Large Scale Demonstration Desalination Feasibility Study City of Corpus Christi Executive summary[1]

Introduction

The State of Texas has experienced significant population growth over the last 50 years in recognition of its scenic beauty, robust economy, recreational opportunities, and desirable living conditions. This growth has led to increased pressure to develop additional water resources to meet the growing demand. In addition, there is an increasing concentration of population in coastal areas throughout the United States, and the establishment of desalination facilities in coastal communities has the potential for providing new resources already located in fast growing areas. There is legislation in the United States Congress to establish subsidies for seawater desalination projects as a benefit to the nation as a whole.

Governor Perry, in recognizing the need to develop additional water resources for Texas, has established a desalination initiative to determine whether those needed resources can be obtained from desalination of seawater. Three projects were funded in the upper, middle, and lower coast regions of Texas to explore this possibility. This summary details the investigation of a potential desalination facility in the Corpus Christi area and discusses elemental factors and benefits involved.

Corpus Christi has a number of factors that make it an optimum location for a seawater desalination project. Those factors are as follows:

- Largest Texas Gulf-Coast city with strategic port
- Largest industrial city in attainment status for air quality
- Progressive history of long-range water planning
  - Garwood water supply/Bay City-Mary Rhodes pipeline
  - Texana water supply/Mary Rhodes pipeline
  - Water demands met through 2052
- Regional water system
- Proximity to users
- Local and regional support
- Potential to supply future customers
- Prime coastal desalination site

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[1] Prepared by Turner Collie & Braden (Professional Engineer seal of Stanley T. Williams) for the City of Corpus Christi under a grant from the Texas Water Development Board, TWDB contract number 2004-483-508.

As noted above, the City of Corpus Christi has developed sufficient water supplies to meet its needs and the needs of its customers for the next 50 years. However, those water supplies are obtained from distant multiple surrounding watersheds and not from within the City or its service area. If seawater desalination is a feasible alternative to provide increased supply to the City of Corpus Christi, then other water-short regions of the State could potentially benefit from the diversion of some of Corpus Christi's existing supplies to those locations.

Scope

The scope of the Large Scale Demonstration Desalination Feasibility Study comprises the following:

- Encompasses taking the initial first step in determining the overall parameters under which a desalination plant might operate
- Explains the processes, costs involved, and decisions applied in determining alternatives
- Ultimately determines whether any fatal flaws exist which would make the project not feasible

Several specific scope tasks were examined and completed during the study and are listed below.

Scope tasks:

1. Site Requirements and Selection
2. Treatment
3. Source Water Blending
4. Potential Partners
5. Potential Customers
6. Power Sources
7. Project Funding and Development
8. Cost Model Development
9. Report

Task 1 – Site Requirements and Selection

An alternative site and process selection matrix was used to determine the best location of the proposed plant as well as the type of treatment that would be required. Industrial sites in the Corpus Christi area were screened using several criteria such as available land area, interest in an on-site large scale desalination facility, existing seawater or baywater intake structure and associated withdrawal permit, and proximity to potential users of the finished product water or byproduct disposal area.

The initial screening of sites identified five sites that could potentially accommodate a large-scale desalination facility. Interviews were conducted with the property owners and plant management and staff to verify the site availability and to discuss the viability and interest in co-locating a large-scale desalination plant on the properties.

Based on this research, the Barney Davis Power Plant site appeared to have the greatest potential for siting the desalination facility. The site is located close to the Gulf of Mexico, and it has a large capacity intake into Laguna Madre, available land area, and an outfall facility with cooling ponds discharging into Oso Bay. However, the owners of the Barney Davis Power Plant were in the process of selling this facility as well as several other power generating facilities, and they did not want to encumber the site with commitments or restrictions that could impact the potential sale.

Because of the available land area and the beneficial location of the Barney Davis site, this site was retained for detailed evaluation. However, because of the uncertainty of the long-term future viability of the site as a power generation facility, the resources on the site, such as the intake and the outfall facilities, were not considered to be available to the desalination facility. The initial analysis of the Barney Davis site was based on developing a desalination facility that would supply all of its own resources and not rely on shared uses with the Barney Davis Power Plant.

The uncertainty of the long-term use of the Barney Davis Power Plant resulted in the retention of the second ranked site for detailed evaluation for the potential development of a large-scale desalination facility. Two sites that were retained for detailed evaluations are the DuPont-Oxychem site and the Barney Davis Power Plant site.

Within days of the conclusion of the study, the evaluation team received confirmation that the sale of the Barney Davis site was consummated and that the new owners of the facility were interested in co-locating a large-scale desalination facility on the property. They also indicated a willingness to allow shared use of their on-site resources such as the intake facilities and the outfall system. A quick review indicated that this shared use of resources could eliminate the cost of the open sea intake, the raw water pipeline, the raw water pump station and the byproduct outfall facilities—potentially saving as much as $80 million in construction costs. Optimized alternatives of the Barney Davis site using the shared resources were then developed and included in *Chapter 4, Section 6.1* of the Report. Additional research is required to fully develop the benefits of the optimized alternatives. Therefore, the optimized alternatives are not identified as official alternatives but are presented for consideration for future analysis and possible significant cost reductions.

