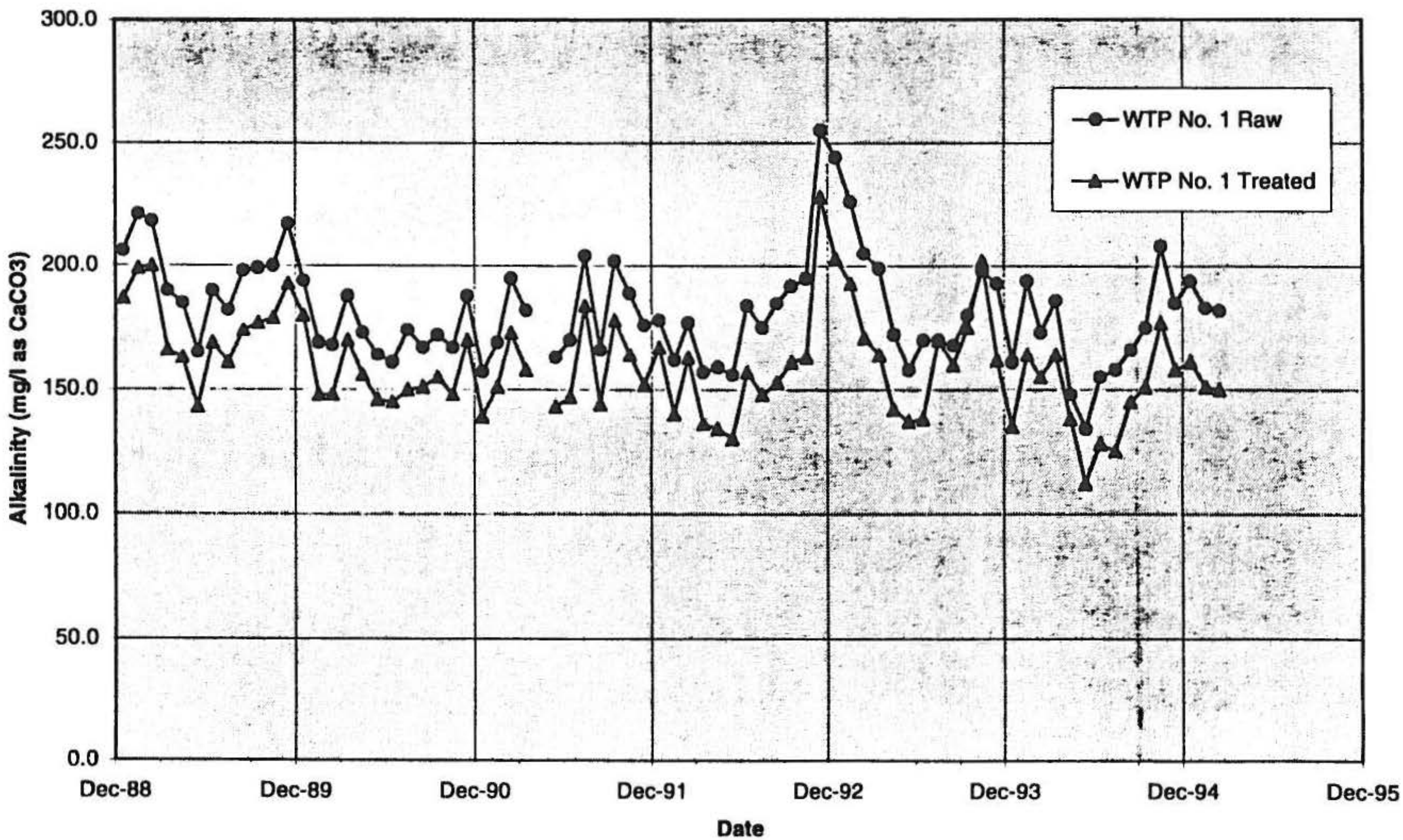

Figure 7 WTP No. 1 Monthly Average Alkalinity

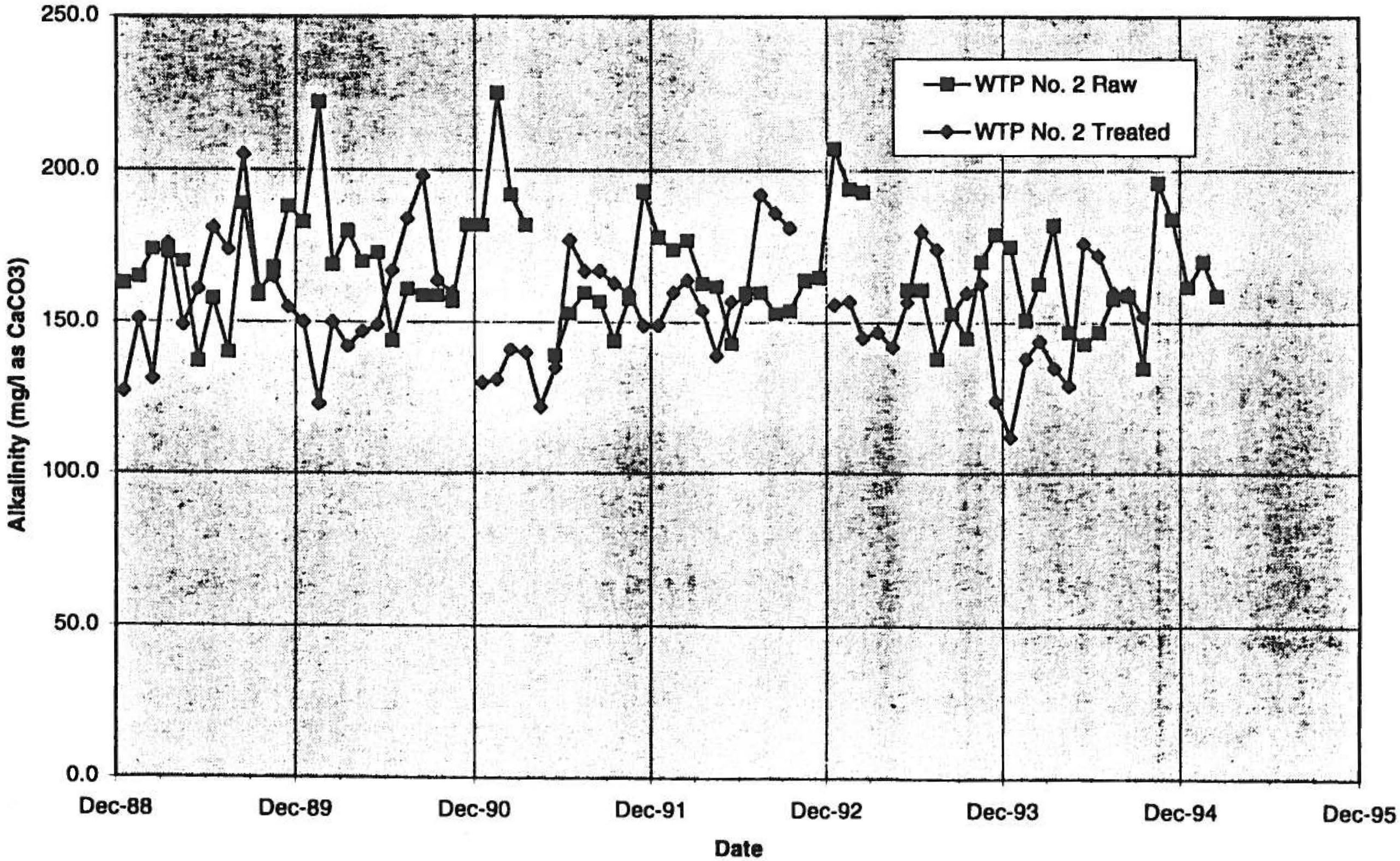

Figure 8 WTP No. 2 Average Monthly Alkalinity

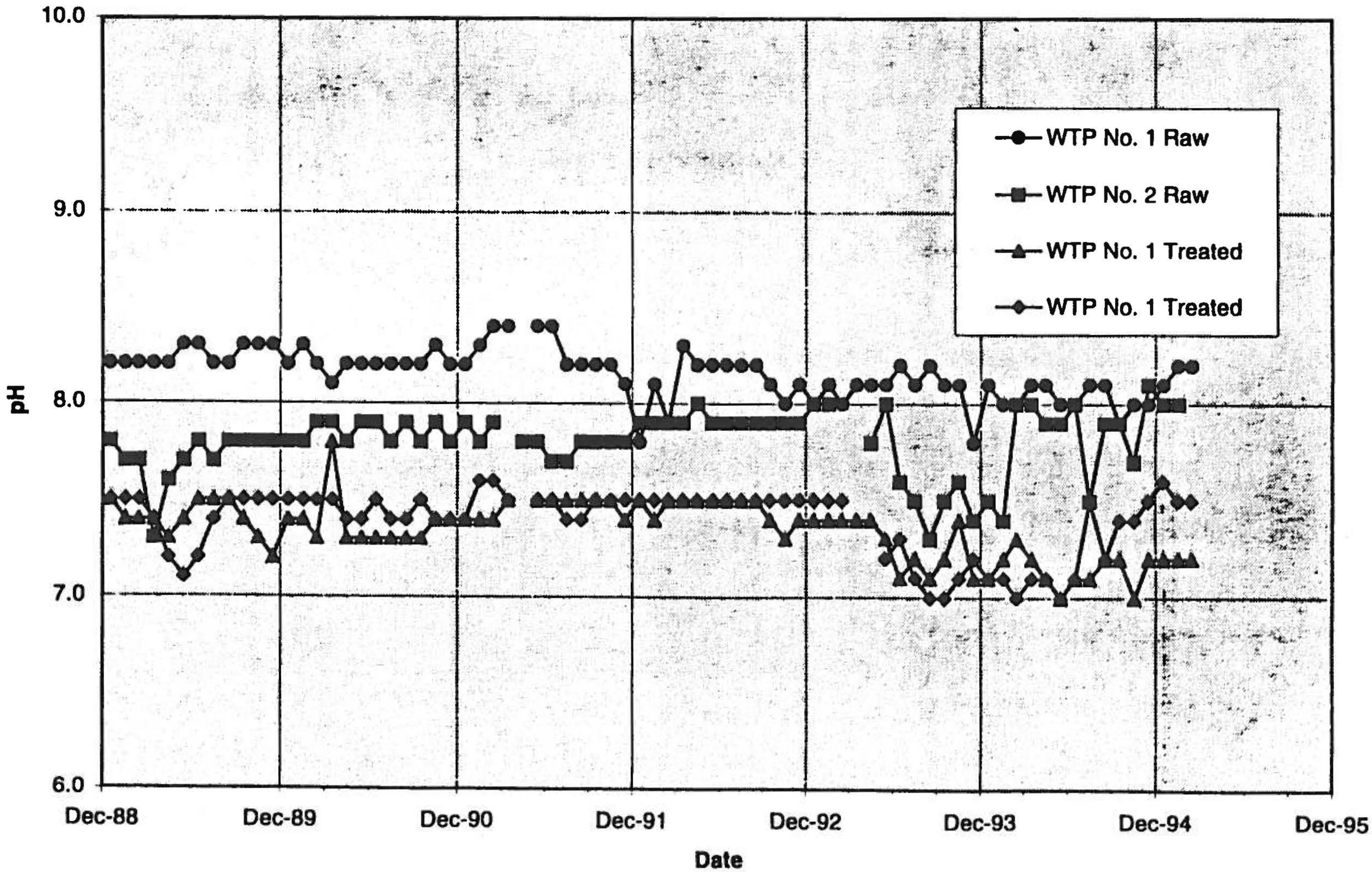

Figure 9 Raw and Treated Water Monthly Average pH

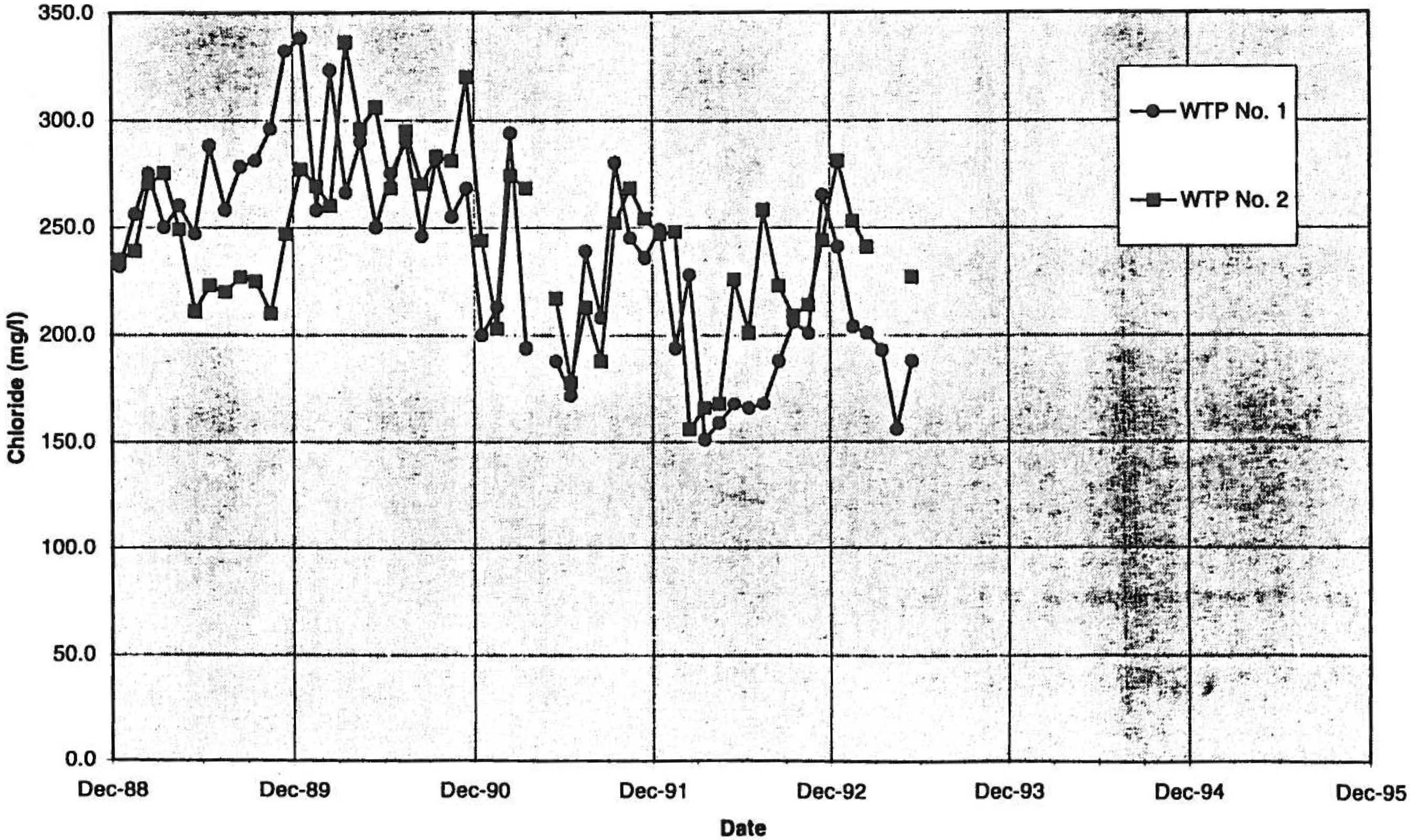

Figure 10 Treated Water Monthly Average Chloride

Table 3
Water Quality Analyses
Brownsville Public Utility
Laboratory: Texas Dept. of Health, Austin, TX

	Raw		WTP No. 1		WTP No. 2	
	3/14/91	3/7/95	6/7/93	12/6/94	6/4/92	9/8/93
Calcium	122	85	82	101	79	83
Chloride	319	193	161	223	173	198
Fluoride	0.8	0.9	0.7	0.9	0.7	0.8
Magnesium	37	27	22	32	16	25
Nitrate (as N)	0.08	0.16	24.25	0.18	0.18	11.00
Sodium	273	189	132	195	146	167
Sulfate	406	310	248	327	234	295
Total Hardness (CaCO3)	459	323	296	385	261	311
pH (units)	8.2	8.3	6.0	7.9	7.6	6.5
Conductivity (umhos/cm)	2464	1782	1440	1836	1377	1672
Alkalinity (CaCO3)	169	128	16	140	107	67
Bicarbonate	206	156	20	171	131	82
Carbonate	0	0	0	0	0	0
Total Dissolved Solids	1265	889	767	971	719	862
Barium	0.115	- -	- -	- -	0.096	- -
Iron	0.40	- -	- -	- -	0.53	- -
Manganese	0.05	- -	- -	- -	0.04	- -

Note: Results in mg/l unless noted

General ASR Application

The above information concerning PUB present and future water demands, water system capacities, and water rights was used to identify conceptually how an ASR system could apply to the PUB's long-term water needs.

The previous discussion on water rights indicates that the PUB currently has a firm annual water right of 33,973 acre-feet of Rio Grande water. This volume of water can be pumped from the Rio Grande for use every year. Over the past several years, potable use of water has been about 79 percent of the total raw water use. Assuming this pattern continues, 26,838 acre-feet of water is available for potable use. Considering the water demand projections discussed earlier, this volume of water will be sufficient only through the year 2002.

The PUB has also obtained rights to raw water under recently acquired Permit 1838. This permit allows the PUB to pump additional raw water when Rio Grande flows exceed 25 cfs. The total volume of water that may be pumped in a given year under this permit is 40,000 acre-feet, but analyses of historic river flows indicates an average of about 17,000 acre-feet will be available. This amount of additional raw water is significant and will serve the PUB well. However, it is only available during high river flows.

To fully utilize the water under Permit 1838, the PUB requires substantial storage to hold this water. The Permit 1838 water will be available during certain parts of the year, but these times may not correspond with PUB peak demand needs. This is where ASR could potentially benefit the PUB. ASR facilities could be used to store this excess water following treatment, and then could be pumped during high demand seasons to supplement treatment plant flows.

An initial analysis of PUB water demands indicates that additional treatment plant capacity could be used to treat and store Permit 1838 water in ASR wells. Beginning in the year 2003, excess plant capacity could be used to store about 6,000 acre-feet annually. This amount of treated water storage combined with direct use of the Permit 1838 water could potentially sustain the raw water needs of the PUB through about 2011.

An ASR system conceptually could receive treated water for storage at average rates up to about 15 mgd during the months of November through May. The stored water would be water produced under Permit 1838 and treated along with other Rio Grande water used to meet seasonal demands. During the months of about June through September, or October, the stored water could be recovered from the ASR system and pumped to the distribution system at rates up to about 20 mgd to meet customer demands. In this way, the ASR system can obtain and store the 1838 permit water when it is available, and then provide water to the customers during peak demands to supplement the PUB firm water rights as needed. A more detailed description of how an ASR system could work for the PUB is included in Appendix 3.

ECS ENVIRONMENTAL CHEMISTRY SERVICES, INC.

August 11, 1995

Mr. Kevin Bral
CH2M Hill
P.O. Box 241325
Denver, CO 80224-9325

RE: ECS Project #CHM074

Dear Mr. Bral:

Enclosed are the pH, TSS, TDS, major cations, metals, pesticides/PCBs, volatile organic and semivolatile organic results for the CH2M Hill Project #116700.BO.ZZ water samples we received on August 1.

The pH of the samples was measured using EPA Method 9040. The method consists of electrometrical measurement using a pH meter. The results are reported in Table 1.

The samples were analyzed for total suspended solids (TSS) by EPA Method 160.2. This analysis measures the amount of residue retained on a standard glass fiber filter. The method was modified by addition of sample volume to provide a lower detection limit. Sample and quality control results are listed in Table 2.