Task 2 – Treatment and Byproduct Management

Introduction

The initial screening produced five sites that met the minimum criteria, which were then narrowed to two, the Oxychem site on the north side of Corpus Christi Bay and the Barney Davis Power Plant located south of Corpus Christi Bay and between Laguna Madre and Oso Bay. Four alternatives were developed for each site that included different combinations of intakes, raw water sources, pre-treatment options, byproduct management, and pipeline costs. A detailed, weighted decision matrix evaluation technique was used to compare each of the eight alternatives. The following paragraphs describe the options that were considered for each of the facility components for the Intake, Pre-Treatment, Primary Treatment and Byproduct Management.

Intakes

The intake selection must be based on the raw water source location and must consider quality, environmental impacts, intake technology, and costs. Therefore, the intake selection is only a component of the entire alternative of which it is a part. No single intake option is optimum for all alternatives.

Considering the above intake factors, three intake concepts were evaluated for this project. The optimized alternatives used the existing intake structure at the Barney Davis Power Plant. Other intake concepts considered included open sea intakes and infiltration intakes. All intake options must allow transport of raw water to the treatment plant site. For any option that uses the Gulf of Mexico as the raw water source, the raw water line must cross Padre Island and either Corpus Christi Bay, Red Fish Bay, or the Laguna Madre. Construction of raw water lines through environmentally sensitive areas greatly increases the cost and complexity of the project.

i. Existing Barney Davis Intake

The primary alternative developed for the project did not initially include the use of the existing intake at the Barney Davis Power Plant because of the uncertainty regarding ownership of the facility. The original owner was attempting to sell the power plant and did not want to encumber the site with any commitments that might inhibit the sale of the property. Also, the long-term operation of the Barney Davis Power Plant was in question.

In addition to the questions regarding ownership, the design team had developed a desired baseline water quality of 35,000 mg/l as a target for raw water to be treated. The Laguna Madre water used at the Barney Davis Power Plant for cooling has extended periods of time when salinities are above 35,000 mg/l, therefore, efforts were directed at determining the availability of brackish groundwater to blend with the Laguna Madre water to meet the 35,000 mg/l salinity limitation. These efforts were unsuccessful due to the lack of availability of groundwater with appropriate levels of total dissolved solids.

For all of the reasons noted above, the primary alternatives were developed based on not using the existing intake at the Barney Davis Power Plant.

Several days before the project was finalized, it was learned that the sale of the Barney Davis Power Plant had been consummated and the new owners intended to be cooperative with the concept of co-locating a desalination facility onsite including use of the existing intake facilities. As a result of the change in ownership status, the recommended Barney Davis site alternative was optimized to include the use of the existing intake facilities. For the optimized alternatives, all modifications necessary to obtain raw water were included in other on-site facilities, and no changes or modifications are anticipated for the intake. The benefits of using the existing intake are somewhat offset by the necessity of increasing the plant size to handle the higher salinities during dry weather conditions.

ii. Open Sea Intake

The open sea intake consists of an onshore fine screen and a pipeline from the shore to the appropriate intake location terminating at the open sea inlet structure.

The open sea inlet structure has coarse screens with very low screen velocities, debris intake, and impingement, and it is constructed of concrete. This structure will be located on the sea floor and extend vertically to rise above the height of vegetation in the area. A 7-foot structure height was chosen for the analysis.

The pipeline between the open sea intake and the onshore fine screens uses high density polyethylene (HDPE) pipe. The sea bottom floor will be wet dredged to a sufficient depth to fully bury the pipe. A granular bedding and backfill will be provided to support the pipe, and a protective rock barrier and anchor will be placed over the top of the pipe. After construction, the finished grade of the sea floor will be returned to its original grade with the rock protective barrier as the finished grade material.

A fine screen assembly will be located onshore to screen finer particles from the intake stream. Multiple isolated screen assemblies will be used to allow periodic maintenance of these screens without affecting intake operations. Periodically these fine screens will be purged with a violent blast of air. The purged material will then be drained and the solid material removed from the purge stream. The cleansed purge stream will be returned to the open sea. The fine screens are located in a structure onshore to facilitate maintenance operations and shield the violent purging operations from sea traffic. If uncontained, the magnitude of the air blast could cause harm to small boats. Also, locating the fine screen onshore eliminates the need to design the raw water pipeline to withstand the high pressures required to deliver the air purge.

iii. Infiltration Intakes

Infiltration Galleries

Infiltration gallery intakes generally consist of drawing water through the existing or constructed soils to an onshore receptor, then pumping the water to the point of use. Infiltration gallery intakes, use the soils surrounding the collector pipes which act as the screening device. The passageways through the soils have very small openings that remove nearly all of the particulate matter from the seawater, thus producing a relatively high quality raw water stream. The alternatives that use the infiltration gallery intake concept have a greatly reduced pre-treatment requirement because of the high degree of filtering. Three types of infiltration gallery intakes were considered: caissons, linear collection wells, and Ranney collectors and are described in more detail below.

- *Caissons*

Caisson infiltration galleries, also called vertical beach wells, are vertical shafts constructed as close to the shore as feasible to be close to the water source. These shafts could be 60 feet or more in depth with a spacing of 300 or more feet. The number of vertical beach wells would need to be developed based on the soils structure in the area, but it is estimated that at least 40 wells would be required. The 55-mgd intake capacity required for this desalination facility is more than twice the capacity of the largest known vertical beach well plant intake system in the world. This intake concept was not used in the development of any alternatives because of questionable long-term reliability, cost, high maintenance requirements, and large onshore land area requirements.

- *Linear Collection Wells*

Linear collection wells are an enhanced version of the vertical beach well. Vertical caissons are constructed, but the collection system is enhanced by horizontal collector pipes buried parallel to the shoreline. All construction is performed onshore. Water is still drawn through the indigenous soils, and the system capacity is dependent on the structure of the soils. This option requires six caissons and 39,000 linear feet of horizontal collector pipes. This intake concept was not used in the development of any alternatives because of questionable long-term reliability, cost, high maintenance requirements, and large on-shore land area requirements.

- ***Ranney Collectors***

The Ranney collector infiltration gallery is an enhanced version of the linear collection well. Caissons are constructed onshore and horizontal collector pipes are constructed under the seabed. Each caisson can accommodate multiple collection legs to reduce the number of caissons. The Ranney collector configuration was used in the alternatives because it significantly reduced the amount of shoreline required to be dedicated to the intake system. The collector pipes could either be constructed by jacking techniques or could be wet dredged in a manner described in the open sea intake. If the collector pipes are jacked into place, the permeability of the existing soils would be the limiting factor on the number as well as the size and length of the collector pipes. If the collector pipes are installed with wet dredging techniques, the backfill and bedding materials could be manufactured and constructed to optimize intake performance. The alternatives that used infiltration galleries for the type of intake are based on using the Ranney collector infiltration gallery. The size and length of the collector pipes are based on using the jacking techniques for installation. The costs for a Ranney intake system were estimated using 39,000 linear feet of collector pipe.

Intake Options Summary

The intake options used in the development of alternatives included the existing Barney Davis intake, the open sea intake, and the Ranney collector intake. The vertical beach well and linear infiltration wells were eliminated for reasons previously stated.

Pros

The existing Barney Davis intake is the optimal intake choice for the following reasons:

- Intake already exists.
- Site is permitted.
- Configuration is compatible with the desalination facility.
- No construction of an expensive raw water line through Laguna Madre and Padre Island or into the Gulf of Mexico is required.

Cons

The existing Barney Davis intake would not make a good intake choice for the following reasons:

- The source of water available at this location is from Laguna Madre and is hypersaline.
- The hypersalinity of the water increases the capital and operating costs of the system, which partially offsets the savings from using the existing facilities.

However, even accounting for these offsetting factors, the use of the existing Barney Davis intake is the recommended intake concept if a final agreement can be reached with the property owners and the project is determined to be feasible from an environmental standpoint.

Conclusion

The open sea intake is considered the next most viable intake primarily because of the long-term reliability compared to the Ranney collector system. The cost of the open sea intake is less than the cost of constructing the Ranney collector, but the reduction in pre-treatment requirements makes the Ranney collector less costly on a total life cycle basis for the evaluation of a complete alternative.

Pre-Treatment

The reverse osmosis (RO) process requires a high quality feedwater to minimize fouling, maximize membrane life, and provide efficient treatment.

Initially, nine candidate pre-treatment options were identified for consideration including:

1. Direct filtration (eliminated prior to pre-screening as not applicable)
2. Conventional flocculation, sedimentation, and filtration
3. Solids contact clarification (Accelator) and filtration
4. Plate or tube settler clarification and filtration
5. Pulsator or Superpulsator clarification and filtration
6. Dissolved air flotation (DAF) clarification and filtration
7. Micro-sand enhanced clarification and filtration
8. Ultrafiltration using immersed membranes (Zenon)
9. Infiltration galleries

After the pre-screening process, which is described in detail in the feasibility report, to achieve the required feedwater quality, four pre-treatment options were considered for detailed evaluation:

Option 1 – Plate or tube settler clarification with filtration

Option 2 – Dissolved air flotation clarification with filtration

Option 3 – Ultrafiltration using immersed membranes (Zenon)

Option 4 – Infiltration galleries using the Ranney collector
Option 4 is more precisely referred to as an intake system, but the screening process inherent to the system greatly reduces the pre-treatment requirements on the plant site.