The samples were analyzed for total dissolved solids (TDS) by EPA Method 160.1. This analysis measures the amount of residue capable of passing through a standard glass fiber filter. Sample and quality control results are listed in Table 3.

The samples were analyzed for the major cations, silica and metals by Method 200.8. This is an inductively coupled plasma/mass spectrometry (ICP/MS) method. The sample and quality control results are in Table 4; quality control results are in Tables 5 and 6.

The samples were analyzed for organochlorine pesticides and polychlorinated biphenyls (PCB) by EPA Method 608. This is a gas chromatography/electron capture detector method. The analysis was performed on a hexane extract of the sample. The surrogate standard was added to all samples to monitor extraction and analysis efficiency. The sample results are tabulated in Table 7; Table 8 contains the quality control results.

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The samples were analyzed for volatile organic compounds by EPA Method 524.2. This is a gas chromatography/mass spectrometry method using purge and trap concentration and a capillary chromatography column. The surrogate standards were added to all samples to monitor purging efficiency. Sample results are listed in Table 9; quality control results are listed in Table 10.

The samples were analyzed for semivolatile organic compounds by EPA Method 625. This is a gas chromatography/mass spectrometry method. The analysis was performed on a methylene chloride extract of the sample. The low surrogate recovery for the samples is a matrix effect, as demonstrated by the duplicate results. The performance of the instrument was checked by the analysis of a blank and/or standard. The results are tabulated in Tables 11 and 12; Table 13 contains the quality control results.

The samples were sent to AccuLabs Research for the anion analyses. The samples were sent to Analytical Technologies for the radiochemistry. The results will be provided as soon as they are available.

Please call if you have any questions.

Sincerely,

John Graves

John Graves
Technical Director

August 11, 1995

ENVIRONMENTAL CHEMISTRY SERVICES, INC.
7108 S. Alton Way, Bldg. E
Englewood, CO 80112
(303) 850-7606

TABLE 1

ECS Project #:	CHM074	Date Received:	8/1/95
CH2M Hill Project #:	116700.BO.ZZ	Date Sampled:	7/31/95
Method #:	EPA 9040A	Date Extracted:	n/a
Matrix:	Water	Date Analyzed:	8/1/95
Units:	n/a		

SAMPLE RESULTS		
Sample #	pH	Temperature (°C)
Plant No. 1	7.4	25
Plant No. 2	7.4	25

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TABLE 2

ECS Project #:	CHM074	Date Received:	8/1/95
CH2M Hill Project #:	116700.BO.ZZ	Date Sampled:	7/31/95
Method #:	EPA 160.2	Date Extracted:	n/a
Matrix:	Water	Date Analyzed:	8/7/95
Units:	mg/L (ppm)		

SAMPLE RESULTS	
Sample #	Total Suspended Solids
Plant No. 1	ND
Plant No. 2	ND

ND = Not detected at levels exceeding the reporting detection limit.

QUALITY CONTROL RESULTS	
	Total Suspended Solids
Blank	ND
Detection Limit	1.0

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TABLE 3

ECS Project #:	CHM074	Date Received:	8/1/95
CH2M Hill Project #:	116700.BO.ZZ	Date Sampled:	7/31/95
Method #:	EPA 160.1	Date Extracted:	n/a
Matrix:	Water	Date Analyzed:	8/7/95
Units:	mg/L (ppm)		

SAMPLE RESULTS

Sample #	Total Dissolved Solids
Plant No. 1	1,000
Plant No. 2	980

ND = Not detected at levels exceeding the reporting detection limit.

QUALITY CONTROL RESULTS

	Total Dissolved Solids
Plant No. 2 Duplicate	970
Relative % Difference	2
Blank	ND
Detection Limit	10

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TABLE 4

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 200.8
Matrix: Water
Units: mg/L (ppm)

Date Received: 8/1/95
Date Sampled: 7/31/95
Date Digested: n/a
Date Analyzed: 8/1-8/6/95

PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	Plant No. 1 Duplicate	BLANK
Calcium	5.0	73	66	73	ND
Magnesium	5.0	28	25	26	ND
Sodium	5.0	170	150	150	ND
Potassium	5.0	6.2	4.8	5.2	ND
Silica	0.10	15	12	15	ND
Aluminum	0.001	0.13	0.11	0.13	ND
Iron	0.005	ND	ND	ND	ND
Manganese	0.001	0.0043	0.012	0.0043	ND
Arsenic	0.001	0.0089	0.0092	0.0093	ND
Barium	0.001	0.13	0.13	0.13	ND
Cadmium	0.001	ND	ND	ND	ND
Chromium	0.001	0.0066	0.0072	0.0068	ND
Lead	0.001	ND	0.0025	ND	ND
Mercury	0.0005	ND	ND	ND	ND
Selenium	0.001	0.0056	0.0057	0.0059	ND
Silver	0.001	ND	ND	ND	ND

ND = Not detected at levels exceeding the reporting detection limit.

August 11, 1995

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TABLE 5

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 200.8
Matrix: Water
Units: mg/L (ppm)

Date Received: n/a
Date Sampled: n/a
Date Digested: n/a
Date Analyzed: 8/1-8/6/95

PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	LCS SPIKE	% RECOVERY
Calcium	5.0	50	52	103
Magnesium	5.0	50	49	98
Sodium	5.0	50	48	96
Potassium	5.0	50	46	92
Silica	0.10	0.20	0.19	93
Aluminum	0.001	0.20	0.21	104
Iron	0.005	0.20	0.22	108
Manganese	0.001	0.020	0.019	96
Arsenic	0.001	0.020	0.020	102
Barium	0.001	0.020	0.020	98
Cadmium	0.001	0.020	0.020	98
Chromium	0.001	0.020	0.019	95
Lead	0.001	0.020	0.020	99
Mercury	0.0005	0.0050	0.0054	109
Selenium	0.001	0.020	0.021	103
Silver	0.001	0.020	0.020	101

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TABLE 6

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 200.8
Matrix: Water
Units: mg/L (ppm)

Date Received: 8/1/95
Date Sampled: 7/31/95
Date Digested: n/a
Date Analyzed: 8/1-8/6/95

PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	Plant No. 2 SPIKE	% RECOVERY
Calcium	5.0	100	170	104
Magnesium	5.0	100	130	109
Sodium	5.0	100	270	124
Potassium	5.0	100	100	97
Silica	0.10	17	29	100
Aluminum	0.001	0.50	0.62	102
Iron	0.005	0.50	0.55	109
Manganese	0.001	0.14	0.13	81
Arsenic	0.001	0.14	0.16	107
Barium	0.001	0.14	0.25	82
Cadmium	0.001	0.14	0.13	89
Chromium	0.001	0.14	0.12	80
Lead	0.001	0.14	0.14	99
Mercury	0.0005	0.0050	0.0046	92
Selenium	0.001	0.14	0.17	112
Silver	0.001	0.14	0.12	84

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TABLE 7

ECS Project #:	CHM074	Date Received:	8/1/95
CH2M Hill Project #:	116700.BO.ZZ	Date Sampled:	7/31/95
Method #:	EPA 608	Date Extracted:	8/2/95
Matrix:	Water	Date Analyzed:	8/3/95
Units:	μg/L (ppb)		

PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
α-BHC	0.050	ND	ND	ND
β-BHC	0.050	ND	ND	ND
γ-BHC (Lindane)	0.050	ND	ND	ND
δ-BHC	0.050	ND	ND	ND
Heptachlor	0.050	ND	ND	ND
Aldrin	0.050	ND	ND	ND
Heptachlor epoxide	0.050	ND	ND	ND
Endosulfan I	0.050	ND	ND	ND
4,4-DDE	0.10	ND	ND	ND
Dieldrin	0.10	ND	ND	ND
Endrin	0.10	ND	ND	ND
Endosulfan II	0.10	ND	ND	ND
4,4-DDD	0.10	ND	ND	ND
Endrin aldehyde	0.10	ND	ND	ND
Endosulfan sulfate	0.10	ND	ND	ND
4,4-DDT	0.10	ND	ND	ND

PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
Methoxychlor	0.50	ND	ND	ND
Chlordane	0.10	ND	ND	ND
Toxaphene	5.0	ND	ND	ND
Aroclor 1016	1.0	ND	ND	ND
Aroclor 1221	2.0	ND	ND	ND
Aroclor 1232	1.0	ND	ND	ND
Aroclor 1242	1.0	ND	ND	ND
Aroclor 1248	1.0	ND	ND	ND
Aroclor 1254	1.0	ND	ND	ND
Aroclor 1260	1.0	ND	ND	ND

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
DBC	0.40	104	104	100
TCMX	0.40	96	82	90

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TABLE 8

ECS Project #:	CHM074	Date Received:	n/a
CH2M Hill Project #:	116700.BO.ZZ	Date Sampled:	n/a
Method #:	EPA 608	Date Extracted:	7/19/95
Matrix:	Water	Date Analyzed:	7/20/95
Units:	μg/kg (ppb)		

PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
α-BHC	0.050	-	ND	-	ND	-	-
β-BHC	0.050	-	ND	-	ND	-	-
γ-BHC (Lindane)	0.050	0.20	0.19	94	0.18	90	4
δ-BHC	0.050	-	ND	-	ND	-	-
Heptachlor	0.050	0.20	0.19	96	0.19	93	3
Aldrin	0.050	0.20	0.17	86	0.16	82	5
Heptachlor epoxide	0.050	-	ND	-	ND	-	-
Endosulfan I	0.050	-	ND	-	ND	-	-
4,4,-DDE	0.10	-	ND	-	ND	-	-
Dieldrin	0.10	0.50	0.49	98	0.46	92	6
Endrin	0.10	0.50	0.53	106	0.58	116	9
Endosulfan II	0.10	-	ND	-	ND	-	-
4,4-DDD	0.10	-	ND	-	ND	-	-
Endrin aldehyde	0.10	-	ND	-	ND	-	-
Endrosulfan sulfate	0.10	-	ND	-	ND	-	-
4,4-DDT	0.10	0.50	0.58	117	0.57	113	4

PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
Methoxychlor	0.50	-	ND	-	ND	-	-
Chlordane	0.10	-	ND	-	ND	-	-
Toxaphene	5.0	-	ND	-	ND	-	-
Aroclor 1016	1.0	-	ND	-	ND	-	-
Aroclor 1221	2.0	-	ND	-	ND	-	-
Aroclor 1232	1.0	-	ND	-	ND	-	-
Aroclor 1242	1.0	-	ND	-	ND	-	-
Aroclor 1248	1.0	-	ND	-	ND	-	-
Aroclor 1254	1.0	-	ND	-	ND	-	-
Aroclor 1260	1.0	-	ND	-	ND	-	-

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT		MATRIX SPIKE		MATRIX SPIKE DUPLICATE		
DBC	0.40		120		112		
TCMX	0.40		104		98		

August 11, 1995

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TABLE 9

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 524.2
Matrix: Water
Units: mg/L (ppm)

Date Received: 8/1/95
Date Sampled: 7/31/95
Date Extracted: n/a
Date Analyzed: 8/4/95

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
	Dichlorodifluoromethane	0.002	ND	ND	ND
	Chloromethane	0.002	ND	ND	ND
	Bromomethane	0.002	ND	ND	ND
	Vinyl chloride	0.002	ND	ND	ND
	Chloroethane	0.002	ND	ND	ND
	Trichlorofluoromethane	0.002	ND	ND	ND
	Methylene chloride	0.005	ND	ND	ND
	1,1-Dichloroethene	0.001	ND	ND	ND
	1,1-Dichloroethane	0.001	ND	ND	ND
	cis-1,2-Dichloroethene	0.001	ND	ND	ND
	trans-1,2-Dichloroethene	0.001	ND	ND	ND
*	Chloroform	0.001	0.0044	0.0061	ND
	Bromochloromethane	0.001	ND	ND	ND
	Dibromomethane	0.001	ND	ND	ND
	1,2-Dichloroethane	0.001	ND	ND	ND
	1,1,1-Trichloroethane	0.001	ND	ND	ND

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
	Carbon tetrachloride	0.001	ND	ND	ND
*	Bromodichloromethane	0.001	0.0047	0.0088	ND
	1,2-Dichloropropane	0.001	ND	ND	ND
	1,1-Dichloropropene	0.001	ND	ND	ND
	trans-1,3-Dichloropropene	0.001	ND	ND	ND
	2,2-Dichloropropane	0.001	ND	ND	ND
	cis-1,3-Dichloropropene	0.001	ND	ND	ND
	Trichloroethene	0.001	ND	ND	ND
	1,3-Dichloropropane	0.001	ND	ND	ND
	1,1,2-Trichloroethane	0.001	ND	ND	ND
*	Dibromochloromethane	0.001	0.0070	0.012	ND
	1,2-Dibromoethane	0.001	ND	ND	ND
*	Bromoform	0.001	0.0052	0.011	ND
	1,1,1,2-Tetrachloroethane	0.001	ND	ND	ND
	1,2,3-Trichloropropane	0.001	ND	ND	ND
	1,1,2,2-Tetrachloroethane	0.001	ND	ND	ND
	Tetrachloroethene	0.001	ND	ND	ND
	Chlorobenzene	0.001	ND	ND	ND
	1,3-Dichlorobenzene	0.001	ND	ND	ND
	1,2-Dichlorobenzene	0.001	ND	ND	ND
	1,4-Dichlorobenzene	0.001	ND	ND	ND
	2-Chlorotoluene	0.001	ND	ND	ND
	4-Chlorotoluene	0.001	ND	ND	ND
	Bromobenzene	0.001	ND	ND	ND
	Styrene	0.001	ND	ND	ND
	Benzene	0.001	ND	ND	ND

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
	Toluene	0.001	ND	ND	ND
	Ethylbenzene	0.001	ND	ND	ND
	Total xylenes	0.001	ND	ND	ND
	Isopropylbenzene	0.001	ND	ND	ND
	n-Propylbenzene	0.001	ND	ND	ND
	1,3,5-Trimethylbenzene	0.001	ND	ND	ND
	1,2,4-Trimethylbenzene	0.001	ND	ND	ND
	s-Butylbenzene	0.001	ND	ND	ND
	t-Butylbenzene	0.001	ND	ND	ND
	p-Isopropyltoluene	0.001	ND	ND	ND
	n-Butylbenzene	0.001	ND	ND	ND
	1,2-Dibromo-3-chloropropane	0.001	ND	ND	ND
	Hexachlorobutadiene	0.001	ND	ND	ND
	Naphthalene	0.001	ND	ND	ND
	1,2,4-Trichlorobenzene	0.001	ND	ND	ND
	1,2,3-Trichlorobenzene	0.001	ND	ND	ND

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 2	BLANK
1,2 Dichloroethane-D4	0.010	99	97	97
Toluene-D8	0.010	107	105	105
Bromofluorobenzene	0.010	101	103	102

August 11, 1995

ENVIRONMENTAL CHEMISTRY SERVICES, INC.
7108 S. Alton Way, Bldg. E
Englewood, CO 80112
(303) 850-7606

TABLE 10

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 524.2
Matrix: Water
Units: mg/L (ppm)

Date Received: n/a
Date Sampled: n/a
Date Extracted: n/a
Date Analyzed: 8/1/95

*	PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
	Dichlorodifluoromethane	0.002	-	ND	-	ND	-	-
	Chloromethane	0.002	-	ND	-	ND	-	-
	Bromomethane	0.002	-	ND	-	ND	-	-
	Vinyl chloride	0.002	-	ND	-	ND	-	-
	Chloroethane	0.002	-	ND	-	ND	-	-
	Trichlorofluoromethane	0.002	-	ND	-	ND	-	-
	Methylene chloride	0.005	-	ND	-	ND	-	-
*	1,1-Dichloroethene	0.001	0.025	0.020	80	0.023	90	12
	1,1-Dichloroethane	0.001	-	ND	-	ND	-	-
	cis-1,2-Dichloroethene	0.001	-	ND	-	ND	-	-
	trans-1,2-Dichloroethene	0.001	-	ND	-	ND	-	-
	Chloroform	0.001	-	ND	-	ND	-	-
	Bromochloromethane	0.001	-	ND	-	ND	-	-
	Dibromomethane	0.001	-	ND	-	ND	-	-
	1,2-Dichloroethane	0.001	-	ND	-	ND	-	-
	1,1,1-Trichloroethane	0.001	-	ND	-	ND	-	-

*	PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
	Carbon tetrachloride	0.001	-	ND	-	ND	-	-
	Bromodichloromethane	0.001	-	ND	-	ND	-	-
	1,2-Dichloropropane	0.001	-	ND	-	ND	-	-
	1,1-Dichloropropene	0.001	-	ND	-	ND	-	-
	trans-1,3-Dichloropropene	0.001	-	ND	-	ND	-	-
	2,2-Dichloropropane	0.001	-	ND	-	ND	-	-
	cis-1,3-Dichloropropene	0.001	-	ND	-	ND	-	-
*	Trichloroethene	0.001	0.025	0.025	98	0.026	104	6
	1,3-Dichloropropane	0.001	-	ND	-	ND	-	-
	1,1,2-Trichloroethane	0.001	-	ND	-	ND	-	-
	Dibromochloromethane	0.001	-	ND	-	ND	-	-
	1,2-Dibromoethane	0.001	-	ND	-	ND	-	-
	Bromoform	0.001	-	ND	-	ND	-	-
	1,1,1,2-Tetrachloroethane	0.001	-	ND	-	ND	-	-
	1,2,3-Trichloropropane	0.001	-	ND	-	ND	-	-
	1,1,2,2-Tetrachloroethane	0.001	-	ND	-	ND	-	-
	Tetrachloroethene	0.001	-	ND	-	ND	-	-
*	Chlorobenzene	0.001	0.025	0.025	99	0.026	105	6
	1,3-Dichlorobenzene	0.001	-	ND	-	ND	-	-
	1,2-Dichlorobenzene	0.001	-	ND	-	ND	-	-
	1,4-Dichlorobenzene	0.001	-	ND	-	ND	-	-
	2-Chlorotoluene	0.001	-	ND	-	ND	-	-
	4-Chlorotoluene	0.001	-	ND	-	ND	-	-
	Bromobenzene	0.001	-	ND	-	ND	-	-
	Styrene	0.001	-	ND	-	ND	-	-

*	PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
*	Benzene	0.001	0.025	0.025	101	0.027	107	6
*	Toluene	0.001	0.025	0.021	84	0.022	87	4
	Ethylbenzene	0.001	-	ND	-	ND	-	-
	Total xylenes	0.001	-	ND	-	ND	-	-
	Isopropylbenzene	0.001	-	ND	-	ND	-	-
	n-Propylbenzene	0.001	-	ND	-	ND	-	-
	1,3,5-Trimethylbenzene	0.001	-	ND	-	ND	-	-
	1,2,4-Trimethylbenzene	0.001	-	ND	-	ND	-	-
	s-Butylbenzene	0.001	-	ND	-	ND	-	-
	t-Butylbenzene	0.001	-	ND	-	ND	-	-
	p-Isopropyltoluene	0.001	-	ND	-	ND	-	-
	n-Butylbenzene	0.001	-	ND	-	ND	-	-
	1,2-Dibromo-3-chloropropane	0.001	-	ND	-	ND	-	-
	Hexachlorobutadiene	0.001	-	ND	-	ND	-	-
	Naphthalene	0.001	-	ND	-	ND	-	-
	1,2,4-Trichlorobenzene	0.001	-	ND	-	ND	-	-
	1,2,3-Trichlorobenzene	0.001	-	ND	-	ND	-	-

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT		MATRIX SPIKE		MATRIX SPIKE DUPLICATE		
1,2 Dichloroethane-D4	0.010	-	101	-	102	-	-
Toluene-D8	0.010	-	99	-	99	-	-
Bromofluorobenzene	0.010	-	100	-	101	-	-