Each of these options is described in more detail below.

Option 1 – Plate or Tube Settlers Clarification and Filtration

Plate or tube settlers followed by granular media filtration are well proven in drinking water treatment. These systems have been effectively used in seawater reverse osmosis and can be considered as a baseline approach capable of treating worst-case water quality. For this reason, they are included in the feasibility analysis as a “baseline” alternative of accepted practice.

Pros

- The enhancements of the tube or plate settlers result in a much smaller process footprint than for conventional sedimentation.
- Clarified turbidity may be slightly higher than for conventional sedimentation, but low turbidities are still achieved through subsequent filtration.
- Residuals concentrations are in an acceptable range of 0.1-0.5 percent solids.

Cons

- Susceptible to rapid changes in water temperature.
- Limited in treating high turbidity and algae.
- The tube openings in tube settlers can become blocked with algae and solids which creates short-circuiting and deterioration in clarifier performance.

Conclusion

Plate and tube settlers are being replaced with more advanced and innovative technologies as described in Options 2 through 4 below.

Option 2 – Dissolved Air Flotation (DAF) Clarification and Filtration

Pros

DAF offers several pre-treatment advantages:

- Achieves very low clarifier effluent turbidities of less than 0.5 NTU and a high level of performance even without using a polymer, which can be an advantage in pre-treatment ahead of RO.
- Not susceptible to thermal variation and has demonstrated significant advantages in treating very cold (dense) water, thus DAF may be very effective in treating high density seawater.
- Proven premier clarifier for treating large concentrations of algae, which are notoriously difficult to settle. This may be a distinct advantage in treatment of seawater where red tides or algae may be of concern.
- DAF followed by granular media filtration can easily treat the expected worst-case raw seawater quality.

Potentially important advantages include:

- Can produce a residual concentration of up to 2 percent solids when mechanical extraction is used. This sludge concentration is about four times the maximum solids concentration achievable with plate, tube, Accelator, or sludge blanket clarifiers.
- Mechanically extracted DAF residuals can be fed directly to dewatering processes such as belt filter presses or centrifuges without further thickening.

DAF is extremely well proven from pilot tests conducted for large plants as indicated by designs for Boston, Massachusetts, at 450 mgd and the New York City Croton Water Treatment Plant at 290 mgd. When the DAF is located above the filtration units, the maximum surface loading rate of both the DAF and the filter must be limited to less than 5 gpm/sf.

Conclusions

For the reasons above, DAF clarification followed by granular media filtration is included as the most robust and favorable high-rate clarification technology to be considered in this analysis. The "stacked" DAF is the most advantageous configuration for reducing plant footprint and is evaluated in detail in the feasibility report.

Option 3 – Ultrafiltration Using Immersed Membranes

Membrane microfiltration (MF) and ultrafiltration (UF) (low pressure hollow fiber membrane treatment) technologies have developed rapidly over the last 5 years. In immersed UF systems, the membrane fibers are immersed in raw or coagulated water, and a vacuum is applied to the lumen of the fibers to draw the water through the membrane and into the lumen.

Pros

- UF membranes provide physical removal of solids, particles, algae, and physical disinfection by removal of pathogens such as Giardia, Cryptosporidium, and some viruses.
- MF and UF have demonstrated effectiveness for providing low silt density indices (SDI) ahead of high-pressure membrane processes such as nanofiltration (NF) and RO resulting in greater NF and RO process efficiency.

Cons

- Unless a coagulant is used, UF membranes do not remove color or organics.

There is some limited experience for MF and UF in seawater pre-treatment.

Conclusions

Because of the high degree of benefit that can be realized by using the Zeeweed process as a full replacement for both clarification and filtration and the proven robustness of the process, the Zenon Zeeweed 500D UF was selected for analysis as the immersed ultrafiltration process for comparison to the conventional pre-treatment approach using tube settler clarification and filtration and DAF filtration. Other approaches using other types of UF as a "filtration" replacement may be considered in the future when the plant is sited, water quality is confirmed, and residuals disposal options are known.

Option 4 – Infiltration Galleries

Bank filtration without pre-treatment was included in this feasibility study to capture the potential least cost process alternative with assumed worst-case water quality. A bank infiltration system is conceptualized to provide "physical" pre-treatment ahead of the RO. The infiltration galleries considerations are presented in *Section 2.2* under the *Intakes* heading. An ultraviolet radiation disinfection system is included on the plant site to assist in the removal of pathogens that are likely to pass through the infiltration galleries.