August 11, 1995

ENVIRONMENTAL CHEMISTRY SERVICES, INC.
7108 S. Alton Way, Bldg. E
Englewood, CO 80112
(303) 850-7606

TABLE 11

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 625
Matrix: Water
Units: mg/L (ppm)

Date Received: 8/1/95
Date Sampled: 7/31/95
Date Extracted: 8/2-8/4/95
Date Analyzed: 8/3-8/7/95

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 1 Dup	8/2/95 BLANK
	Phenol	0.010	ND	ND	ND
	Bis(2-chloroethyl)ether	0.010	ND	ND	ND
	2-Chlorophenol	0.010	ND	ND	ND
	1,3-Dichlorobenzene	0.010	ND	ND	ND
	1,4-Dichlorobenzene	0.010	ND	ND	ND
	1,2-Dichlorobenzene	0.010	ND	ND	ND
	Bis(2-chloroisopropyl)ether	0.010	ND	ND	ND
	Hexachloroethane	0.010	ND	ND	ND
	N-Nitrosodi-n-propylamine	0.010	ND	ND	ND
	Nitrobenzene	0.010	ND	ND	ND
	Isophorone	0.010	ND	ND	ND
	2-Nitrophenol	0.010	ND	ND	ND
	2,4-Dimethylphenol	0.010	ND	ND	ND
	Bis(2-chloroethoxy)methane	0.010	ND	ND	ND
	2,4-Dichlorophenol	0.010	ND	ND	ND
	1,2,4-Trichlorobenzene	0.010	ND	ND	ND
	Naphthalene	0.010	ND	ND	ND
	Hexachlorobutadiene	0.010	ND	ND	ND
	4-chloro-3-methylphenol	0.020	ND	ND	ND

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 1 Dup	8/2/95 BLANK
	2,4,6-Trichlorophenol	0.010	ND	ND	ND
	2-Chloronaphthalene	0.010	ND	ND	ND
	Dimethylphthalate	0.010	ND	ND	ND
	Acenaphthylene	0.010	ND	ND	ND
	Acenaphthene	0.010	ND	ND	ND
	2,4-Dinitrophenol	0.020	ND	ND	ND
	4-Nitrophenol	0.020	ND	ND	ND
	2,4-Dinitrotoluene	0.010	ND	ND	ND
	Diethylphthalate	0.010	ND	ND	ND
	Fluorene	0.010	ND	ND	ND
	4-Chlorophenylphenylether	0.010	ND	ND	ND
	4,6-Dinitro-2-methylphenol	0.020	ND	ND	ND
	4-Bromophenylphenylether	0.010	ND	ND	ND
	Hexachlorobenzene	0.010	ND	ND	ND
	Pentachlorophenol	0.010	ND	ND	ND
	Phenanthrene	0.010	ND	ND	ND
	Anthracene	0.010	ND	ND	ND
	Di-n-butylphthalate	0.010	ND	ND	ND
	Fluoranthene	0.010	ND	ND	ND
	Pyrene	0.010	ND	ND	ND
	Butyl benzyl phthalate	0.010	ND	ND	ND
	Chrysene	0.010	ND	ND	ND
	3,3'-Dichlorobenzidine	0.020	ND	ND	ND
	Benz(a)anthracene	0.010	ND	ND	ND
	Bis(2-ethylhexyl)phthalate	0.010	ND	ND	ND
	Di-n-octyl phthalate	0.010	ND	ND	ND

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 1 Dup	8/2/95 BLANK
	Benzo(b)fluoranthene	0.010	ND	ND	ND
	Benzo(k)fluoranthene	0.010	ND	ND	ND
	Benzo(a)pyrene	0.010	ND	ND	ND
	Indeno(1,2,3-cd)pyrene	0.010	ND	ND	ND
	Dibenz(a,h)anthracene	0.010	ND	ND	ND
	Benzo(g,h,i)perylene	0.010	ND	ND	ND
	Hexachlorocyclopentadiene	0.010	ND	ND	ND
	Benzidine	0.050	ND	ND	ND
	2,6-Dinitrotoluene	0.010	ND	ND	ND
	N-Nitrosodiphenylamine	0.010	ND	ND	ND
	N-Nitrosodimethylamine	0.020	ND	ND	ND

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT	SAMPLE # Plant No. 1	SAMPLE # Plant No. 1 Dup	8/2/95 BLANK
Phenol-D5	0.10	0	0	37
2-Fluorophenol	0.10	18	48	55
Nitrobenzene-D5	0.050	60	119	71
2-Fluorobiphenyl	0.050	59	94	63
2,4,6-Tribromophenol	0.10	58	81	93
Terphenyl-D14	0.050	95	118	101

August 11, 1995

ENVIRONMENTAL CHEMISTRY SERVICES, INC.
7108 S. Alton Way, Bldg. E
Englewood, CO 80112
(303) 850-7606

TABLE 12

ECS Project #: CHM074
CH2M Hill Project #: 116700.BO.ZZ
Method #: EPA 625
Matrix: Water
Units: mg/L (ppm)

Date Received: 8/1/95
Date Sampled: 7/31/95
Date Extracted: 8/2-8/4/95
Date Analyzed: 8/3-8/7/95

*	PARAMETER	DETECTION LIMIT	SAMPLE # Plant No. 2	SAMPLE # Plant No. 2 Dup	8/4/95 BLANK
	Phenol	0.010	ND	ND	ND
	Bis(2-chloroethyl)ether	0.010	ND	ND	ND
	2-Chlorophenol	0.010	ND	ND	ND
	1,3-Dichlorobenzene	0.010	ND	ND	ND
	1,4-Dichlorobenzene	0.010	ND	ND	ND
	1,2-Dichlorobenzene	0.010	ND	ND	ND
	Bis(2-chloroisopropyl)ether	0.010	ND	ND	ND
	Hexachloroethane	0.010	ND	ND	ND
	N-Nitrosodi-n-propylamine	0.010	ND	ND	ND
	Nitrobenzene	0.010	ND	ND	ND
	Isophorone	0.010	ND	ND	ND
	2-Nitrophenol	0.010	ND	ND	ND
	2,4-Dimethylphenol	0.010	ND	ND	ND
	Bis(2-chloroethoxy)methane	0.010	ND	ND	ND
	2,4-Dichlorophenol	0.010	ND	ND	ND
	1,2,4-Trichlorobenzene	0.010	ND	ND	ND
	Naphthalene	0.010	ND	ND	ND
	Hexachlorobutadiene	0.010	ND	ND	ND
	4-chloro-3-methylphenol	0.020	ND	ND	ND

*	PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
	2,4,6-Trichlorophenol	0.010	-	ND	-	ND	-	-
	2-Chloronaphthalene	0.010	-	ND	-	ND	-	-
	Dimethylphthalate	0.010	-	ND	-	ND	-	-
	Acenaphthylene	0.010	-	ND	-	ND	-	-
	2,6-Dinitrotoluene	0.010	-	ND	-	ND	-	-
*	Acenaphthene	0.010	0.050	0.043	86	0.039	78	10
	2,4-Dinitrophenol	0.020	-	ND	-	ND	-	-
*	4-Nitrophenol	0.020	0.10	0.057	57	0.054	54	5
*	2,4-Dinitrotoluene	0.010	0.050	0.041	82	0.040	81	1
	Diethylphthalate	0.010	-	ND	-	ND	-	-
	Fluorene	0.010	-	ND	-	ND	-	-
	4-Chlorophenylphenylether	0.010	-	ND	-	ND	-	-
	4,6-Dinitro-2-methylphenol	0.020	-	ND	-	ND	-	-
	4-Bromophenylphenylether	0.010	-	ND	-	ND	-	-
	Hexachlorobenzene	0.010	-	ND	-	ND	-	-
*	Pentachlorophenol	0.010	0.10	0.078	78	0.077	77	1
	Phenanthrene	0.010	-	ND	-	ND	-	-
	Anthracene	0.010	-	ND	-	ND	-	-
	Di-n-butyl phthalate	0.010	-	ND	-	ND	-	-
	Fluoranthene	0.010	-	ND	-	ND	-	-
*	Pyrene	0.010	0.050	0.047	95	0.049	97	2
	Butyl benzyl phthalate	0.010	-	ND	-	ND	-	-
	Chrysene	0.010	-	ND	-	ND	-	-
	3,3'-Dichlorobenzidine	0.020	-	ND	-	ND	-	-
	Benzo(a)anthracene	0.010	-	ND	-	ND	-	-
	Bis(2-ethylhexyl)phthalate	0.010	-	ND	-	ND	-	-

•	PARAMETER	DETECTION LIMIT	SPIKE AMOUNT	MATRIX SPIKE	% RECOVERY	MATRIX SPIKE DUPLICATE	% RECOVERY	RELATIVE % DIFFERENCE
	Di-n-octylphthalate	0.010	-	ND	-	ND	-	-
	Benzo(b)fluoranthene	0.010	-	ND	-	ND	-	-
	Benzo(k)fluoranthene	0.010	-	ND	-	ND	-	-
	Benzo(a)pyrene	0.010	-	ND	-	ND	-	-
	Indeno(1,2,3-cd)pyrene	0.010	-	ND	-	ND	-	-
	Dibenzo(a,h)anthracene	0.010	-	ND	-	ND	-	-
	Benzo(g,h,i)perylene	0.010	-	ND	-	ND	-	-
	Hexachlorocyclopentadiene	0.010	-	ND	-	ND	-	-
	Benzidine	0.050	-	ND	-	ND	-	-
	2,6-Dinitrotoluene	0.010	-	ND	-	ND	-	-
	N-Nitrosodiphenylamine	0.010	-	ND	-	ND	-	-
	N-Nitrosodimethylamine	0.010	-	ND	-	ND	-	-

ND = Not detected at levels exceeding the reporting detection limit.

SURROGATE % RECOVERY

SURROGATE	SURROGATE AMOUNT		MATRIX SPIKE		MATRIX SPIKE DUPLICATE		
Phenol-D5	0.10		37		32		
2-Fluorophenol	0.10		58		48		
Nitrobenzene-D5	0.050		107		84		
2-Fluorobiphenyl	0.050		81		72		
2,4,6-Tribromophenol	0.10		100		98		
Terphenyl-D14	0.050		93		96		

Accu-Labs® Research, Inc.
4663 Table Mountain Drive Golden, Colorado 80403-1650
(303) 277-9514 FAX (303) 277-9512

Date: 08/15/95
Page 1

REPORT OF ANALYSIS

Ms Lisa Graves
Environmental Chemistry Serv
7108 S Alton Way Bldg E
Englewood, CO 80112

Lab Job Number: 003596 ENV003
Date Samples Received: 08/01/95

ALR Designation:	95-A12596	95-A12597
Client Designation:	PLANT NO 1	PLANT NO 2
Sample Location:		
Location II:		
Date/Time Collected	07/31/95 14:28	07/31/95 13:38
Alkalinity, Total (mg/L CaCO3)	120	85
Ammonia (as N) (mg/L)	1.7	1.5
Bicarbonate (as HCO3-) (mg/L HCO3-)	150	100
Biochemical Oxygen Demand (mg/L)	8	18
Carbonate (as CO3=) (mg/L CO3=)	< 5	< 5
Chemical Oxygen Demand (mg/L)	10	< 5
Chloride (mg/L)	210	250
Color (Pt/Co)	< 5	< 5
Fluoride (mg/L)	1.0	1.0
Hydroxide (as OH-) (mg/L OH-)	< 5	< 5
Nitrate (as N) (mg/L)	0.15	0.16
Nitrate plus Nitrite (mg/L)	0.15	0.16
Nitrite (as N) (mg/L)	< 0.05	< 0.05
Orthophosphate (as P) (mg/L)	< 0.02	< 0.02
Phosphorus, Total (as P) (mg/L)	0.03	0.02
Specific Conductance (umhos/cm)	1400	1500 ▲
Sulfate (as SO4) (mg/L)	310	400
Sulfide (as S) (mg/L)	< 1	< 1
Total Kjeldahl Nitrogen (TKN) (mg/L)	3	2
Total Nitrogen (mg/L)	3	2
Total Organic Carbon (mg/L)	5	5
TOX (as Cl) (ug/L)	230	330
Turbidity (NTU)	0.8	0.9
pH ()	7.2	7.1 ▲

NOTES: When present, *** indicates that the analyte in question was not requested for that sample.
▲ Indicates that samples were received and analyzed past holding time.

Scheduled sample disposal/return date: September 14, 1995.

Susan J. Barker
Susan J. Barker
Inorganic Chemistry Supervisor

Re: 003596

Case Narrative

Aqueous Samples 95-A12596 and 95-A12597 were received past holding time for conductivity and pH analysis. The same samples were analyzed past holding time for orthophosphate and turbidity analysis due to analyst error. All other analyses were completed within holding time.

AnalyticalTechnologies,Inc. 225 Commerce Drive Fort Collins, Colorado 80524 (303) 490-1511

August 15, 1995

Ms. Lisa Graves
Environmental Chemistry Services, Inc.
7108 S. Alton Way, Bldg. E
Englewood, CO 80112

RE: ATI Workorder: 95-08-012
Client Project Name: Brownsville
Client Project Number: CHM074

Dear Ms. Graves:

Two samples were received from Environmental Chemistry Services, Inc. on Aug 2, 1995. The samples were scheduled for Gross Alpha/Beta analysis.
The results for this analysis are contained in the following report.

Thank you for your confidence in Analytical Technologies, Inc. Should you have any question, please call.

Sincerely yours,

John Whalen

John Whalen
Project Manager

JW/kml

Enclosures

Analytical**Technologies,**Inc.

QUALITY ASSURANCE
DATA REVIEW

Date: 8-12-95

ATI Workorder: 95-05-012 Analysis: Gross α/β in water

The data contained in the following report have been reviewed and approved by the personnel listed below:

Emily Baily
Radiochemistry Instrumentation/Reporting

James R Foster Jr
Radiochemistry Final Data Review

CERTIFICATION

Analytical Technologies, Inc. certifies that the analyses reported herein are true, complete, and correct within the limits of the methods employed.

A case narrative ✓ is __ is not included with this report.

ATI FM 145FC1 (03/13/95)

Narrative Comments for Work Order 95-08-012
Gross Alpha/Beta Analysis in Water
08/14/95

Work Order 95-08-012 was received on 08/02/95 and scheduled for gross alpha/beta analysis. The gross alpha/beta analysis was completed on 08/10/95.

The detection limits for gross alpha/beta are higher than what would normally be expected. This is due to the high solids content on the planchet, which severely attenuates the observed activity and limits the amount of sample that can be used for the analysis.

James R Robben Jr.
Radiochemistry Instrument Technician

ALPHA/BETA ANALYSIS RESULTS SUMMARY

Method 900.0/9310 (Modified)

Lab Name: Analytical Technologies, Inc. Date Collected: 07/31/95

Client Name: Environmental Chemistry Date Analyzed : 08/10/95

Client Project ID: Brownsville -- CHM074 Sample Matrix : Water

Lab Sample ID Series: 95-08-012 Count Duration: 30 Min.

Analyzed By : JRR

Client Sample ID	Lab Sample ID	Gross Alpha (pCi/liter)	Gross Beta (pCi/liter)
Plant No. 2	08-012-01	< 20(BDL)	< 16(BDL)
Plant No. 1	08-012-02	< 19(BDL)	< 15(BDL)

Reported Uncertainties are the Estimated Total Propagated Uncertainties (2σ). See ATI SOP 743FC for TPU determinations.

These samples were prepared using ATI SOP702FC and analyzed using ATI SOP705FC.

BDL = Below Detection Limit; see method for DL determination

Remarks:

Full client name is Environmental Chemistry Services, Inc.

ALPHA/BETA ANALYSIS RESULTS SUMMARY

Method 900.0/9310 (Modified)

Lab Name: Analytical Technologies, Inc. Date Collected: 08/03/95

Client Name: Environmental Chemistry Date Analyzed : 08/10/95

Client Project ID: Brownsville -- CHM074 Sample Matrix : Water

Lab Sample ID Series: 95-08-020- Count Duration: 30 Min.

Analyzed By : JRR

Client Sample ID	Lab Sample ID	Gross Alpha (pCi/liter)	Gross Beta (pCi/liter)
Blank	08-020-B1	< 0.66 (BDL)	< 1.3 (BDL)

Reported Uncertainties are the Estimated Total Propagated Uncertainties (2σ). See ATI SOP 743FC for TPU determinations.

These samples were prepared using ATI SOP702FC and analyzed using ATI SOP705FC.

BDL = Below Detection Limit; see method for DL determination

Remarks:

Blank is for work orders 95-08-020 and 95-08-012.
Full client name is Environmental Chemistry Services, Inc.

GROSS ALPHA/BETA BLANK SPIKE RESULTS

Method 900.0/9310 (Modified)

Lab Name: Analytical Technologies, Inc. Date Collected: 08/03/95

Client Name: Environmental Chemistry Date Analyzed : 08/10/95

Client Project ID : Brownsville -- CHM074 Sample Matrix : Water

Lab Workorder Number : 95-08-020 Units : liter

Alpha Recovery Data

Lab Sample ID	Alpha Spike Added	Alpha Reported	Percent Recovery	Flag
95-08-020-S1	116.4	125.7	108.0	Pass

Beta Recovery Data

Lab Sample ID	Beta Spike Added	Beta Reported	Percent Recovery	Flag
95-08-020-S1	108.8	114.3	105.1	Pass

ATI sets control limits for gross alpha/beta measurements based on EPA/EMSL Laboratory Intercomparison Control Limits.

Acceptange Range for Percent Recovery of blank spike samples is known ± 43% for gross alpha, known ± 26% for gross beta.

Remarks:

Bl nk spike is for work orders 95-08-020 and 95-08-012.
Full client name is Environmental Chemistry Services, Inc.

Appendix 2

GEOLOGY AND GROUND-WATER CONDITIONS NEAR BROWNSVILLE, TEXAS

Prepared for:

CH2M Hill
and the
Brownsville Public Utilities Board

Prepared By:

R. W. HARDEN & ASSOCIATES, INC.
Consulting Hydrologists and Geologists
Austin, Texas

July 1994

Table of Contents

FIGURES

TABLES

GEOLOGY AND GROUND WATER

Introduction

Ground-water conditions in the Lower Rio Grande Valley and near the City of Brownsville vary considerably both laterally and vertically with respect to availability and water quality. The purpose of this report is to identify on a preliminary basis aquifer zones which may be considered further for use in an aquifer storage and recovery (ASR) program by the Public Utilities Board (PUB) of the City of Brownsville (City). Specifically, this report addresses to the degree allowed by readily-available data, information on the extent, hydraulic character and water quality of specific water-producing zones which may be suitable for ASR purposes. Currently it is anticipated that this and other work will be used to assess the applications of ASR to meet PUB future water needs and assist in developing a field drilling and testing program to better identify the character and quality of potential ASR zones at selected sites. If test drilling results are favorable, a pilot ASR production well can be drilled and applications of ASR tested. For the test drilling program, currently two sites are being considered. Both sites are at the PUB's existing water plants, and have favorable access, a ready supply of potable water and likely favorable water disposal options. Therefore, where applicable, site-specific information on subsurface conditions beneath these two water plants are provided in this report.

Previous Investigations

Several previous ground-water investigations (see References) have been conducted in the immediate area of the City of Brownsville. The most applicable and site-specific work that was conducted in the immediate Brownsville area was conducted by the City of Brownsville in 1953, when they developed a well field consisting of about eight wells within the City. All of these wells were drilled and completed to a depth of approximately 200 feet below ground level. The wells were reported to only be used for a few years and were abandoned due to the brackish water produced. The current condition of these wells is unknown, but it is reported that the wells have been plugged.