Summary of Pretreatment Options

Four alternatives for each treatment site were developed based on selecting compatible combinations of intakes, off-site pipeline, pre-treatment, and common elements (including RO components). A weighted prioritization method was used to evaluate the alternatives using the following factors as the decision criteria:

- Total life cycle cost
- Reliability
- Complexity of implementation

The intake pre-treatment combination using infiltration galleries was the least cost alternative, but this option received low marks for reliability and complexity of implementation. Tube and plate settlers and the DAF system have similar life cycle costs, but the DAF pre-treatment was determined to be more reliable than the tube and plate settler option. The immersed UF membrane was the most costly of the pre-treatment options, but it scored favorably in the reliability of treatment and complexity of implementation.

Conclusions

Based on the information available, the alternatives using DAF appeared to be the optimum pre-treatment options for the Corpus Christi Desalination project. It should be noted that in view of the cost competitive nature of this application and the long-term trend of decreasing costs of micro- and ultra-filtration membranes, the immersible membrane should also be considered for any future developments.

Treatment

RO is a state-of-the-art technology used in processing large scale desalination for raw waters containing a total dissolved solids concentration higher than 3,000 mg/l. Other technologies using thermal techniques, electrodialysis reversal, and other treatment processes have significant drawbacks for use with the raw water sources available in the Corpus Christi area and are only applicable in niche applications; therefore, RO is the only primary treatment process considered in this feasibility analysis.

Byproduct Management

Several potential options for byproduct disposal were considered including:

- Deep well injection
- Evaporative lagoons
- Offshore discharge
- Discharge to a wastewater treatment plant
- Membrane-thermal zero liquid discharge
- Beneficial reuse
- Dilution and discharge to Oso Bay

Deep Well Injection

Deep well injection required the construction of a minimum of 25 to 30 widely spaced wells with an estimated capacity of 1 mgd each. In addition to the wells, well distribution lines and high pressure injection pumps operating at approximately 1,000 psi are required. The cost of this byproduct disposal option was very high and was therefore eliminated from further consideration.

Evaporative Lagoons

In this option, large lagoons are constructed to contain the water until it is evaporated to atmosphere leaving only the salts behind. To evaporate 25 to 30 mgd of byproduct water would require a land area of 38,000 acres. Although evaporative lagoons were considered, the estimated cost for purchasing the land and constructing a lined lagoon system is over $2 billion and, therefore, is not considered a feasible solution.

Offshore Discharge

Offshore discharge is considered the most straightforward and reliable method of byproduct disposal. The byproduct stream will have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall will require further investigation.

The design of the outfall is important to assure that environmental impacts are minimized and that the discharged material does not migrate back to the intake area at concentrations higher than normal ambient conditions. To accomplish these features, the outfall needs to be located at the proper depth and distance from shore and sufficiently remote from the intake. To minimize cost, most of the discharge outfall pipe is constructed in the same trench as the intake line, but diverges at the appropriate location to attain the proper separation distances.

The relative locations of the outfall and discharge pipes must be determined by detailed hydraulic modeling during subsequent design phases. For this assessment, an estimate of a 0.25-mile (1,400 feet) separation distance was determined to be reasonable for planning purposes.

The byproduct outfall needs to be located in water deep enough to avoid conflicts with marine traffic but also shallow enough to benefit from mixing that results from surface wave action. For mixing and diffusion, a maximum water depth of 40 feet was chosen.

Two types of currents predominate in the Gulf of Mexico in this area, riptides and wind-driven currents. Riptides predominate along the coast and are generally contained within one-half mile of the shoreline. Riptides close to shore must be avoided to prevent the discharge from recirculating and possibly concentrating toward the shore. The wind-driven current in the area is known as the Texas Coastal Current. The Texas Coastal Current will aid in the mixing and dispersion of the byproduct stream and prevent the discharge from reaching the intake structure.

The 2.0-mile offshore distance was chosen as the optimum location in consideration of depth and currents in the area, as described above, and to ensure that riptides do not interfere.

Pros

Although significant and important environmental concerns would have to be addressed, it appears that discharging to the Gulf of Mexico offers the greatest opportunity for environmental support.

Cons

The byproduct stream would have a TDS concentration of twice the ambient conditions, but proper design of diffusion outfalls should minimize environmental impacts. The final location of the outfall requires further investigation.

Conclusion

Option 3 involves pumping the desalination byproduct stream approximately two miles offshore. Because the result is a diffused discharge that minimizes environmental impacts, offshore disposal was the selected byproduct disposal method.

A 2.0-mile offshore distance was chosen as the optimum location in consideration of depth and currents in the area as described above and to ensure that riptides do not interfere.

Discharge to a Wastewater Treatment Plant

Discharging the byproduct to a wastewater treatment plant was considered but quickly determined not to be viable. The byproduct stream would have a flow of approximately 25 mgd and a TDS concentration of 70,000 mg/l. The largest wastewater plant in the area, the Oso Treatment Plant, has a rated capacity of 16.2 mgd, and the effluent is used to dilute the hypersaline conditions in the bay. If the plant could be made to accommodate the proposed byproduct stream, the resultant dissolved solids concentration would be approximately 49,000 mg/l and would negatively impact Oso Bay’s salinity.

Conclusion

This option was determined not to be feasible due to the negative salinity impact and, therefore, was eliminated.

Membrane-Thermal Zero Liquid Discharge (ZLD)

Zero liquid discharge technologies involve concentrating the byproduct stream to essentially dry salts and disposal of the dried cake residue. Research indicates that this technology is the most expensive of all byproduct disposal options and is only considered viable when a valuable byproduct can be recovered.

Conclusion

Due to the cost of this option and the lack of a reliable, long-term customer for the byproduct salts, this option was eliminated.

Beneficial Reuse

During the site selection investigations, a potential customer for seawater salts was found near the Oxychem site. The customer is currently trucking in saltwater at a concentration of 300,000 mg/l to use as a feedstock for their manufacturing facility. The processes to concentrate the byproduct to the desired concentration are similar to but not as extensive as the previously mentioned ZLD technology.

Cons

- High cost
- Entire desalination facility operations would be dependent on the economic viability of the product being manufactured by the byproduct customer.

Conclusion

This option was determined not to have satisfactory reliability as the sole disposal method for the byproduct stream and, therefore, was eliminated from consideration.

Dilution and Discharge to Oso Bay

The Barney Davis Power Plant currently has the ability and permits to withdraw over 500 mgd of water from Laguna Madre for cooling and then discharge the warmed water through cooling ponds and release it into Oso Bay. Oso Bay is a flow limited body of water, and the continued circulating flow from the cooling tower operations is considered highly beneficial, even though the salinity of the discharge is higher than background conditions in Oso Bay. The byproduct stream from the desalination facility is approximately 25 mgd with a salinity of 70,000 mg/l. Combining the cooling water discharge with the byproduct stream would increase the salinity of the discharge to Oso Bay by approximately 5 percent.

Conclusion

This option represents a significant cost savings from all other options and should be considered in all future discussions and evaluations.

Byproduct Management Summary

Of all the options for byproduct stream disposal, the open sea outfall is determined to be the most reliable. Diluting the byproduct stream with the cooling water and discharging the blended stream to Oso Bay offers a potentially significant cost savings but involves environmental issues that must be addressed. Both of these options are carried forward in the detailed evaluations and cost modeling performed for the *Large Scale Demonstration Desalination Feasibility Study*.

Service Area

Water from the proposed treatment facility would be post treated after both pre-treatment and RO to make it compatible with existing City of Corpus Christi water and would be tied directly into the distribution system. The existing City demand is significantly greater than the 25 mgd that the plant would produce, allowing the desalination plant to operate in a constant flow condition for maximum economy.

Conclusion

The connection to the Corpus Christi distribution system is nearby, minimizing the cost of connection and maximizing the potential economic benefit.

Task 3 – Source Water Blending and Byproduct Management

Source Water Blending

The quality of the feedwater to a desalination facility has a significant impact on the cost of treating the water. The higher the total dissolved solids (TDS)concentration, the greater the cost to treat. Similarly, the desalination facility produces a byproduct water that is approximately twice the concentration of the influent feedwater to the plant. The TDS concentration of the byproduct is of concern to the environment. For these reasons, the possibility of using brackish groundwater to make significant reductions in the TDS concentration of either the feedwater or the byproduct was investigated as a part of this study.

There is significant brackish groundwater in the Corpus Christi area, but the closer to the coast a facility is, the higher the concentration of dissolved solids that are found in the water. The higher the TDS concentration, the greater the volume that must be pumped to make a significant difference in the quality of the blended water. For the Barney Davis Plant site, the average TDS concentration of the Laguna Madre source for the cooling water pumps at the plant was over 41,000 mg/l. If the area groundwater has a TDS of 10,000 mg/l, it would take 10 million gallons per day (mgd) of brackish groundwater to blend with 45 mgd of Laguna Madre water to reach the 35,000 mg/l desired feedwater quality. The electric logs available indicated that production of these groundwater quantities is unlikely and would potentially have consequences related to land subsidence. In addition, the test well that was drilled as a part of the Padre Island Desalination Project (a separate study funded by the City of Corpus Christi to determine feasibility of a small desalination plant on Padre Island) showed rapid deterioration of quality as the well was pumped. If wells were drilled and water quality deteriorated, it would require increasing quantities of groundwater to make the same dilution.

Byproduct Management with Blending

The same situation exists with efforts to blend brackish groundwater to dilute the concentration of the byproduct water. Reducing the blended concentration to the same concentration as the Laguna Madre would require approximately 25 mgd of brackish groundwater to blend with the 25 mgd of byproduct water. In addition, the brackish groundwater may contain constituents that are harmful to the marine environment.