More recently, the Texas Water Development Board (TWDB) conducted a detailed test drilling program in 1973 to investigate ground-water conditions in the City and extending approximately 15 miles to the west of the City. The results of this work was provided in TWDB Report 279. Several other investigations pertinent to this study, including work on a potable ground-water supply west of the City have also been conducted. However, most of the previous work has been limited to reasonably shallow depths, typically no more than about 200 to 400 feet below ground level.

This report provides a summary of the geohydrologic conditions in the Brownsville area based on readily-available information. As the available data allows, information is presented on the shallower ground-water systems and also for deeper aquifer zones which may be applicable for ASR use.

Regional Geohydrologic Setting

The Brownsville area lies in the Rio Grande embayment of the Gulf Coastal Plain. The Gulf Coastal Plain is characterized by a relatively flat, low-lying topographic surface which slopes gradually to the Gulf of Mexico. The major geologic units of importance are Quaternary and Tertiary deposits of Pliocene, Pleistocene and Recent age. These deposits dip and thicken towards the Gulf of Mexico so that the older formations dip more steeply than the younger ones. Locally, the occurrence of salt domes, faults and folds may cause reversals of the regional dip and thickening or thinning of the formations. These materials extend updip about 90 miles west of the City in western Starr County. Near and adjacent to the river, significant alluvial materials associated with the Rio Grande overlie the older deposits.

The Gulf Coastal Plain sediments and alluvial sediments are composed of complexly interbedded sedimentary deposits of gravel, sand, silt and clay of fluvial and deltaic origins. Historically, geologic strata from Miocene to Recent have been classified as the Gulf Coast Aquifer. However, these deposits have also been designated as the Lower Rio Grande Valley Aquifer and the Chico and Evangeline Aquifers. While the alluvium associated with the Rio Grande has a limited occurrence adjoining the river, the other sediments occur along the Gulf Coast throughout Texas. Table 1 provides a stratigraphic section of the geologic zones in the City of Brownsville area.

Geology in Study Area

Introduction

The geologic materials present in the Brownsville vicinity are Cenozoic in age. From shallowest to deepest, these geologic materials include Recent alluvium, the Beaumont and Lissie Formation of Pleistocene age, the Uvalde Gravel of Pleistocene or Pliocene age and the Goliad Formation of Pliocene age. Due to the extreme similarity of materials in the subsurface, delineation of the stratigraphic units of Pliocene, Pleistocene and Recent age is extremely difficult. Table 1 provides a stratigraphic section of the geologic materials. For purposes of this report, and application of ASR in the Brownsville area, two geologic/hydrologic units are designated, the alluvium of Recent age which is associated with Rio Grande deposition and which for purposes of this report has been further divided into the Gravel Zone and Intermediate Zone and a geologic unit identified herein as the Lower Zone which consists of the Beaumont, Lissie, Uvalde Gravel and Goliad Formations. Figure 1 provides a stratigraphic cross-section showing the general relationship of the different zones identified. These divisions are made due to the currently understood geology and hydrology of the Brownsville area and its applications to ASR. Further site-specific drilling and testing activities can result in better identification and refinement of site-specific zones suitable for ASR.

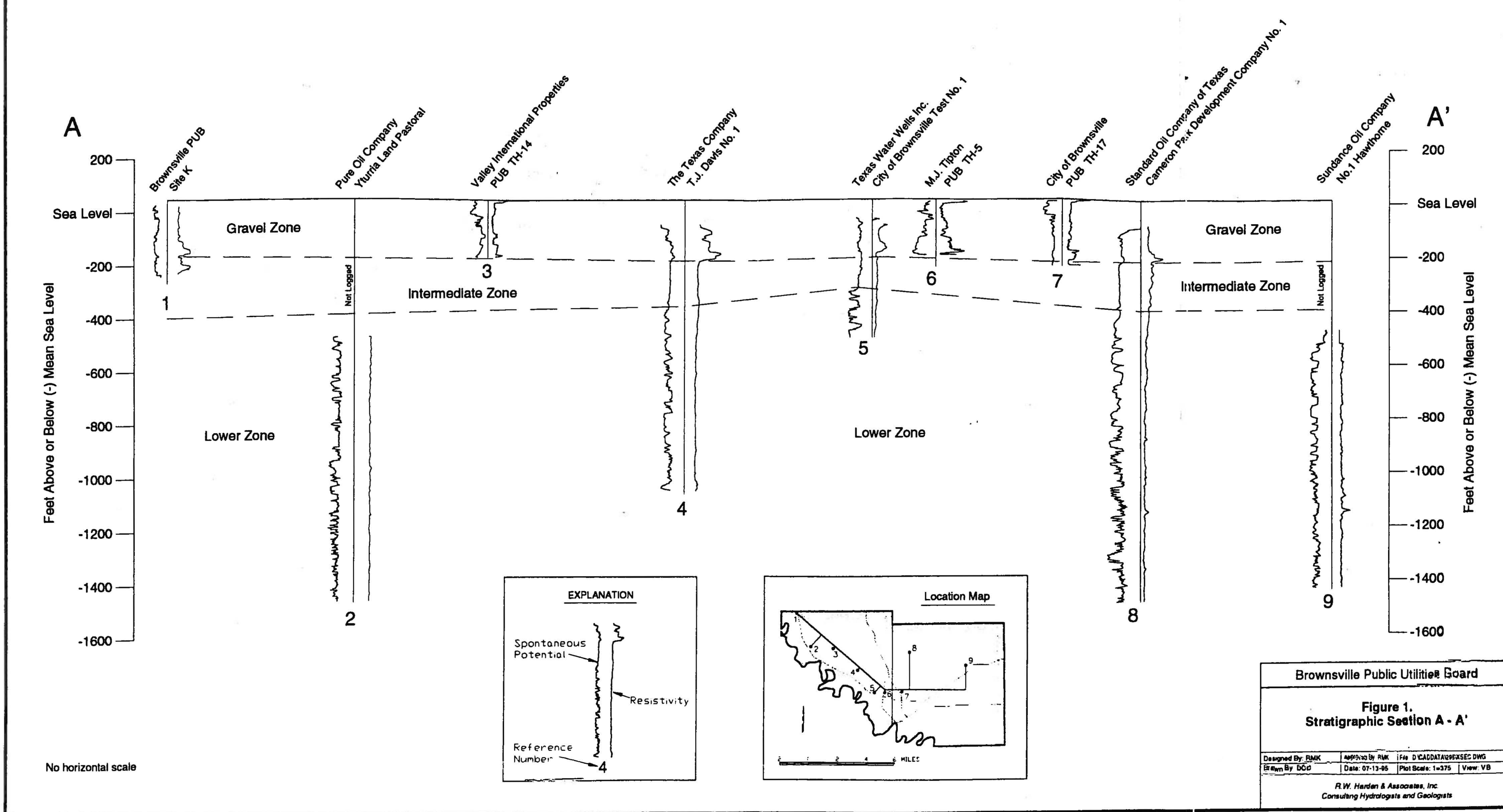
Alluvium

The alluvial deposits of Recent age consist of unconsolidated gravel, sand, silt and clay associated with floodplain and delta deposits of the Rio Grande. Materials are typically calcareous, gray and tan to dark brown. The sand is predominantly composed of quartz. The gravel includes sedimentary rocks from the Cretaceous

Table 1. Stratigraphic Section of the City of Brownsville Area

<table>
<tr><th>Era</th><th>System</th><th>Series</th><th>Stratigraphic Unit</th><th>Character of Material</th><th colspan="2">Geologic/Hydrologic Designations Used in this Report</th><th colspan="2">Geologic/Hydrologic Designation Used in TWDB Report 316</th><th>Geologic/Hydrologic Designation Used in TWDB Report 279</th></tr>
<tr><td rowspan="7">Cen-o-zoic</td><td rowspan="4">Quater-nary</td><td rowspan="2">Recent (Holocene)</td><td rowspan="2">Alluvium</td><td rowspan="2">Gravel, sand, silt and clay</td><td rowspan="2">Alluvium</td><td>Gravel Zone</td><td rowspan="4">Chicot Aquifer</td><td rowspan="7">Gulf Coast Aquifer</td><td rowspan="6">Lower Rio Grande Aquifer</td></tr>
<tr><td>Intermediate Zone</td></tr>
<tr><td rowspan="2">Pleistocene</td><td>Beaumont Formation</td><td>Mostly clay with some sand and silt.</td><td colspan="2" rowspan="4">Lower Zone</td></tr>
<tr><td>Lissie Formation</td><td>Clay, silt, sand, gravel and caliche</td></tr>
<tr><td rowspan="3">Terti-ary</td><td>Pleistocene or Pliocene</td><td>Uvalde Gravel</td><td>Sand and gravel</td><td rowspan="2">Evangeline</td></tr>
<tr><td>Pliocene</td><td>Goliad Formation</td><td>Clay, sand, sandstone, marl, caliche, limestone, and conglomerate.</td></tr>
<tr><td>Miocene</td><td>Miocene Formations Undifferentiated</td><td>Mudstone, claystone, sandstone, tuff, and clay.</td><td colspan="2"></td><td></td><td></td></tr>
</table>

Figure 1.   Statigraphic Section A - A'



and Tertiary and a wide variety of igneous and sedimentary rocks from Texas, New Mexico and Mexico (Fisher, 1976). The alluvium also includes materials from the Beaumont and Lissie Formations (Peckham, 1963).

The thickness of the alluvial deposits is difficult to estimate due to similarity with the underlying formations and is likely extremely variable. Previous investigators have indicated that the thickness ranges up to approximately 200 feet. However, recent work indicates that the thickness of the alluvial deposits can range from approximately 200 feet to 400 feet. It is believed the alluvium typically thins in a northerly and southerly direction away from the Rio Grande. Based on Bureau of Economic Geology mappings, the surface geology throughout the Brownsville area is this alluvial material. This alluvial material extends about 20 miles to the north of the City, and based on limited information, appears to extend to a similar distance to the south. The lateral extent of these alluvial deposits narrows upstream. At Los Indios, approximately 20 miles west of Brownsville, the alluvium extends only approximately 5 to 10 miles north of the river. The most western extent of these alluvial deposits occurs in far western Hidalgo County, near Sullivan City.

This alluvial material was deposited by the Rio Grande which accounts for a wide variation in depth, thickness and composition. Data indicate wide variations in thickness and type of materials encountered in the alluvium within short distances. The complex series of gravel, sand, silt and clay zones throughout the entire thickness of this alluvial material results in a complex geohydrologic system with numerous water-bearing zones. For ASR applications, reasonably prolific and isolated sand and/or gravel zones are needed. Two zones have been identified, which are believed to have the potential for ASR applications. These two zones are herein referred to as the Gravel Zone and Intermediate Zone. The Gravel Zone is composed of alluvial materials. The Intermediate Zone also is believed to be alluvial materials, but in some areas may be composed of Pleistocene materials. Shallower zones, above approximately 125 feet in depth, are generally too shallow, thereby limiting production, and have poorer quality water to be favorable for application of ASR technology.

Gravel Zone: The shallowest identified zone which may have applications for ASR is identified herein as the Gravel Zone. The Gravel Zone consists of unconsolidated gravels, sometimes exceeding two inches in diameter with interbedded fine sands. The Gravel Zone usually occurs between depths of approximately 150 and 200 to 225 feet below ground level in the study area. This Gravel Zone is erratic in occurrence and based on work done approximately 15 miles to the west is typically only found in sufficient thicknesses suitable for large production wells at about 50 percent of the sites drilled. In the Brownsville area, it is reported that there is a gradual lessening of coarser materials towards the Gulf. Test holes drilled by the TWDB indicated mostly fine sand and clay in the southeastern most test holes (Preston, 1983). These conclusions could not be confirmed during this investigation. However, based on TWDB work and results of City of Brownsville work conducted in the 1950's, it is believed that sites in the immediate Brownsville area can be found having thick sections of very coarse gravel which will result in favorable production well characteristics. Two areas believed to have favorable Gravel Zone characteristics for large production are in the area of the City's old well field (northwest portion of the City) and at the PUB's Water Plant No. 2. However as the Gravel Zone is extremely variable over short distances, even drilling in the vicinity of these two sites does not guarantee finding favorable conditions in the Gravel Zone.

Thicknesses of gravel in the Gravel Zone can vary from near zero to about 50 feet in thickness. Where the gravel is not present, the zone typically consists of very fine to medium grained sands with occasional interbedded clays and silts.

Intermediate Zone: For purposes of this report the Intermediate Zone is composed of geologic materials below the Gravel Zone and to about 400 feet in depth. The Intermediate Zone typically overlays older Pleistocene materials and typically consists of complexly interbedded fine to medium grained sand and, on occasion, some minor amounts of gravel. In areas, the Intermediate Zone may be composed of Pleistocene materials. Information on the Intermediate Zone is limited as most past drilling conducted for ground-work exploration in the area stopped at the Gravel Zone which is the zone typically used for water production. It is believed that the Intermediate Zone has a similar lateral extent as the Gravel Zone, as it is believed to be associated with Rio Grande deposition. However, some investigators (Preston, 1983 and others) have indicated that this Intermediate Zone may actually be composed of older Pleistocene Beaumont and Lissie Formations. Test drilling conducted to the west indicates some very coarse gravels in the Intermediate Zone on occasion, generally indicating more of a likelihood that it is associated with the Rio Grande Alluvium. However, due to the variable erosional surface of the underlying Pleistocene beds the Intermediate Zone at any specific site may consist of alluvial materials or a combination of alluvium and older Pleistocene materials.

The Intermediate Zone generally extends from a depth of approximately 200 feet to about 400 feet below ground level. The zone consists of a complex series of interbedded gravels, sands, silts and clays. From limited information, it appears that the Gravel Zone and the Intermediate Zone are more typically geologically and hydrologically separated, locally, by low permeability clays. However, on occasion, it appears that the Gravel Zone and the Intermediate Zone can be in geologic/hydraulic contact. The Intermediate Zone has from less than a few tens of feet up to approximately 150 feet of sands and, on occasion, some gravel within its thickness. Interbedded silts and clays are common. The character and composition of the Intermediate Zone is extremely variable in its composition and appears to be quite variable over relatively short distances. At many sites the Intermediate Zone may be unfavorable for ASR use due to insufficient water sands. This would especially be true if at any given site the Intermediate Zone consisted of older Pleistocene materials. Very limited data within the City indicates this may be the case. However, several miles northwest of the City the Intermediate Zone is known to have coarse gravels of equal or greater thickness than the Gravel Zone.

The Lower Zone

The Lower Zone consists of Pleistocene and Pliocene Coastal Plain sediments. The Lower Zone is comprised of from shallowest to deepest the Beaumont Formation, Lissie Formation, Uvalde Gravel and Goliad Formation. The depth of this zone is in excess of a few thousand feet. For purposes of this study we have limited the investigation to approximately 1,500 feet in depth. The Lower Zone is made up of a complex depositional framework of interbedded layers and lenses of predominately sand, silt and clay. Directly beneath the alluvial materials lies the Beaumont Formation. The thickness of the Beaumont is extremely variable as in some places it has been eroded and replaced by alluvial materials, especially in the lower reaches of the Rio Grande. However, in areas of far eastern Cameron County, it is believed the Beaumont can reach thicknesses of up to approximately 270 feet (Rose, 1954). The Beaumont Formation consists predominately of clay, silt and sand of mainly stream channel, point bar, natural levee and back swamp deposits (Fisher, 1976). Typically, the Beaumont consists of massive clay with thin lenses and layers of sand. However in the Rio Grande Valley the portion of sand is much larger and may contain up to 80 percent sand (Sellards, 1958). The sand is typically light gray or bluish and medium to fine grained. The sand is mostly quartz and chert grains with a small amount of pyrite and mica. The clay is typically purple, gray and red and calcareous in composition. The clay is generally of low shear strength, high plasticity, high compressibility and of high shrink-swell potential (Sellards, 1958). Table 2 provides the composition of materials from the Beaumont Formation in the Houston area.

The Beaumont clay is underlain conformably by the Lissie Formation, which consists of alternating layers of unconsolidated sand, silt and clay, typically bluish to greenish gray and red and oftentimes interbedded with sandy caliche. The Lissie Formation is typically composed of 60 percent sand, 20 percent sandy clay, 10 percent gravel and 10 percent clay (Sellards, 1958). Sands are typically very fine to medium grained, with some gravel. Table 2 provides the composition of a typical sample.

Beneath the Lissie Formation, is the Uvalde Gravel. The Uvalde Gravel consists of chert, well rounded pebbles and cobbles (Fisher, 1976). However, the thickness is typically not in excess of 20 feet and is likely not present throughout most of the study area. Underlying the Uvalde Gravel is the Goliad Formation. The Goliad Formation typically consists of about 10 percent clay, 85 percent sand, gravel and sandstone, and 15 percent calcium carbonate (Sellards, 1958). The clay is typically pink and green. The sand and sandstone is typically grayish, medium to very course grained, sometimes cemented, cross-bedded, mostly quartz with black and red chert. In South Texas, the sands and gravels are mixed with as much as 20 percent caliche (Sellards, 1958). Table 2 provides the composition of a typical

Table 2. Example Mineral Composition of Lower Zone

Beaumont Formation

	Percent
Silica	85.6
Alumina	6.71
Ferric Oxide	1.44
Lime	Trace
Magnesia	0.43
Soda	0.65
Potash	0.50
Titanic acid	1.00
Water	3.10

Lissie Formation

	Percent
Clay	22
Quartz	63
Chert	10
Chalcedony	3
Feldspar	1
Limonite	1

Goliad Formation

	Percent
Clay	50
Quartz	25
Feldspar	14
Pegmatite	5
Chert	5
Limonite	1

Source: Sellards, 1958

sample. The Beaumont, Lissie and Goliad Formations are difficult to differentiate in the subsurface therefore, their thicknesses cannot be accurately determined. However, the combined thickness of the three formations can be in excess of 3,000 feet. Based on geophysical log analyses, it is estimated that approximately 40 percent of the combined Lissie and Goliad Formations have sand capable of yielding reasonable quantities of water to wells. Individual sand zones within the Beaumont, Lissie and Goliad formations may be applicable aquifer zones for ASR use.

The Lower Zone of Pleistocene and Pliocene materials occurs throughout the Texas Gulf Coastal Plain. The outcrop of the Lissie Formation begins approximately 32 miles west of Brownsville, while the outcrop for the Goliad Formation begins approximately 65 miles west of Brownsville. The dip of these beds is difficult to determine because of the interbedded nature of the deposits, but it is believed to be on the order of approximately 20 feet per mile (Preston, 1983).

The Bureau of Economic Geology's Core Research Center in Austin, Texas has several dozen cores in Cameron County available for inspection. While not included in the study, more detailed and site-specific information may be available from that source.

Ground-Water Conditions in Study Area

<u>Identification of Important Aquifer Zones</u>

The application of ASR technology requires reasonably prolific, preferably isolated water-bearing materials. Based on current information, three potential ASR zones have been identified and are referred to herein as the Gravel Zone, Intermediate Zone, and Lower Zone. Shallower water-producing zones above the Gravel Zone are not considered due to their lower productivity, and poorer quality water. Zones deeper than the Lower Zone, (deeper than approximately 1,500 feet below ground level) are not further considered as it is believed that if the Lower Zone is selected as an ASR zone, sufficient prolific sand units can be identified and targeted within the interval below the Intermediate Zone and above 1,500 feet. Based on current information from the various studies previously conducted, it is believed that at any given site sufficiently thick and course sand or gravel suitable for ASR purposes may or may not be present in the Gravel and Intermediate Zones. Both of these zones appear to be extremely variable spatially. The lateral extent and continuity of sand units within the Lower Zone are very likely more consistent and favorable. Also, conditions favorable for large production wells can likely be found at most sites drilled into the Lower Zone.