Conclusion

TDS results from a previous desalination study, existing log data, and the interpretation of a professional hydrogeologist provided the facts needed to determine that using brackish groundwater for blending is not cost effective. This same result was determined with blending with either the feedwater or the byproduct water.

Task 4 – Potential Partners

The City is committed to a public process for the development of a seawater desalination facility. As a part of that process, there is a great likelihood that a public private partnership could be developed if legislation is passed permitting such an arrangement for municipalities in Texas.

However, the City wants to have maximum competition in the development of such partnerships, which can only come after development of a Request for Qualifications leading to the selection of qualified firms who will be given an opportunity to respond to a Request for Proposal to design, build, and potentially operate a desalination facility for a firm fixed price.

Conclusion

For the reasons noted above, the City has not formed any alliances with private firms at this time.

Contacts have been made with universities in the area to coordinate on research and data collection needs, but no sources of funding are anticipated from those efforts. The universities are supportive of the City's efforts and have expertise in data collection and analysis that will be crucial to the long term development of facilities.

Task 5 – Potential Customers

Files from the 2001 regional plans submitted to the TWDB were analyzed to determine potential customers for water that would become surplus to the City with the advent of a desalination facility. Demands in the aggregate of 10 mgd or more were located and the current strategies reviewed. However, the 2006 regional plans are in the process of being prepared, and there has been increased emphasis placed on the development and movement of groundwater, at least partially in response to the junior water rights provision in Senate Bill 1. The change in senior rights to junior rights for surface water involved in interbasin transfers has created less interest in surface water transfers and more interest in groundwater transfers. Several likely customers for City water have become involved in projects to determine the cost of groundwater, as well as one of the City's regional customers. The City has entered into an agreement with the San Antonio Water System (SAWS) to investigate cooperative ventures in the Nueces Basin through a U.S. Army Corps of Engineers Feasibility Study. This study was recently signed by all parties and will examine the potential for further cooperative efforts by the parties, including efforts related to desalination.

Conclusion

For the reasons noted above, no firm negotiations on price were possible, and potential revenue streams from sale of surplus water were estimated based on raw water costs statewide.

Task 6 – Power Sources

Both conventional and alternative power sources were investigated during the course of this feasibility study. Conventional power sources are referred to as the purchase of retail power at competitive rates from the electric power grid. Alternative energy sources consist of developing a power source using wind or solar energy specifically designed to meet the power requirements of the desalination facility.

Costs for conventional power were derived from conventional grid-based power sources estimated at $0.065 per kilowatt hour based on available supplies and a retail power cost. The results of the study indicate that conventional power is likely to be the most viable option for the desalination facility.

Pros

- All costs to obtain the power are readily definable.
- Cost projections for the next 30 years indicate relatively stable power costs are anticipated.
- Recent correspondence from Topaz Power Partners has indicated the potential for lower cost power if a retail electric provider can be developed to retail the power from the Barney Davis Plant to the desalination facility.

Cons

Wind-generated power appears to be close in cost for the desalination plant. However, it is necessary to consider the following disadvantages:

- Wind power is dependent on a noncontrollable resource.
- Only marginally cost-effective at the available power rate structure.
- Additionally, uncertainties about a potential suitable location, the cost of the land for a wind generation facility, and the cost of transmission to the desalination facility represent significant unknown costs at this point.

Conclusion

Solar power was considered, but the conceptual costs for solar power on the scale needed for the Large Scale Desalination Facility were an order of magnitude higher than either conventional power or wind-generated power.

Task 7 – Project Funding and Development

As noted previously, the concept of public private partnerships and some method of design/build/own/operate/transfer have been used in other states as a means of reducing costs and delivering projects in a timely fashion. Current Texas law does not permit Corpus Christi to avail itself of this option. However, this project did perform a review of the different project funding and development methods and that information is contained in the report. Costs as presented in *Task 8 Cost Model Development* below were estimated based on conventional design, bid, and build practice as normally practiced by cities in Texas.

Conclusion

Analysis of project descriptions in other areas leads to an assumption that costs could be 10 percent to 20 percent less if estimated using an alternative delivery method.

Task 8 – Cost Model Development

A spreadsheet cost model was developed (see *Appendix 10-A* in the report) to compare the cost of City operations with and without a desalination facility. For the purposes of this cost model, it was assumed that the expenses for the construction of a pipeline to bring water from the Colorado River to the intake pump station at Lake Texana would be avoided if a desalination facility were to be constructed. All other City expenses for upgrades to the O. N. Stevens Plant were assumed to be needed, although operations costs were lessened by the reduction in flow through the plant. Costs were brought back to a present worth in a 2004 comparison, and the amount of subsidy was adjusted until the present worth of the No-Desalination option was the same as the present worth of the desalination option. The subsidy required under this analysis was $874/acre foot. The primary reason for the size of the subsidy is the past performance of the City of Corpus Christi in developing lower cost water supplies for future needs. The subsidy would be in addition to an estimated revenue of $5,000,000 annually from the sales of surplus City water supplies.