Based on the limited geologic, hydrologic and water quality information available, it is estimated that the Gravel Zone and the Intermediate Zone typically act as separate hydrologic units locally. However, regionally, these zones probably act similarly and as a single leaky aquifer system and on occasion are hydraulically well-connected at selected sites. Mostly, the Lower Zone acts as a totally separate hydrologic unit with minimum hydraulic communication between it and the shallower zones. To the extent data allows, the following provides information on the hydraulic characteristics, water use and water quality of each of the identified zones.

Hydraulic Characteristics

Gravel Zone: Of the three targeted ASR zones, the hydraulic conductivity and transmissivity are best defined in the Gravel Zone. The Gravel Zone is the primary zone where past test drilling and well construction activities have been conducted. Due to production characteristics, better water quality and the difficulty in maintaining drilling fluid circulation to drill through the Gravel Zone, deeper geologic units have not been investigated. The hydraulic characteristics of the Gravel Zone are dependent on the amount and thickness of gravel encountered at each site. Where no gravel is found, only silts, clays and fine sands, the hydraulic conductivity and transmissivity of the Gravel Zone is very low. Where sufficiently thick gravel is found, the transmissivity and related production capability can be quite high. Hydraulic characteristics have been determined based on about 12 tests conducted in Cameron and Hidalgo Counties in the Gravel Zone. These aquifer tests indicate hydraulic conductivities ranging from approximately 50 gpd/ft^2 (gallons per day per foot squared) to about 4,000 gpd/ft^2. Transmissivities range from approximately 4,000 gpd/ft (gallons per day per foot) to about 80,000 gpd/ft depending on types of materials composing the Gravel

Zone. Most significant to this study are several pumping tests conducted by the U.S. Geological Survey and TWDB on City of Brownsville wells. The U.S. Geological Survey reported an average transmissivity of 54,000 gpd/ft, a hydraulic conductivity of 900 gpd/ft^2 and a storage coefficient of .00044 (Preston, 1983). The TWDB test results indicated an average transmissivity of 80,000 gpd/ft, an approximate hydraulic conductivity of about 3,000 gpd/ft^2 and an average storage coefficient of 0.000025 (Preston, 1983). Records indicate these wells were constructed only in the Gravel Zone and, based on test results, in reasonably thick, coarse gravels. These test results likely represent more prolific sites and the average transmissivity of the Gravel Zone likely is less. On average, it is estimated that a reasonably suitable site for a production well in the Gravel Zone would have a minimum of about 20 feet of very coarse gravel and a transmissivity of approximately 30,000 gpd/ft. The Gravel Zone is under artesian conditions in the Brownsville area, and a storage coefficient of about 0.0005 is estimated.

Intermediate Zone: No pump test information is available specifically for the Intermediate Zone. The hydraulic characteristics of the Intermediate Zone will vary dramatically depending on the amount and character of sand and gravel in the zone at each site. At many drill sites, the Intermediate Zone may have, only minor amounts of sand, very low transmissivity and may not be suitable for ASR use. In fact, very limited data indicates that within the City this may typically be the case. However, based on analysis of geophysical logs and some specific capacity information representing the Intermediate Zone in areas to the northwest of Brownsville, it is believed that fine to medium grained sands where present may have a permeability on the order of 150 gpd/ft^2 while coarser gravels, if present, may have hydraulic conductivities equal to or in excess of the Gravel Zone. With sufficient sand, we estimate transmissivities at better sites in excess of 10,000 gpd/ft when about 70 feet of sand is present. However, this can vary considerably and transmissivities at sites having significant gravels may exceed 30,000 gpd/ft. One well located several miles northwest of the City and reported to be screened in the Intermediate Zone but which may also be screened in the Gravel Zone was tested to have a transmissivity of 100,000 gpd/ft. This well had over 25 feet of large gravel in the Intermediate Zone, thus indicating the extreme variability of this zone and the potential for it to be as productive or more productive than the Gravel

Zone. The Intermediate Zone is under artesian conditions and a storage coefficient on the order of 0.0005 is estimated.

Lower Zone: No site-specific information is available on the hydraulic characteristics of the Lower Zone in the vicinity of Brownsville, as this zone contains poor quality water and has not been extensively investigated for ground-water production purposes. However, four pumping tests were conducted in sand zones in the Lower Zone in Willacy and Hidalgo Counties. In addition, as the Lower Zone is part of the Gulf Coastal Plain Aquifer, assumptions and preliminary analysis can be made regarding the hydraulic characteristics of the Lower Zone from data available to the north and as estimated by Ryder (1988). Based on this information, the hydraulic conductivity in the cleaner, more permeable sand zones ranges from about 80 to 150 gpd/ft^2. Where the sands contain clay, silt and/or clay breaks, hydraulic conductivity will be significantly less. The transmissivity of Lower Zone wells is dependent on how much sand is present at the site and is screened in a production well. Approximately 40 percent of the Lower Zone is sand and if 1,000 feet of material were screened in a well, a transmissivity of on the order of 40,000 gpd/ft is estimated. However, contiguous sands in the Lower Zone are typically on the order of 30 to 70 feet thick and rarely more than 100 feet thick. For each clean sand zone averaging 50 feet in thickness, a transmissivity of about 6,000 gpd/ft is estimated. However, values will vary considerably based on sand character and thickness. The Lower Zone is under artesian conditions. While no site-specific storage coefficient information is available on the Lower Zone, Carr (1985) estimated the average storage coefficient in the Chico aquifer to be 0.0004 and in the Evangeline aquifer to be 0.0005. A storage coefficient of about 0.0005 appears applicable.

Water Levels and Subsurface Flow

Gravel Zone: Depth to water in wells in the Gravel Zone is generally shallow, typically ranging between 10 and 30 feet below ground level, depending principally on surface elevation and relationships to recharge and discharge areas. Water-level elevations typically range from approximately 20 feet above sea level in the western portion of the study area to approximately 10 feet above sea level near and in Brownsville. Based on water-level measurements between 1953 and 1987, the maximum water-level fluctuation appears to be approximately 12 feet.

Generally, ground water in the Gravel Zone moves from areas of recharge to areas of discharge. No detailed mapping of the potentiometric surface in the Gravel Zone has been conducted in Brownsville. Preston (1983) mapped the potentiometric surface in the Gravel Zone in the western portion of the City and extending approximately 20 miles to the west. Generally, ground water in the Gravel Zone principally moves to the east and southeast, except where locally it is modified by local recharge or discharge conditions. In and near Brownsville, it is believed that the water generally moves south and southeast, however, this can be significantly modified by local discharge conditions. It is believed that the principal recharge to the Gravel Zone occurs where the gravel outcrops, probably several tens of miles west of Brownsville. In addition, based on water quality and potentiometric mappings conducted by Preston (1983) it appears that there is also some leakage from the Rio Grande into the Gravel Zone west of Brownsville. Nearer to Brownsville, however, it appears that the Rio Grande may be acting as a point of discharge as the hydraulic gradient becomes steeper and slopes towards the river.

Peckham (1963) indicates a hydraulic gradient in the Gravel Zone of between 1 and 2.5 feet per mile in western Cameron County. Preston (1983) reports a hydraulic gradient of generally less than about 10 feet per mile.

Based on a hydraulic gradient of approximately 0.002 ft/ft and using a hydraulic conductivity of 2,000 gpd/ft^2 which would be typical for gravel at an acceptable ASR well site and using a porosity of 0.25, we estimate a typical water velocity in the Gravel Zone where coarse gravels are present of about 800 ft/yr. (feet per year). However, locally, due to significantly higher hydraulic conductivities in the Gravel Zone, and/or steeper hydraulic gradients due to local discharge, rates in excess of 1,500 ft/yr. are possible. At sites where the hydraulic gradient is flatter or where the gravels are not present, movement rates are much slower.

Intermediate Zone: Little information is available regarding the depth to water in wells and elevation of the potentiometric surface in the Intermediate Zone in the study area. However, work conducted approximately 20 miles to the west of Brownsville indicates that the depth to water in the Intermediate Zone approximates the depth to water in the Gravel Zone. Data in the Villa Nuevo area, approximately eight miles northwest of the City, indicates a depth to water in the Intermediate Zone of approximately 16 feet below ground level. It is estimated that depth to water in the Intermediate Zone will range from 10 to 30 feet below ground level. This is consistent with depth to water in the Intermediate Zone further to the west. In addition, studies indicate that the alluvial materials have lower hydraulic head with depth. However, the head differences are likely only on the order of a couple of feet over the entire thickness of the alluvial materials.

Generally, it is believed that the potentiometric surface and hydraulic gradients in the Intermediate Zone are very similar to the Gravel Zone, with the water generally moving to the east and southeast in the immediate Brownsville area. Movement rates in the Intermediate Zone are largely dependent on the character and type materials found at sites. On average, a movement rate in the Intermediate Zone of about 60 ft/yr. is estimated, assuming a hydraulic gradient of 0.002 ft/ft, a porosity of 0.25 and a hydraulic conductivity of approximately 150 gpd/ft^2. However, where the hydraulic gradient is significantly steeper, and/or where the Intermediate Zone contains significant amounts of gravel, the movement rates will be significantly greater. Where the Intermediate Zone contains only silt and clay movement rates will be significantly lower.

Lower Zone: No specific information is available regarding the depth to water, water-level elevation or hydraulic gradient of the potentiometric surface in the Lower Zone.

Based on regional comparisons, depth to water in wells is estimated to be shallow, generally less than about 30 feet below ground level and may be slightly above ground level in some sand zones and locations. Based on information on Pleistocene and Pliocene materials in other areas along the Gulf Coast, it is believed that the general ground-water movement is to the east towards the Gulf of Mexico. This is consistent with work conducted by Ryder (1988). Ryder (1988) also estimated a hydraulic gradient in the Brownsville area in the Lower Zone of approximately 0.0002 to 0.0003 ft/ft. Assuming this gradient, a hydraulic conductivity of 125 gpd/ft^2 and a porosity of 0.25, a typical ground-water movement rate in clean sands of the Lower Zone is probably less than about 10 ft/yr. It must be emphasized that little local information is available on water levels, the potentiometric surface, and movement rates in these sediments

Ground Water Use

In the immediate vicinity of Brownsville, there is little ground-water use due to its poor quality. The City's eight production wells, drilled in 1953 because of severe drought conditions and low flows in the Rio Grande, have not been used for many years because of their poor water quality.

There is no known or recorded significant use of ground water within the City. Ground-water use records (current as of 1973) are old and therefore should be updated. Any ground water that is in use is likely of small quantity. Records available indicated that there are likely many abandoned, unplugged wells within and near the City.

To the west, and northwest of the City, the water quality improves, and there is some use of ground water from the Gravel Zone, principally for small domestic supplies, but also for irrigation. However, most of the irrigation wells to the west of the City are not currently used as surface water is the dominant source of irrigation water. There is little production from the Intermediate and Lower Zones due to poor quality water and the expense of drilling deeper. The little that is produced from these zones occurs north and west of the City from wells which also produce water from the Gravel Zone. The use or former use of wells in the area is as follows (Preston, 1983):

Use	Percent
Domestic and Livestock	42%
Irrigation	42%
Industrial	6%
Public Supply	10%

Almost all of these wells are north and northwest of the City and include wells west of the City to Los Indios and north of the City to San Benito.

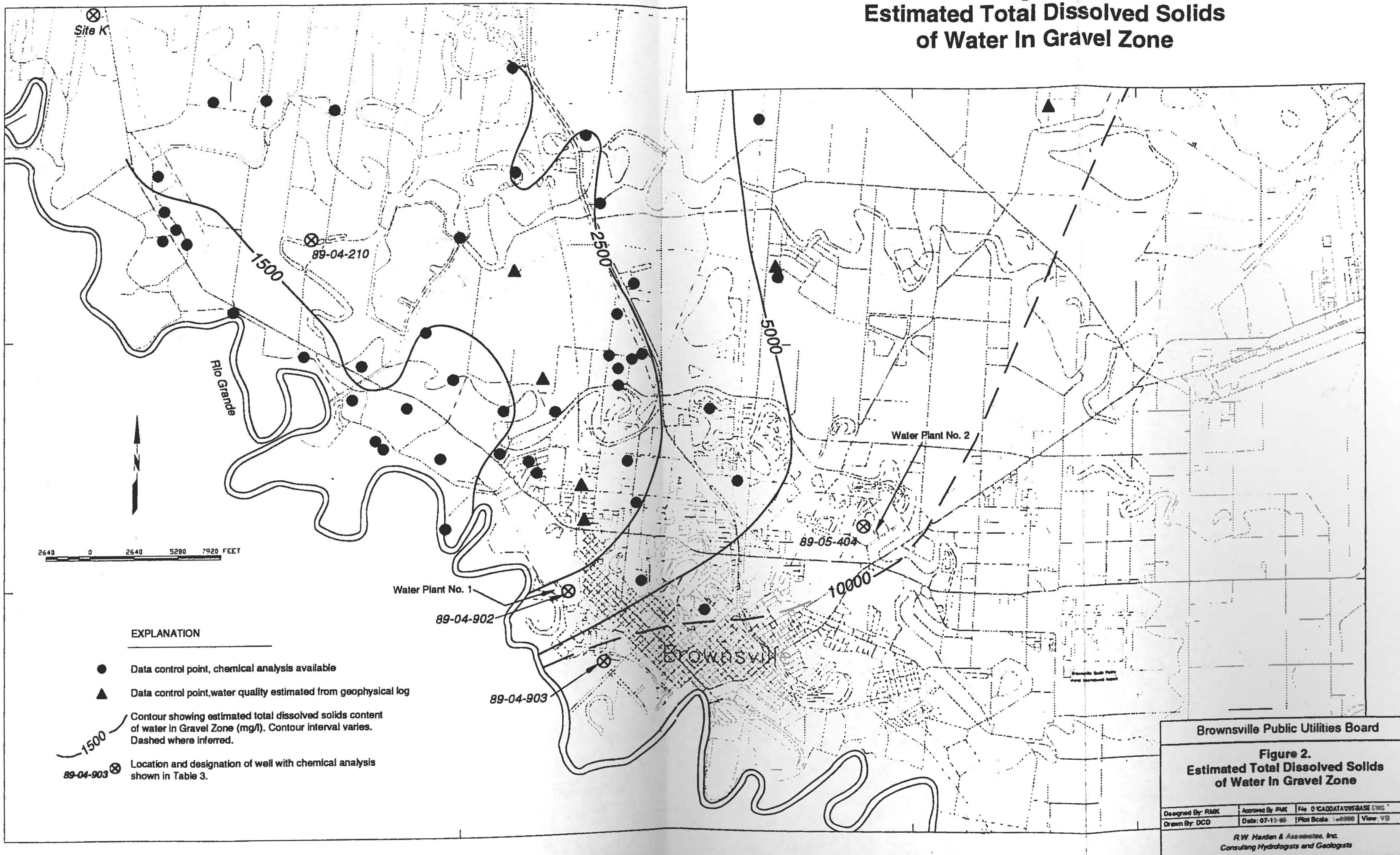
Water Quality

Introduction: Ground-water quality in the Brownsville area is characterized by a wide variation in chemical composition. The water quality varies significantly, both laterally and vertically, generally increasing in mineralization from west to east and also vertically, generally increasing in mineralization from shallow to deep. The zones identified for investigation for ASR purposes are generally overlain by water-bearing zones of mostly poorer water quality. The water quality in these shallower zones can range from about 1,000 mg/l (milligrams per liter) to over 35,000 mg/l total dissolved solids. In much of the area, especially the western study area, this shallow water is poorer in quality than water in the Gravel Zone. Water-bearing zones deeper than approximately 1,500 feet are also present and generally have higher mineralization than the targeted ASR zones.

Existing information appears adequate to identify and quantify the water quality in the Gravel Zone. Specific water quality in the Intermediate and Lower Zones are limited to non-existent, and estimates can only be made based on available geophysical logs and experience. The following provides information with regard to water quality in the targeted zones.

Gravel Zone: Water quality in the Gravel Zone is reasonably well mapped and is mostly based on chemical analyses from wells in the area. Figure 2 shows the total dissolved solids of water estimated to be in the Gravel Zone. Much of this information comes from historical records on wells in the area. However, due to the construction of many of the wells and the overlying poorer quality water, the reliability of any selected analysis is questionable as to whether it actually represents water quality in the Gravel Zone. However, the data as a whole indicates an increasing trend in mineralization of water in the Gravel Zone from west to east, as shown on Figure 2. Data also indicates large variability in water quality locally in the Gravel Zone and exceptions to this overall trend are possible and likely. In addition, locally, surface water features such as reservoirs and resacas may affect water quality in the Gravel Zone.

Figure 2.
Estimated Total Dissolved Solids of Water In Gravel Zone



Also shown on Figure 2 are selected wells for which specific chemical analyses have been provided in this report. The chemical analyses of water from these wells are provided in Table 3 and generally show the range of individual constituents in water from the Gravel Zone. Table 3 also shows the Gravel Zone water quality at the PUB's two water plants. The water quality analyses provided in Table 3 for the Gravel Zone are based on test drilling conducted by the TWDB in 1973, and are believed to be representative of the Gravel Zone. TWDB analyses were selected rather than water quality analyses from local domestic wells as the producing intervals are known and data quality is considered good.

In the western portion of the study area, the water is predominantly a sodium sulfate type water. However, as the mineralization increases, the water gradually changes to a sodium chloride type water. The water typically has significant concentrations of iron and manganese. Based on available data, the mineralization gradient for water in the Gravel Zone increases significantly in the City. The reason for this is unknown.

Intermediate Zone: Water quality in the Intermediate Zone is specifically known at only one site in the western portion of the study area and is herein identified as Site K. Analytical results for this site are shown on Table 3. The location of this site is shown on Figure 2. This site was drilled during the PUB's well field investigations and represents water quality in the Intermediate Zone. Based on work conducted to the west, generally the water quality in the Intermediate Zone in the western portion of the City and study area is slightly higher in mineralization than in the Gravel Zone, but is generally of the same type water, principally being a sodium sulfate type water. In and around Brownsville, no water quality analyses are available which are believed to represent the Intermediate Zone. It is estimated that in the Brownsville area, the lateral gradient of the water quality in the Intermediate Zone is similar to that in the Gravel Zone, especially where the Intermediate Zone is composed of alluvial materials. However, it is estimated that the water quality will be slightly to significantly higher in mineralization than in the Gravel Zone, depending on depth. The water in the Intermediate Zone will likely increase in mineralization and change to a sodium chloride type water eastward and with depth. In the immediate

Table 3. Representative Water Quality

Well Designation:	89-04-210	89-04-902 (Water Plant No. 1)	89-04-903	89-05-404 (Water Plant No. 2)	Site K	88-59-411*
Zone:	Gravel	Gravel	Gravel	Gravel	Intermediate	Lower
Date Sampled:	4/03/73	6/12/73	4/02/73	2/22/73	5/07/94	6/04/89
Producing Interval (Ft. BGL):	194-217	200-220	166-188	165-225	220-260	932-952
Constituents:						
Laboratory pH, units	8.2	8.2	7.8	7.4	8.0	7.7
Total Dissolved Solids, mg/l	2,280	2,860	11,900	8,400	1,480	26,277
Total Alkalinity, mg/l ($CaCO_3$)	402	224	328	246	370	95
Total Hardness, mg/l ($CaCO_3$)	476	171	2,800	1,990	278	4,347
Specific Conductance, umhos	3,060	4,170	12,000	10, 540	2,200	53,760
Cations:						
Boron, mg/l	2.5	2.0	6.6	3.6	<1	–
Calcium, mg/l	90	14	510	369	61	1,048
Magnesium, mg/l	61	27	370	258	30.5	420
Potassium, mg/l	–	–	–	16	7.1	34
Silica, mg/l	34	<1	36	19	30.4	12
Sodium, mg/l	600	1,010	3,260	2,260	440	7,946
Anions:						
Bicarbonate, mg/l (HCO_3)	490	273	400	300	451	116
Chloride, mg/l	357	1,000	5,430	3,680	229	11,904
Flouride, mg/l	0.9	1.2	1.2	1.7	0.72	0.9
Nitrate, mg/l (NO_3)	0.5	0.5	5.5	<0.4	0.95	0.04
Sulfate, mg/l	890	670	2,080	1,610	481	4,855
Metals:						
Total Iron, mg/l	0.82	–	1.6	3.74	0.43	–
Total Manganese, mg/l	–	–	–	<0.05	0.052	–

* Site located approximately 20 miles west of Brownsville in Los Indios area.

Brownsville area, it is estimated that water quality in the Intermediate Zone ranges from about 1,500 mg/l to about 15,000 to 20,000 mg/l total dissolved solids, depending on depth, location in Brownsville and type geologic materials present. The water is believed to have significant concentrations of iron and manganese.

Lower Zone: No site-specific water quality information is available for the sands in the Lower Zone in or near the Brownsville area. Mineralization of water in the Lower Zone probably increases from shallow to deep and likely west to east. Based on analyses of geophysical logs, it is estimated that in the immediate Brownsville area, at a depth of about 400 to 600 feet below ground level, water in the Lower Zone will exceed 20,000 mg/l total dissolved solids. Water quality estimates from geophysical logs are only approximations and as such should be used accordingly. Estimates of water quality with depth for waters above 20,000 mg/l total dissolved solids were attempted but could not be made from available geophysical logs, due to the presence of clay and thin-bedded sand zones, the use of conflicting drilling fluids, and/or electrochemical effects.

Water quality in the Lower Zone is estimated to be primarily a sodium chloride type water. Shown in Table 3 is some water quality which we believe represents typical individual constituent concentrations for water in the Lower Zone having a total dissolved solids of about 26,000 mg/l. These data were obtained from a test hole drilled approximately 20 miles to the west of Brownsville by the TWDB. Water in the Lower Zone having higher total dissolved solids will likely principally have increases in sodium and chloride concentrations.

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Texas Water Development Board, undated, located and plotted well records, Grids 89-04 and 89-05, file data.

Geophysical Logs for water, oil and gas test holes, including:

City of Brownsville, P.U.B. Site K
City of Brownsville, P.U.B. TH-17.
City of Brownsville/TWDB:

88-60-806	89-04-628
88-60-902	89-04-629
89-04-208	89-04-630
89-04-209	89-04-631
89-04-210	89-04-902
89-04-211	89-05-102
89-04-308	89-05-404
89-04-309	89-05-405
89-04-510	89-05-701
89-04-627	89-05-903

City of Brownsville Water Well 1
City of Brownsville Water Well 3

City of Brownsville Water Well 4
City of Brownsville Water Well 6
City of Brownsville Water Well 7
City of Brownsville Water Well 8
Discorbis Oil Company, Granada Unit 1
Engelke, R. H., City of Brownsville, No. 1
Grand-Lienard Water Well 2
Pure Oil Company, Ytussia Land Pastoral.
Sohio Petroleum Company, First National Bank No. 1
Standard Oil Company, Cameron Park Development Company No. 1
Sundance Oil Company, Gonzales No. 1
Sundance Oil Company, Hawthorne No. 1
Sundance Oil Company, Hawthorne No. 2
Tejas Production Company, Thelma, Dawson No. 1
The Texas Land Company, T. J. Davis No. 1.
Texas Water Wells, Inc., City of Brownsville Test No. 1.
Tipton, M. J., P.U.B. TH-5
Turnbull & Zoch, Loop Brothers No. 1
Valley International Properties, P.U.B TH-14.
Wardner Water Well 5

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TECHNICAL MEMORANDUM

CH2M HILL

PREPARED FOR: Brownsville PUB

PREPARED BY: CH2M HILL

DATE: August 23, 1995

SUBJECT: Geochemical Evaluation - Brownsville ASR Project

PROJECT: 116700.C0.ZZ

Summary

Considering the historical groundwater quality information and recent treated water chemistry, recharge of the aquifer with treated water near Water Treatment Plant (WTP) No. 1 is more desirable from a geochemical point of view than near WTP No. 2. A significant reduction in total dissolved solids (TDS) and other water chemistry constituents will likely result from recharging the Gravel Zone using treated recharge water from either treatment plant with a total dissolved solids (TDS) of less than about 2,000 milligrams per liter. The initial recharge rate should be relatively slow, increasing to the design recharge rate over a period of a few days to minimize the instability of clays attached to the aquifer particles. The actual composition and stability of the clays is unknown but experience in other areas suggest that the slow initial recharge may be important in the successful recharge of the aquifer.

Recharge Water

Six water analyses of raw Rio Grande water (1991 through 1995), four treated water analyses from the WTPs (WTP No. 1, 6/7/93 and 7/31/95, WTP No. 2, 9/8/93 and 7/31/95), and a recent treated water analysis (WTP No. 1 and No. 2, 8/95) were included in this preliminary geochemical evaluation. In addition, paired raw and treated water analyses for turbidity, alkalinity, and pH from both WTPs were also available.

The Rio Grande river water chemistry has a relatively broad range in TDS (1,350 to 2,464 milligrams per liter (mg/L)) but relatively minor, but important, changes in ionic percentages. Water with a TDS less than about 2,000 mg/L has a dominant water chemistry involving sodium, sulfate, and chloride, in their order of importance. Above about 2,000 mg/L TDS, sodium is the dominant cation but chloride is higher than sulfate. The implication is that sulfate has reached a solubility limit with calcium to form gypsum, a hydrated calcium-sulfate mineral. This is confirmed by the decrease in calcium percentage from the mid 30s to about 29 percent. This same mechanism has and is probably currently occurring in the aquifer where the TDS increases above about 2,000 mg/L. Cements in the aquifer therefore will range from a calcium-carbonate to calcium-sulfate.

The Rio Grande water also has a near neutral to alkaline pH. At the near neutral pH, calcium-carbonate is probably near or at equilibrium with the water chemistry. However, at the higher pH (above about 8.0), calcium-carbonate is probably precipitating from the water. Therefore, when the water with a high pH is treated, calcium-carbonate probably precipitates somewhere in the treatment cycle. When water with the highest pH is treated, calcium-sulfate may also be precipitating.

The treated water from both treatment plants indicate that about half or more of the bicarbonate is missing from the treated water and the pH has become slightly acidic to about neutral. Both of these characteristics are at least partially beneficial for using the water for recharge purposes. The lower alkalinity and low to near neutral pH will reduce the tendency for calcium-carbonate precipitation. The lower alkalinity is the most important because, even if calcium-carbonate precipitates, the amount of potential precipitation is probably of minimal importance. The treatment plant also reduces the turbidity about two orders of magnitude which is of considerable benefit to the success of the recharge project.

The decrease in the pH of the raw water from above 8.0 to about 7.4 or 7.5 is beneficial because it also reduces the tendency for calcium-carbonate to precipitate, but a decrease to less than about 6.8 can present a problem. The pH of the recharge water should be nearer neutral pH to reduce the potential of the recharge water in dissolving calcium-carbonate in the aquifer (creating carbon dioxide gas and temporarily reducing permeability) and/or increasing the iron and manganese concentrations. It is important that when the pH is adjusted, the pH be as near 7 as possible. A pH range from about 6.8 to 7.2, which is the pH range of the treated water in 1995 would be the best range for recharge. This pH range minimizes the precipitation of calcium-carbonate and will result in the maximum stabilization of iron and manganese in the aquifer.

Recharge with treated water with a TDS less than 1,500 mg/L is preferred and above about 2,000 mg/L discouraged because of the tendency for calcium-sulfate precipitation in the aquifer. The treated water sampled during 1995 is expected to represent the TDS of the recharge water. The amount of available calcium and sulfate is sufficiently high in the greater than 2,000 mg/L TDS water to potentially cause significant loss in permeability where the recharge water and in situ groundwater are in contact.

The recharge water from WTP No. 1 is a sodium-sulfate-chloride water chemistry type and from WTP No. 2, a sodium-chloride type. A relatively low calcium and bicarbonate was observed in the treated water from both treatment plants. All other parameters analyzed in the samples of treated water collected in July 1995 indicate reasonably low concentrations relative to the historical Rio Grande data. Nutrients (nitrate ammonia and organic forms of nitrogen (TKN analysis)) indicate a low concentration. The trihalomethanes are within regulatory concentrations and, from CH2M HILL's experience, will likely be further reduced by storage in the aquifer.

In situ Groundwater

Four in situ groundwater analyses (collected in 1973) for the Gravel Zone, and one each from the Intermediate (1994) and Lower (1989) Zones were used in this evaluation. The in situ groundwater has a broader range in TDS and water chemistry than the Rio Grande. Lower TDS (less than about 2,500 mg/L) groundwater is a sodium-sulfate-chloride water chemistry type, but higher TDS groundwater is a sodium-chloride water chemistry type. Similar to the surface water, the transition from sodium-sulfate-chloride to sodium-chloride-sulfate probably involves the precipitation of calcium-sulfate in the aquifer forming a cement and reducing the permeability of the aquifer where the precipitation occurs.

There appears to be a difference between the groundwater from wells completed in the Gravel Zone near WTP No. 1 and WTP No. 2. Groundwater from Well 89-04-903 near WTP No. 1 is a sodium-chloride water chemistry type with a low TDS (2,860 mg/L) when compared with the groundwater from Well 89-05-404 near WTP No. 2 which is a sodium-chloride-sulfate with a relatively high TDS (10,540 mg/L). The calcium and sulfate concentrations suggest that calcium-sulfate has precipitated in the Gravel Zone part of the alluvial aquifer somewhere upgradient of Well 89-04-903.

The Intermediate Zone as represented by the data reviewed appears to have similar characteristics to that of the Gravel Zone near WTP No. 1. Recharge conditions for this aquifer, therefore, are similar to the conditions for recharging the Gravel Zone near WTP No. 1. The field pH of groundwater from this zone is also particularly important because there is sufficient bicarbonate to combine with the recharge water calcium to potentially precipitate calcium-carbonate and present a potential permeability problem.

Potential Recharge Near Treatment Plants 1 And 2

Recharge is more favorable for the area adjacent to WTP No. 1 where the historical TDS is lower than near WTP No. 2 where the TDS, iron, calcium, and sulfate are high. The lower TDS and sodium chloride water chemistry type mean that calcium-sulfate will not have a tendency to precipitate, less iron will be precipitated in the aquifer, and the clays within the aquifer particles will not have a tendency to become destabilized with the lower TDS recharge water. However, if the field pH of the groundwater is at or above about 8.0, there is a potential for some calcium-carbonate precipitation where the recharge water and in situ groundwater are in contact. The impact of this potential can be reduced by not recovering the groundwater beyond the amount or water recharged. Given the near neutral pH and the relatively low calcium plus bicarbonate concentrations, the potential for precipitation is still high but the amount of precipitation will probably be within a level that, if not continually repeated, the aquifer should not be severely impacted.

Even though physical recharge will likely be less troublesome at WTP No. 1, recharge at WTP No. 2 may provide better results from the water chemistry standpoint. The TDS and other parameter reductions in the recovered water may be significantly lower than the in situ groundwater. The TDS could be reduced by almost an order of magnitude (comparing the historical groundwater chemistry (1973) and the recent treated water (1995)). Other parameters would likewise be significantly reduced in concentration. The pH would be about the same between the recharge and in situ groundwater so no significant chemical reaction between the aquifer materials and the recharge water is expected other than the reduction in TDS.

There is also the potential that the calcium-sulfate has precipitated in the vicinity of WTP No. 1. This could mean that the initially recovered water will have a higher TDS, calcium, and sulfate than the injected water. If present, the higher concentrations would result from dissolving calcium and sulfate from the aquifer. This dissolution would probably decrease with each recharge cycle and the storativity (and probably the permeability) of the aquifer will increase proportionally to the amount of calcium-sulfate removed from the aquifer.

There is a potential problem created by the significant reduction in TDS present in the treated water compared with the in situ groundwater. Since both the recharge water and the in situ groundwater contains sodium as the dominant cation, the exchangeable ion on the clays will be essentially unchanged. However, the reduction in the salinity will probably mean that the clays may expand when either area is recharged.

The degree of expansion and the relative stability of the clay on the aquifer particles is unknown, but the potential impact of the expansion can be minimized by the rate at which the recharge water is recharged and by minimizing recovery of more water than has been recharged. Such measures should be taken if the Gravel Zone near either WTP No. 1 or WTP No. 2 or the Lower Zone near Well 88-59-411 are selected for recharge (and other areas with groundwater TDS greater than about 2,500 mg/L). The recharge water should be initially introduced at a relatively low rate to allow the clay minerals in the aquifer to remain stable with the much lower TDS recharge water. Normal and/or high initial recharge rates will result in the potential destabilization of clay minerals in the aquifer and irreversible loss in permeability. The recharge rate can be increased with time to a normal rate over about two days time. Recovery of more than the amount of recharged water is to be discouraged because the in situ groundwater could destabilize the clay minerals near the well. However, if some recharge water is left in the aquifer, this initial lower recharge rate will sufficiently condition the clays that normal recharge rates can occur for all future cycles. Potential damage to the area around the well can be minimized by not recovering more water than has been recharged.

Appendix 3

TECHNICAL MEMORANDUM CH2M HILL

PREPARED FOR: Brownsville PUB

PREPARED BY: CH2M HILL

DATE: August 14, 1995

SUBJECT: ASR Applications

PROJECT: 116700.D0.ZZ

Purpose and Scope

The City of Brownsville Public Utilities Board (PUB) has contracted with CH2M HILL to provide a Feasibility Investigation on the applicability of Aquifer Storage Recovery (ASR) for their water supply system. The complete investigation considered water supply and demand issues, area hydrogeology, water quality, and geochemistry issues to evaluate the feasibility of ASR. This memorandum was prepared to present how ASR could specifically be utilized for the PUB considering the previous work.

The topics covered by this memorandum are as follows:

- ASR Conceptual Applications
- Potential ASR Rates and Volumes
- Preliminary Cost Opinion

ASR Conceptual Applications

Conceptual Operation

The ASR concept provides a utility with a large volume of treated water by using groundwater aquifers for storage. Large volumes of treated water are injected into wells when the water is available and later recovered by pumping the wells. The storage is typically applied seasonally by storing water over several months, or, in some applications, over several years.

The City of Brownsville is experiencing growth and the associated increase in water demands. Current firm raw water supplies from the Rio Grande River are projected to sustain the water needs until the year 2003. Additional water supplies are available through Permit 1838, however, this water is tied to minimum river flows and requires capture and storage for reliable use. The water treatment capacity of the PUB is currently being expanded to a total of 40 million gallons per day (mgd). This capacity is projected to supply adequate treated water until the year 2005.

Aquifer Storage Recovery could provide a method for the PUB to:

- Meet seasonal demand peaks with previously stored treated water.
- Supplement firm water rights by storing Permit 1838 water for later use.

The existing water treatment plants (WTPs) will soon have the capacity to treat and produce 40 mgd. Using conventional operational schedules, WTP operation may only run at this rate for several days during the peak demand months of summer. This type of operation leaves several months during the year of substantial unused plant capacity. By operating the WTPs at a rate somewhat higher than that needed to meet typical winter demands, extra treated water could be produced for storage in ASR wells. During peak demands in the summer, the stored water could be recovered by pumping the wells, thus supplementing the treatment plant flows and offsetting the high rates otherwise required by the WTPs. This application essentially extends the capacity of the existing system to meet higher demands and, therefore, the useful life of the system.

In addition, Permit 1838 allows the PUB to divert water from the Rio Grande when river flows are at or exceed 25 cubic square feet (cfs). Historical records indicate this water is available for much of the year, however, the quantity is not guaranteed. To maximize the benefit of this water, substantial storage is needed so river flows could be diverted and held for later use. The application of ASR could potentially provide this required storage. Water diverted under Permit 1838 could be treated and stored in ASR wells. Later, this water could be recovered and used for peak demands and to supplement the annual firm water rights used by the PUB.

Water Balance

Monthly historical flows were used to estimate how ASR could potentially operate with the PUB system. Typical monthly average and maximum day demands were generated using past water use patterns and the PUB projected water demands. A monthly water balance was constructed assigning raw water production to either distribution and use, or to ASR storage. During the summer months, water was pumped from ASR storage to meet peak demands and supplement firm water rights.

The methodology used in the water balance was to first use the WTPs to treat firm water rights water to meet the average monthly demand. Capacity in excess of the average monthly demand was then used to treat Permit 1838 water for storage in ASR wells. It was assumed the WTPS could operate at an average continuous rate of 36 mgd, 90% of their rated maximum capacity. Storage months for the ASR wells were selected as November through May based on historical demand patterns. Water was recovered from the ASR wells to offset peak demands during the months June through October and to supplement the PUB firm water rights with the stored Permit 1838 water. This process was continued until it was not possible to treat and store an adequate volume of Permit 1838 water to meet the total raw water demand. The last year of successfully meeting demands following this methodology was the year 2008. The results of the water balance for that year are shown in Table 1.

Table 1 Year 2008 ASR Operations

Operating Month	2008 Monthly Demands Raw (mgd)	Avg. (mgd)	Max. (mgd)	Firm Water Rights Pumped (Acre-ft)	Permit 1838 Rights Pumped (Acre-ft)	Total Raw Water Pumped (Acre-ft)	WTP Avg Operating Rate (mgd)	ASR Avg Injection Rate (mgd)	ASR Avg Recovery Rate (mgd)	Cumulative ASR Storage (Acre-ft)
January	30.7	24.9	32.7	2,864	966	3,830	34	9	- -	2,622
February	27.2	24.3	33.0	2,538	1,074	3,611	34	10	- -	3,555
March	32.8	26.7	36.2	3,059	751	3,811	34	7	- -	4,209
April	33.5	25.9	36.3	3,124	859	3,983	34	8	- -	4,956
May	33.8	26.3	36.4	3,157	859	4,016	34	8	- -	5,702
June	37.3	29.8	41.3	2,362	- -	2,362	18	- -	12	4,582
July	42.9	31.9	41.8	2,883	- -	2,883	20	- -	12	3,462
August	44.6	33.9	44.1	3,046	- -	3,046	22	- -	12	2,342
September	36.6	28.9	40.2	2,297	- -	2,297	17	- -	12	1,221
October	35.9	27.9	37.1	2,232	- -	2,232	16	- -	12	101
November	31.4	25.3	32.7	2,929	966	3,895	34	9	- -	840
December	32.1	25.0	36.7	2,994	966	3,960	34	9	- -	1,680
			Totals	33,486	6,441	39,927				

Notes:
1. ASR rates shown as average, expected maximum rates are 15 mgd injection, 19 mgd recovery.
2. ASR storage of 2,622 acre-ft in January includes 1,782 acre-ft from previous year.
3. WTP rate shown as average monthly rate. Maximum day rate could be as high as 40 mgd.
4. PUB mid-level demand projections used in water balance.
5. ASR operation combined with Permit 1838 water results in year end firm water rights pumped less than permitted 33,973 acre-feet.
6. It is assumed that raw water losses in transmitting the Permit 1838 water are equal to those seen transmitting the firm rights water.

It is important to note that the above water balance was constructed for the purposes of estimating how ASR may work with the existing system and is not represented to be an exact simulation. Actual system demands and operational procedures will dictate the actual monthly distribution of water and many different combinations are possible. Following actual ASR cycle testing and the determination of actual ASR rates and recoveries, it will be advisable to conduct a daily water balance simulation to assist with final system layout and design. However, the monthly water balance does demonstrate one potential way in which ASR can work with the existing system to meet higher demands longer into the future.

The water balance suggests that the limitations of storing the Permit 1838 water is the ability to treat enough water for both ASR storage and to meet projected demands. The amount of water that can be placed into ASR storage is not large enough to make up the difference in firm water rights and raw water demand. By the year 2009, the monthly water demands are consuming a larger portion of the treatment capacity and it is not possible to treat and store as much Permit 1838 water as needed. However, several conservative assumptions were made in this analysis which limited the balance. First, it was assumed that the WTPs could operate at a continuous rate of only 90 percent of their rated capacity. It was also assumed that storage in the ASR wells could not occur any time during the months of ASR recovery. During a typical year of operation, it may be possible to work with these assumptions and extend the ASR application somewhat.

Another operational variation was considered to estimate how the PUB system could further meet higher demands with the Permit 1838 water and ASR. If Permit 1838 water could be used directly instead of being stored in the ASR system first, use of the firm water rights could be further reduced. This methodology provides the PUB use and treats Permit 1838 water as it is available for both ASR storage and direct treatment and distribution. This allows the PUB then to use a smaller portion of their firm rights throughout the year.

This type of operation presents a unique operational concern. The PUB orders its firm water right release one week prior to its use. If the PUB were to implement the above, the water release request would have to consider an estimated quantity of Permit 1838 water that would be available the following week. If the estimate was wrong, either insufficient raw water would be available, or too much water would be released and therefore lost.

However, if the above water release estimate is made with a known volume of water available in ASR storage, the penalty for an incorrect estimate becomes less severe. If the Permit 1838 water is available in abundance during a given week, it can be diverted toward ASR storage. If Permit 1838 water is counted on and then is not available, the difference can be made up by pumping the ASR wells. Working together, the ASR system and the Permit 1838 water can greatly benefit the PUB. The water balance was calculated considering the above discussion. Water demands for the year 2012 were met using the firm water rights, the ASR system, and the Permit 1838 water. The results of this water balance is shown in Table 2.

Table 2 Year 2012 ASR Operations

	2012 Monthly Demands Raw (mgd)	Avg. (mgd)	Max. (mgd)	Firm Water Rights Pumped (Acre-ft)	1838 Rights Pumped to ASR (Acre-ft)	1838 Rights Pumped to Distribution (Acre-ft)	Total Raw Water Pumped (Acre-ft)	WTP Avg Operating Rate (mgd)	ASR Avg Injection Rate (mgd)	ASR Avg Recovery Rate (mgd)	Cumulative ASR Storage (Acre-ft)
January	34.3	27.8	36.6	2,453	859	751	4,063	36	8	- -	2,504
February	30.4	27.2	36.9	2,088	966	751	3,806	36	9	- -	3,344
March	36.7	29.8	40.5	2,671	644	751	4,067	36	6	- -	3,904
April	37.4	29.0	40.6	2,744	751	751	4,247	36	7	- -	4,558
May	37.8	29.4	40.7	2,781	784	751	4,316	37	7	- -	5,239
June	41.7	33.4	46.2	2,694	- -	- -	2,694	22	- -	11	4,194
July	48.0	35.7	46.7	3,277	- -	- -	3,277	25	- -	11	3,148
August	49.9	38.0	49.3	3,459	- -	- -	3,459	27	- -	11	2,102
September	41.0	32.3	45.0	2,621	- -	- -	2,621	21	- -	11	1,057
October	40.2	31.2	41.5	2,548	- -	- -	2,548	20	- -	11	11
November	35.1	28.3	36.6	3,277	859	- -	4,136	36	8	- -	747
December	35.9	27.9	41.0	3,350	859	- -	4,209	36	8	- -	1,494
			Totals	33,964	5,722	3,757	43,443				

Notes:

1. ASR rates shown as average, expected maximum rates are 15 mgd injection, 19 mgd recovery.
2. ASR storage of 2,504 acre-ft in January includes 1,757 acre-ft from previous year.
3. WTP rate shown as average monthly rate. Maximum day rate could be as high as 40 mgd.
4. PUB mid-level demand projections used in water balance.
5. ASR operation combined with Permit 1838 water results in year end firm water rights pumped less than permitted 33,973 acre-feet.
6. It is assumed that raw water losses in transmitting the Permit 1838 water are equal to those seen transmitting the firm rights water.

It may be possible to meet even higher demands using this approach. However, two limitations exist: 1) The WTP capacity is limiting the volume of water in ASR storage, 2) The assumption that the Permit 1838 water is available in sufficient volumes during the first five months of the year.

The volume of water that could be stored in the ASR system in the year 2012 was less than that in the year 2008, and the corresponding recovery rate was lower. This is a function of the available capacity of the WTPs to treat enough water for ASR storage and meet demands. The water balance suggests that around the year 2012, additional treatment capacity would be needed for optimum system operation.

Also during the year 2012, almost 3,300 acre-feet of Permit 1838 water is needed to offset the use of firm water rights water. This amounts to an average use of about 7 mgd continuously over the first five months of the year. This amount of water may typically be available, however, it is recommended to conduct further river flow analyses on this subject to be sure the WTPs can effectively treat the water during the potentially short periods of availability.

Potential ASR Rates and Volumes

System Rates

Previous work done considering the PUB water demands and supply, including the above water balance work, indicates the PUB system could benefit from an ASR system with a relatively high rate of potential injection. Water available from Permit 1838 may be pumped from the river at high rates during river flows of 25 cfs or greater. Work reported in the PUB's Water Supply and Conservation Report, December 1994, indicate an average of 17,000 acre-feet of Permit 1838 water could be available during a typical year. This volume of water amounts to a continuous yearly pumping rate of about 15 mgd. It is likely that during many times of Permit 1838 water availability, water may be available in quantities much higher than 15 mgd, and also higher than the PUB system can utilize. Following this logic, an ASR system with a high potential injection rate would be of the most benefit to the PUB.

The water balance work indicates an ASR system with an average injection capacity of about 10 mgd is required. The average recovery rate used was 12 mgd. These values represent average values. Injection and recovery rates will have to vary to keep up with water availability for injection and recovery needs during maximum day demands. The maximum injection rates needed will be during minimum day demands on the WTPs, and when Permit 1838 water is available in large quantities. Minimum day demands on the WTPs historically have been about 0.5 of the average annual treated water demands. Considering the projected water demands from 1995 through 2014, the useful maximum calculated rate of injection then ranges from 26 to 20 mgd.

However, it may not be cost effective to construct the required ASR wells to fully take advantage of this possible maximum injection rate. Additionally, daily or even hourly changes to the ASR injection rates would be required to maintain maximum injection rates which may be difficult from an operations viewpoint. For the purposes of this investigation, it was assumed that weekly adjustments in the ASR rates would be more reasonable and that this frequency of adjustment could provide the required volume of storage. It was further assumed that this injection rate would correspond to the difference between WTP continuous capacity and a point about half way between the average annual demand and the minimum day demand. Again considering the projected water demands from 1995 through 2014, the calculated maximum injection rate ranges from 13 to 21 mgd. From this range of values, 15 mgd was selected for the maximum injection rate.

Average recovery rates of about 12 mgd were seen to be required from the water balance. This rate of recovery fits the PUB system well and great differences between the average and maximum rate of recovery are not as critical as for injection. However, it is desirable to have the ability to recover at a rate somewhat higher than injection for purposes of backflushing wells. Additionally, higher potential rates of recovery will provide the PUB with substantially more flexibility in overall operation. From this, a maximum rate of recovery of 19 mgd was selected. This rate is 25 percent higher than the maximum injection rate which is typical of other ASR facilities.

Individual ASR Well Rates

Previous work completed on the Brownsville area hydrogeology indicate three aquifer zones have potential for ASR applications. The selection of the appropriate injection zone will require a test drilling program where the different geological units are explored and tested. At that point, substantially more information will be available to select the appropriate zone for future ASR testing.

The three zones exist at three different depths, have different water qualities, and hydraulic characteristics. Considering the information known at the writing of this report, one of these zones appears to exhibit more desirable qualities for ASR applications. This zone is identified as the Gravel Zone. The Gravel Zone is considered the shallowest zone and will, therefore, result in the lowest well construction costs for the PUB. It is also thought to be of appropriate yield, which is also higher than the other two zones. Water quality in the Gravel Zone is also of equal or higher quality than the corresponding Intermediate and Lower Zones.

For the above reasons, the Gravel Zone will be considered in the estimate of ASR well rates and overall system size. It must be stated that the selection of the Gravel Zone for the final ASR zone can only be made after a test program where test wells are constructed. The Gravel Zone has many quality features for an ASR zone, but many uncertainties still exist. Only after a test program is conducted can more of these unknowns be identified and the actual ASR zone be selected.

ASR wells in the Gravel Zone would be completed to about 300 feet in total depth, with the screen section being approximately 50 feet in length and the top set as shallow as 150 feet below ground surface. Depth to water levels in the Gravel Zone were estimated as deep as 30 feet below ground surface which would allow approximately 110 feet of available drawdown for pumping. Transmissivities in Gravel Zone sections suitable for ASR purposes were estimated at approximately 30,000 gallons per day (gpd)/ft. It is assumed that wells completed into this zone would exhibit a pumping specific capacity of about 13 to 15 gallons per minute (gpm)/ft, which could result with wells with pumping capacities in excess of 1,400 gpm. Considering well inefficiencies and inter-well interference, it is estimated that individual wells in an ASR well field would have an average pumping capacity of approximately 1,000 gpm in the Gravel Zone.

Injection into ASR wells is typically conducted at rates somewhat less than pumping. This is because of the desire to backflush wells at a rate higher than the injection rate for cleanout purposes. Additionally, the hydraulics of injection usually result in lower injection rates for a corresponding water level change relative to pumping. For these reasons, and to be consistent with the overall system capacities discussed previously, individual injection rates of 800 gpm were assumed. Considering a 30 foot depth to static water level in the Gravel Zone, approximately 25 to 30 psi wellhead pressure would be required to attain this injection rate.

The above discussion indicates that individual ASR wells completed into the Gravel Zone are estimated to yield a pumping capacity of approximately 1,000 gpm, and an injection capacity of approximately 800 gpm. An overall ASR system capable of maximum pumping and injection rates of 19 mgd, and 15 mgd, respectively, will require a minimum of 13 wells. Additional wells would then be needed to obtain firm capacity.

Conceptual ASR System Configuration

The ultimate ASR system needs to be capable of injecting treated water into the selected storage zone. To accomplish this, the system needs to be located near a source of treated water with an adequate amount of pressure to inject at the required injection rates. This pressure is available in typical distribution system lines and these are assumed to be the source of water for ASR injection.

Recovery of the stored water will generally be back into the distribution system as finished water. It will be necessary to provide disinfection of the recovered flows, compatible with the other treated water in the system. There will also be times during the ASR operations where it will not be possible to return recovered water to the treated water pipelines. This will occur for several minutes following pump startup, and also during backflush times when the ASR wells are periodically pumped during injection to clean out the screens and wellbore. During these operating times, it will be necessary to either discharge the recovered water, or return the water to the WTPs for retreatment.

It follows that the ASR system requirements are a source of treated water at distribution system pressure, a disinfection facility, and either a line to waste or a raw water collection line returning to a WTP. For these reasons, the best places for the ASR system will be at the WTPs.

At the present time it is not known which hydrogeologic zone is best suited for the ultimate ASR zone. This is true not only in terms of depth but also in terms of areal location.

Hydrogeologic information indicates that the geology underlying Brownsville varies in terms of both aquifer hydraulic properties and water quality. It will be necessary to conduct substantial field testing to determine the best depth and areal location for the ultimate ASR facility. For the purposes of this conceptual ASR system configuration, the information currently known was used to evaluate where the most appropriate locations would be for the ultimate ASR facility. This conceptual configuration was developed to provide the PUB with an idea of how the system may result, and also to estimate general cost levels for system development and construction.

It is not possible at this time to estimate the required final well spacing or configuration for the ASR wells. Current information and experience with other ASR facilities suggest well spacing may be on the order of 800 to 1,200 feet. The well system configuration may be best aligned in rows along local groundwater gradient to allow downgradient capture of stored water if required.

The required ASR system capacity is substantially large relative to either of the WTPs. Although the average capacity of the ASR system is less, the maximum recovery capacity of the ASR system is equal to either one of the WTPs. It may be difficult hydraulically to manage this volume of water at any one location. For this reason, it is recommended to separate the total ASR capacity into several locations. One location could be placed at each of the WTPs, and one location placed at each of three PUB elevated storage tanks in the northern and central area of Brownsville. Each ASR facility at a WTP would consist of 5 or 6 ASR wells, and the piping and controls needed to transmit the appropriate recharge and recovery flows. Each ASR facility at the elevated storage tanks would consist of 1 or 2 ASR wells and the associated piping. This type of configuration would provide the PUB added flexibility in system operation as ASR flows would be distributed through the system and not just hydraulically concentrated at one point.

Injection flows at either of the WTPs would likely be transmitted off the high service piping leaving the WTP. Recovery flows from the ASR wells could be returned to the WTP, either upstream of, or into the clearwell to take advantage of mixing in the tank and existing chlorination facilities. Depending on WTP hydraulics at the time, it could also be possible to pump the ASR recovered water directly into distribution piping off the high service discharge. The ASR facilities at the WTP would also include a recovery return line to pump water back through the treatment process. This line would probably be directed back to the raw water intake piping. Additional piping from the ASR facility to the sanitary sewer or other waste area may be required for more extensive well cleaning or testing. These requirements will be evaluated during initial ASR testing and can not be accurately estimated at this point.

The ASR facility located at the PUB elevated tanks would consist of 1 or 2 ASR wells at each site and would receive injection flows from the distribution system piping near each tank. Recovered flows would be directed back into the tank to again allow the recovered water to blend with the system water at that point. It will be necessary to provide a discharge line to sanitary sewers at each tank located ASR system. This piping would be used to discharge initial flush water and the water produced during periodic backflush of the wells.

Another advantage to the PUB of developing the ultimate ASR system at several locations is the flexibility in ultimate construction. The PUB would be well advised to develop the ASR system in stages, adding capacity at different locations, as needed by existing distribution system hydraulics and other system needs. Following this path, the PUB can work out specific design issues on the first sites, and add sites as needed through the planning period.

Preliminary Cost Opinion

Preliminary costs for the conceptual ASR facilities discussed above were developed. The costs include the design and construction activities to implement the conceptual ASR system. It is assumed these activities begin following the completion of the previously discussed test drilling, and prototype ASR well construction and testing. The costs are considered preliminary in nature as they are based on several assumptions which could change the conceptual facility. These include actual injection and recovery rates sustained by the wells, the number of wells, piping distance requirements, and other assumptions. However, the following estimate was prepared to provide information to the PUB about the general level of costs associated with this system. The cost estimate is provided in Table 3.

The cost estimate was prepared by considering the major items required for each ASR location and estimating the general magnitude of costs for these items. Contingencies were then applied at 20 percent and engineering and testing were estimated at 15 percent of the total.

Table 3 Preliminary ASR Cost Estimate (Page 1 of 2)

Brownsville ASR Preliminary Cost Estimate
ASR System Completed into Gravel Zone
2 WTP sites with 6 ASR Wells Each
3 Elevated Tank sites wtih 2 ASR Wells Each
Total System Average Capacity; 10 mgd Injection, 12 mgd Recovery
Total System Maximum Capacity; 16 mgd Injection, 20 mgd Recovery

Cost Each Site at WTP No. 1 and WTP No. 2				
Item	Unit	No. Required	Estimated Unit Cost	Estimated Total Cost
ASR Well, 16-inch dia., 300 ft Total Depth, 75 ft Screen	each	6	$150,000	$900,000
Well Vertical Turbine Pump, Wellhead Piping	each	6	$125,000	$750,000
Well Collection Piping, 8" and 10"	foot	5,000	$36	$180,000
Connection Piping, 30"	foot	5,000	$120	$180,000
WTP Pump Upgrade Allowance	each	1	$150,000	$150,000
I & C Allowance	each	1	$300,000	$300,000
Miscellaneous Other Construction	10%	1	$246,000	$246,000
Engineering and Testing	15%	1	$405,900	$405,900
Contingency	20%	1	$622,380	$622,380

Total Each ~~Elevated Tank~~ WTP Site **$3,734,280**

Total for 3 ~~Elevated Tank~~ WTP Sites **$7,468,560**

Table 3 Preliminary ASR Cost Estimate (Page 2 of 2)

Cost Each Site at 3 Elevated Tank Sites				
Item	Unit	No. Required	Estimated Unit Cost	Estimated Total Cost
ASR Well, 16-inch dia., 300 ft Total Depth, 75 ft Screen	each	2	$150,000	$300,000
Well Vertical Turbine Pump, Wellhead Piping	each	2	$125,000	$250,000
Well Collection Piping, 8"	foot	1000	$32	$32,000
Connection Piping, 10"	foot	300	$40	$12,000
I & C Allowance	each	1	$100,000	$100,000
Chlorination System	each	1	$40,000	$40,000
Miscellaneous Other Construction	10%	1	$69,400	$69,400
Engineering and Testing	15%	1	$120,510	$120,510
Contingency	20%	1	$184,782	$184,782

Total Each Elevated Tank Site **$1,108,692**

Total for 3 Elevated Tank Sites **$3,326,076**

Total for ASR System at WTP No. 1, WTP No. 2, and 3 Elevated Tank Sites **$10,794,636**

Appendix 4

TECHNICAL MEMORANDUM

CH2M HILL

PREPARED FOR: Brownsville PUB

PREPARED BY: CH2M HILL

DATE: August 7, 1995

SUBJECT: Temporary UIC and Surface Water Permit Application

PROJECT: 116700.B0.ZZ

Introduction

This technical memorandum documents the process to apply for temporary Underground Injection Control (UIC) and surface water permits required to perform aquifer storage and recovery (ASR) activities in the State of Texas. The Texas Natural Resources and Conservation Commission (TNRCC) administrates both permits. Recent legislation passed by the State (House Bill No. 1989 [HB1989]) shows that the underground storage of appropriated water, incidental to a beneficial use, is a beneficial use of water. HB1989, provided in Attachment 1, explicitly encourages TNRCC to issue temporary or term permits for pilot demonstration projects and, consequently, temporary and term UIC and surface water permits are readily obtainable.

According to HB1989, temporary and term permits shall only be valid for the duration of a pilot project to provide TNRCC and the Texas Water Development Board (TWDB) further opportunity to evaluate the storage of appropriated water in aquifers for subsequent retrieval and beneficial use before granting a final order. At the conclusion of a pilot project, a permit holder may file to TNRCC for a final order granting an appropriate permit application or permit amendment authorizing storage of appropriated water in aquifers for beneficial use. TNRCC will issue a final order after evaluating pilot project information. However, according to HB1989, a final order may not be issued before June 1, 1999.

UIC Permit

Currently, temporary UIC permits for ASR pilot projects are granted by letter of authorization by TNRCC (TNRCC-UIC Division, 1995). To apply for a letter of authorization, an applicant must forward a letter of request describing the proposed pilot project. TNRCC will grant a temporary UIC permit based on this letter of request. Although no specific written guidelines currently exist for information to be included in the letter of request, the information should be sufficient to provide TNRCC the necessary information to evaluate the proposed pilot project. According to conversation with TNRCC staff, this information should include a description of the following:

- Project location

- Target injection, pumping, and rates
- Target aquifer (size, geometry, hydrogeologic properties, etc.)
- Potential for recharge water to migrate to and impact nontarget aquifers
- Potential for recharge water to adversely impact groundwater
- Potential for ASR activities to impact other existing groundwater users

A list developed by TNRCC for suggested information to be provided in the letter of request is provided in Attachment 2. The above information is related to the items specified in HB1989 that will be considered by TNRCC in evaluating the success of a pilot project in consideration of granting a final order. Those items specified in HB 1989 include the following:

- Whether injected water will detrimentally alter the physical, chemical, or biological groundwater quality to the extent that subsequent production would (1) harm people, animals, vegetation, or property or (2) require treatment of recovered groundwater prior to a beneficial use

- Whether the injected water can be successfully harvested for beneficial use

- Whether injected water can be protected from unauthorized withdrawals to the extent necessary to maximize recovery and beneficial use of stored water without experiencing unreasonable loss of appropriated water

As part of the permit, the following conditions may need to be met as specified in HB1989.

- Register the permit holder's injection and recovery wells with an underground water conservation district that has jurisdiction over the reservoir or subdivision

- Provide the district, if any, with a written report showing the previous calendar month's activities, including the amount of water injected for storage and the amount recaptured for use

A permit application fee currently does not exist. However, a fee may be required in the future.

Surface Water Permit

The Rio Grande River Basin is an adjudicated basin and because all water rights are appropriated, no additional rights are available. Consequently, obtaining appropriated surface water rights for beneficial use consists of reallocating existing rights. Two options are available:

- Amend an existing water right
- Apply for a temporary surface water permit

Amend Existing Water Right

If an owner has an existing water right, they may amend their water right to specify ASR as the beneficial use from the existing specified beneficial use other than ASR (e.g., agricultural, municipal). This process consists of filing the one page *Application for Amendment to a Water Right* form (Attachment 3) to the TNRCC Water Rights Permitting Division together with the UIC Permit letter of request and TNRCC letter of authorization (described above). A brief letter description of the proposed ASR pilot project should accompany the application.

Up to 3 months may be required from the time an application is filed to the time the water right is amended. Although a maximum time duration for the amendment does not explicitly exist, it would generally be granted for the duration of a pilot project. As stipulated in HB1989, a final order granting a permit or a permit amendment authorizing storage of appropriated water in aquifers for subsequent beneficial use, other than for the pilot projects, may not be issued before June 1, 1999.

Application for a Temporary Permit to Divert Surface Water

A temporary permit to divert surface water may be obtained contingent upon a valid contract with an owner holding an appropriated water right. This process consists of filing the one page *Application for a Temporary Permit* form (Attachment 3) to the TNRCC Water Rights Permitting Division together with the UIC Permit letter of request and TNRCC letter of authorization (described above). A brief description of the proposed ASR pilot project should accompany the application. About 3 to 4 weeks would be required from the time an application is filed to the time the temporary water right is granted. A temporary water right is valid for 3 years.

A notice will be placed in the Texas Register describing the application to provide an opportunity for a public hearing. A mailed notice to other water rights holders will not be required. A hearing will not be held if no comments are received.

Filing and Recording Fees

The filing and recording fee for amending an existing water right or applying for a temporary permit varies depending upon water right size, but generally may be about $100 assuming that no irregularities occur. A maximum fee of $1,000 may be charged for a 10,000 acre-foot application and a maximum fee of $2,000 may be charged for a 250,000 acre-foot application.

Permit Application Sequence

Temporary UIC and Surface Water Permits should be applied for before implementing a pilot ASR project but after enough information has been obtained to satisfy permit requirements. Filing for a final order for these permits should occur after the pilot ASR project. However, as described above, a final order may not be issued before June 1, 1999 as specified in HB1989.

The general sequence of permit application is listed below.

- Perform exploratory field investigation
- Design ASR pilot project(s)
- Apply for temporary permits for pilot project(s)
- Perform ASR pilot project(s)
- Design final ASR facility
- Apply for final permits
- Construct final ASR facility

References

TNRCC, UIC Division. Personal Communication. August 7, 1995.

TNRCC, Water Rights Permitting Division. Personal Communication. August 7, 1995.

Attachment 1
House Bill No. 1989

CHAPTER 309 H.B. No. 1989

AN ACT

relating to the underground storage of appropriated water incidental to a beneficial use.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF TEXAS:

SECTION 1. The legislature finds that:

(1) the underground storage of appropriated water, incidental to a beneficial use, is a beneficial use of water;

(2) the use of aquifers for storage of appropriated water:

(A) enhances the conservation and protection of appropriated water by minimizing seepage and evaporation losses;

(B) reduces the incidental environmental impacts associated with the construction of conventional water storage facilities such as aboveground reservoirs; and

(C) enhances and protects groundwater resources;

(3) the underground storage of appropriated water maximizes the conservation and beneficial use of water resources;

(4) the storage of appropriated water in aquifers recognizes existing property rights, including the rights of a landowner in groundwater;

(5) the storage of appropriated water in aquifers recognizes the authority and jurisdiction of an underground water conservation district;

(6) the use of aquifers for storage of appropriated

water may reduce a portion of the economic burden on taxpayers and utility ratepayers associated with the construction of conventional water storage facilities;

(7) the successful storage of appropriated water underground has been demonstrated in Kerr County by the Upper Guadalupe River Authority in the Hosston-Sligo Aquifer; and

(8) the Texas Natural Resource Conservation Commission and the Texas Water Development Board are encouraged to evaluate additional aquifers within the state to identify the potential for storage of appropriated water underground to maximize and enhance the future availability and beneficial use of the water resources of the state.

SECTION 2. Subchapter D, Chapter 11, Water Code, is amended by adding Sections 11.153, 11.154, and 11.155 to read as follows:

<u>Sec. 11.153. PILOT PROJECTS FOR STORAGE OF APPROPRIATED WATER IN AQUIFERS. (a) The commission shall investigate the feasibility of storing appropriated water in various types of aquifers around the state by encouraging the issuance of temporary or term permits for pilot demonstration projects for the storage of appropriated water for subsequent retrieval and beneficial use in the following aquifers in the specified counties:</u>

<u>(1) the Anacacho, Austin Chalk, and Glen Rose Limestone aquifers in Bexar County and Medina County;</u>

<u>(2) the Carrizo-Wilcox aquifer in Bexar, Webb, Smith, Wood, Rains, and Van Zandt counties;</u>

<u>(3) the Hickory and Ellenberger aquifers in Gillespie County; and</u>

(4) the Gulf Coast aquifer in Cameron and Hidalgo counties.

(b) A permit described by Subsection (a) must be for only the duration of the pilot project to provide the commission and the board further opportunity to evaluate the storage of appropriated water in aquifers for subsequent retrieval and beneficial use.

(c) At the conclusion of a pilot project, a permit holder may file an appropriate application for a permit or permit amendment. After considering the success of the project and the criteria set out in Section 11.154, the commission shall determine whether to issue a permit or permit amendment authorizing the continued storage of appropriated water in the aquifer.

(d) A final order granting a permit or amendment to a permit authorizing the storage of appropriated water in aquifers for subsequent beneficial use, other than for the pilot projects authorized by this section, may not be issued before June 1, 1999.

(e) The board shall participate in the study of the pilot projects authorized by Subsection (a). The pilot projects are eligible for grants from the water loan assistance fund established by Section 15.101. The board may authorize use of money from the research and planning fund established by Section 15.402 to participate in the study of pilot projects.

Sec. 11.154. PERMITS TO STORE APPROPRIATED WATER IN AQUIFERS. (a) An application filed with the commission to undertake a pilot project under Section 11.153 must include:

(1) the information required for an application for a permit or permit amendment to appropriate state water;

(2) all information required for an application for a permit for a Class V injection well without requiring a separate hearing or notice; and

(3) a map or plat showing the injection facility and the aquifer in which the water will be stored.

(b) If the application is for a permit or permit amendment to store appropriated water in an underground water reservoir or a subdivision of an underground water reservoir, as defined by Chapter 52, that is under the jurisdiction of an underground water conservation district:

(1) the applicant shall:

(A) provide a copy of the application to each underground water conservation district that has jurisdiction over the reservoir or subdivision;

(B) cooperate with the districts that have jurisdiction over the reservoir or subdivision to ensure compliance with the rules of each district;

(C) cooperate with each district that has jurisdiction over the reservoir or subdivision to develop rules regarding the injection, storage, and withdrawal of appropriated water stored in the aquifer; and

(D) comply with the rules governing the injection, storage, or withdrawal of appropriated water stored in the reservoir or subdivision that are adopted by a district that has jurisdiction over the reservoir or subdivision; and

(2) the commission shall require that any agreement the applicant reaches with a district that has jurisdiction over

the reservoir or subdivision regarding the terms for the injection, storage, and withdrawal of appropriated water be included as a condition of the permit or permit amendment.

(c) On completion of a pilot project and receipt of an appropriate application for a permit or an amendment to an existing permit, the commission shall evaluate the success of the pilot project for purposes of issuing a final order granting a permit or permit amendment authorizing the storage of appropriated water incident to a beneficial use. The commission shall consider whether:

(1) the introduction of water into the aquifer will alter the physical, chemical, or biological quality of native groundwater to a degree that the introduction would:

(A) render groundwater produced from the aquifer harmful or detrimental to people, animals, vegetation, or property; or

(B) require treatment of the groundwater to a greater extent than the native groundwater requires before being applied to that beneficial use;

(2) the water stored in the receiving aquifer can be successfully harvested from the aquifer for beneficial use; and

(3) the permit holder has provided evidence that reasonable diligence will be used to protect the water stored in the receiving aquifer from unauthorized withdrawals to the extent necessary to maximize the permit holder's ability to retrieve and beneficially use the stored water without experiencing unreasonable loss of appropriated water.

(d) In making its evaluation under Subsection (c), the commission may consider all relevant facts, including:

(1) the location and depth of the aquifer in which the stored water is located;

(2) the nature and extent of the surface development and activity above the stored water;

(3) the permit holder's ability to prevent unauthorized withdrawals by contract or the exercise of the power of eminent domain;

(4) the existence of an underground water conservation district with jurisdiction over the aquifer storing the water and the district's ability to adopt rules to protect stored water; and

(5) the existence of any other political subdivision or state agency authorized to regulate the drilling of wells.

(e) A permit to store appropriated water in an underground water reservoir or subdivision, as defined by Chapter 52, shall provide as a condition to the permit that the permit holder shall:

(1) register the permit holder's injection and recovery wells with an underground water conservation district that has jurisdiction over the reservoir or subdivision, if any; and

(2) each calendar month, provide the district, if any, with a written report showing for the previous calendar month:

(A) the amount of water injected for storage; and

(B) the amount of water recaptured for use.

Sec. 11.155. AQUIFER STORAGE PILOT PROJECT REPORTS. (a) On completion of each pilot project, the board and the commission jointly shall:

(1) prepare a report evaluating the success of the project; and

(2) provide copies of the report to the governor, lieutenant governor, and speaker of the house of representatives.

(b) The board shall make other studies, investigations, and surveys of the aquifers in the state as it considers necessary to determine the occurrence, quantity, quality, and availability of other aquifers in which water may be stored and subsequently retrieved for beneficial use. The board shall undertake the studies, investigations, and surveys in the following order of priority:

(1) the aquifers identified in Section 11.153(a);

(2) areas designated by the commission as "critical areas" under Section 52.053; and

(3) other areas of the state in a priority to be determined by the board's ranking of where the greatest need exists.

(c) Not later than January 1 of each odd-numbered year, the board shall prepare and provide to the legislature a report that includes at least the following information:

(1) the progress of the pilot projects authorized under this subchapter and of any related project;

(2) the results of the board's studies of the other aquifers of the state during the preceding biennium; and

(3) the anticipated appropriation from general revenues necessary to investigate other aquifers in the state

during the upcoming biennium.

SECTION 3. (a) The change in law made by this Act applies only to an application made on or after the effective date of this Act for a permit or a permit amendment for a pilot project to appropriate water and to store appropriated water in an aquifer identified in this Act.

(b) A permit issued by the commission authorizing the storage of appropriated water in an aquifer incident to a beneficial use before the effective date of this Act or an application for a permit or permit amendment to appropriate water that includes authorization to store appropriated water in an underground structure filed before the effective date of this Act is not affected by the changes in law made by this Act.

SECTION 4. The importance of this legislation and the crowded condition of the calendars in both houses create an emergency and an imperative public necessity that the constitutional rule requiring bills to be read on three several days in each house be suspended, and this rule is hereby suspended, and that this Act take effect and be in force from and after its passage, and it is so enacted.

President of the Senate

Speaker of the House

I certify that H.B. No. 1989 was passed by the House on April 28, 1995, by the following vote: Yeas 136, Nays 0, 2 present, not voting; and that the House concurred in Senate amendments to H.B. No. 1989 on May 18, 1995, by the following vote: Yeas 144, Nays 0, 1 present, not voting.

Chief Clerk of the House

I certify that H.B. No. 1989 was passed by the Senate, with amendments, on May 15, 1995, by the following vote: Yeas 31, Nays 0.

Secretary of the Senate

APPROVED: 6-5-95

Date

Governor

FILED IN THE OFFICE OF THE SECRETARY OF STATE
11 50 am O'CLOCK

JUN 05 1995

Secretary of State

Attachment 2
Class V Injection Well Data Summary Form
Aquifer Storage and Recharge

RETURN TO:
TNRCC
Surface Casing MC 151
PO Box 13087
Austin, Texas 78711-3087
512/239-0520

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

CLASS V INJECTION WELL DATA SUMMARY

AQUIFER REMEDIATION
EPA Code 5X26

SC No.
Reg. No.

Received
Authorized

1. TNRCC Coordination Team	2. Contact Person	3. Phone No.
4. Agent/Consultant Name and Address (Street, City, State and Zip Code)	5. Contact Person	6. Phone No.
7. Operator/Owner Name Address (Street, City, State and Zip Code) - Owner Type:	8. Contact Person	9. Phone No.
10. Facility Name and Address (Street, City, State and Zip Code)	11. TNRCC Region	12. Contact Person
13. Type of Well Construction	14. Well No(s).	15. County
16. Water Well Driller and Address (Street, City, State and Zip Code)	17. License No.	18. Phone No.
19. Purpose of Injection System		

Well Site Location (Attach Plat)

20. Legal Location (Subd. & Lot and/or Sec., Blk., of Survey; give perpendicular calls from two designated survey lines)	21. Distance and Direction FROM nearest Town or Post Office	22. Longitude/Latitude and USGS Topo Quad

Down Hole Design (Attach Diagram)

Name of String	Well No.	Size	Setting Depth	Sacks Cement/Grout - Slurry Volume - Top of Cement	Top Determined By	Hole Size	Weight PVC/Steel
23. Casing							
24. Tubing							
25. Screen							

Trench System (Attach Design)

26. Trench(s) (Plat Location)	27. Trench Dimension	28. Trench Construction	29. Fluid Level(s)

Injection Zone (IZ) and Hydrogeological Data (Attach Chemical Analyses of Aquifer and Injection Fluids)					
30. Aquifer Name (IZ)	31. Formation Name	32. Well/Trench Total Depth	33. Surface Elevation	34. IZ Depth	35. Size of contamination plume in ac/ft
36. IZ Vertically isolated?	37. Impervious Strata (in feet) between IZ and nearest Aqurfer	38. Formation (IZ) Water TDS in PPM	39. Injection Fluid TDS in PPM at the Well Head	40. Lowest Known Depth <3,000 TDS in PPM	41. Lowest Known Depth <10,000 TDS in PPM
42. Injection Vol/Pres Av/Max	42. Water Wells within ¼ mile radius	44. Injection Wells within ¼ mile radius	45. Monitor, Wells	46. Sampling Frequency	47. Know Hazardous Components in Injection Fluid

Site History			
48. Type of Facility and Contamination Event(s)	49. Contamination Date(s)	50. Original Contamination/Quantity	51. Previous Remediation

Attachment 3
Application for a Temporary Permit

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. Box 13087 Austin, Texas 78711
Telephone No. (512) 239-4433

APPLICATION FOR A TEMPORARY PERMIT

This form is for an application for a temporary permit to divert water under Section 11.138, Texas Water Code; the application must be notarized.

1. Data on Applicant and Project: Social Security or Federal ID No. ____________

   A. Name ____________

   B. Mailing Address ____________
   ____

   C. Telephone Number ____________ Fax Number ____________

   D. Describe Use of Water ____________

   E. Description of Project (TDH Project No. if applicable) ____________

   F. Highway Designation No. ____________ County ____________

2. Type of Diversion (check one):

   ☐ From Stream

   ☐ From Reservoir

3. Rate of Diversion:

   A. Maximum ____________ gpm (capacity of pump)

4. Amount and Source of Water:

____________ acre-feet of water within a period of ____________ (specify term period not to exceed a three year term).

The water is to be obtained from ____________, tributary of ____________, tributary of ____________, tributary of ____________, ____________ Basin.

5. Location of Diversion Point:

(At) or (Near) the stream crossing of), (At a reservoir in the vicinity of) ____________ (R-O-W) (Highway), located ________ miles in a ________ direction from ____________ (County Seat), ____________ County, and ________ miles in a ________ direction from ____________, a nearby town shown on County road map. Note: Distance in straight line miles.

Enclose a vicinity map on letter size paper or larger with sufficient information to enable the Commission Staff to locate on the ground the diversion site and the return water discharge points, if any. A portion of a county road map would suffice. Owner's written consent is required for water used from any private reservoir, or private access to diversion point.

6. Access to Diversion Point (check one):

   ☐ Public right-of-way.

   ☐ Private property.
   (A letter of permission from landowner is attached).

   ☐ Other. (Explain).

7. Fees Enclosed:

	10 ac-ft or less	greater than 10 ac-ft
Filing	$100.00	$250.00
Recording	$ 1.25	$ 1.25
Use ($1.00 for ea ac-ft or fraction thereof)	______	______
(Note: 1 ac-ft = 325,851 gals. 1 ac-ft = 7758.35 bbls.) Total	$______	$______

Upon completion of any project for which a temporary water permit is granted, the Permittee is required by law to report the amount of water used.

This document must be properly signed and duly notarized before it can by accepted or considered by the Texas Natural Resource Conservation Commission.

Executed ____________ day of ____________, 19________.

____

____

Subscribed and sworn to before me as being true and correct on this the ____________ day of ____________, 19____.

____

Attachment 4
Application for Amendment to a Water Right

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. BOX 13087
Austin, Texas 78711-3087
Telephone No. (512) 239-4609 FAX (512) 239-4444

APPLICATION FOR AMENDMENT TO A WATER RIGHT

☐ *REQUIRING* MAILED AND PUBLISHED NOTICE
See Texas Administrative Code Section 295.158(b); or

☐ *NOT REQUIRING* MAILED AND PUBLISHED NOTICE
See Texas Administrative Code Section 295.158(c)

1. Name: ____________________

Address: ____________________

____
(City) (State) (Zip Code)

Telephone: Home: ____________ Office: ____________

Social Security or Federal ID. No.: ____________________

☐ Permit ☐ Certified Filing or ☐ Adjudication Cert. No.: ____________________

2. Stream ____________ Watershed ____________

Reservoir (present condition, if one exists): ____________________

County: ____________________

3. Proposed Changes To Water Right Authorizations: ____________________

____

____

____

(attach additional statement if necessary; also attach map/plat depicting project location, diversion point, place of use, and other pertinent data)

4. I understand that the Agency may require additional information in regard to the requested amendment before considering my application.

5. I have submitted the required fees herewith. (Sections 295.131-295.139)

Witness ____(my)______(our)______ hand at ____________________, Texas, this ____________ day of ____________, 19 ________.

____

____

Subscribed and sworn to as being true and correct before me the ____________________ day of ____________, 19 ______.

____

Notary Public, State of Texas