Cost Analysis Summary

The above cost analysis was performed under worst-case conditions. Despite the many data collection programs taking place under State, Federal, and university programs, much of the specific data needed to optimize a desalination treatment facility does not currently exist. This fact points to the importance of pilot plant testing and data gathering as key components of the process in gaining further insight into the cost of treatment and residuals management. Corpus Christi is ideally situated to be a participant in this process and is looking forward to continuing to work with the Governor's Office and the TWDB to make desalination of seawater a reality in Texas.

Task 9 – Report

The draft *Large Scale Demonstration Desalination Feasibility Study* was prepared in accordance with the guidelines and schedules contained in the Research and Planning Fund Regional Facility Planning Contract between the City of Corpus Christi, Texas, and the Texas Water Development Board, and as modified during the development of the Study.

A draft of the findings of the Study was presented to the City of Corpus Christi City Council at their regular meeting on August 24, 2004. After approval of the Draft Report by the City of Corpus Christi, the Draft Report was submitted to the Texas Water Development Board on August 31, 2004 and simultaneously made available for public review at five public locations in Corpus Christi, Texas. A summary presentation of the Draft Report was made to the Region N Planning Group on September 9, 2004. A public meeting was held on September 9, 2004 at the Corpus Christi Main Public Library. A public comment period was open through September 16, 2004. No public comments were received. Comments from the Texas Water Development Board, Texas Parks and Wildlife Department, and the United States Bureau of Reclamation were received on September 30, 2004.

Draft responses to the comments were returned to the commentors on November 1, 2004. Revisions to the Draft Report necessitated by the written comments were developed during November 2004. The final *Large Scale Demonstration Desalination Feasibility Study* was submitted to the Texas Water Development Board on November 30, 2004.

Results and conclusions

The results of the Large Scale Demonstration Desalination Facility Study in the Corpus Christi area are as follows:

- There are no significant technical issues that would prevent such a facility from being constructed. The processes that were investigated are available for application to this facility and all have some amount of experience with applications to seawater.
- There are significant environmental issues that need further investigation. The issue of sea grass beds is of great concern, and routing studies are needed to determine the routing that

provides the least disturbance of these areas. This is of such significant concern since the availability of suitable mitigation areas is limited. Identification of such areas is also needed as a part of the investigation of the impacts of these pipeline routings. In addition, there are environmental concerns with the discharge of the desalination byproduct with the Barney Davis Plant cooling water into Oso Bay. This alternative would eliminate the disturbance of the sea grass beds noted above, but would have environmental consequences of its own. These areas need further study to better define the relative merits of each.

- There are institutional concerns with the method that is used to build large scale desalination facilities. Such facilities throughout the world are generally being constructed through alternative delivery methods, which include some modification of the design, build, own, operate, and ultimately transfer of the facilities to a municipal owner. Currently, Texas law does not allow municipalities to procure such facilities through alternative delivery methods. It is estimated that a savings of 10 to 20 percent is possible from the cost reported in this report if alternative delivery methods could be used.
- Finally, the report indicated that substantial subsidies are required to make the facilities comparable in costs to other potential water sources. There is recognition that desalinated seawater has higher reliability and higher quality than most conventional sources, but it is difficult to quantify the value added for this water.

Conclusions

The following conclusions were reached as a result of this study.

- Seawater desalination produces a truly drought-proof supply with added value.
- Pilot scale investigation and data gathering studies are needed to further define the costs of the facilities to provide additional insight into the viability of desalination along the Texas Coastline.
- The viability of desalination of seawater is primarily a question of timing. The technology exists currently if funding can be provided to build plants which will provide a valuable contribution to the expansion of the current water supply.
- Support of the Texas Water Development Board, the Governor’s Office, and many interested State Legislators has been invaluable in achieving the results to date.
- Costs for desalination facilities and environmental challenges that are faced in siting and operating such facilities are highly site specific.
- Subsidies will be needed for the foreseeable future to spur development of such facilities.
- The size of the subsidy needed for Corpus Christi is a direct result of the City’s proactive procurement of water supplies to meet their needs from less costly sources. Corpus Christi has shown the resolve to move forward with large projects to ensure their long term water supplies. This same resolve is a key element in moving forward in the investigation of desalination as a further augmentation of their supply.

Benefits of continued investigations

The development of additional water supplies is crucial to a continued healthy economy in Texas and to proper management of the growth that is occurring. The major ports of the coastal cities like Houston, Galveston, Corpus Christi, and Brownsville play a significant role in attracting business investment in Texas. Desalination of seawater for potable water supply is a quantum leap in technology and in development of truly drought-proof supplies for a thirsty nation.

The three demonstration projects that have been partially funded by the Texas Water Development Board through Governor Perry’s desalination initiative have brought positive benefits to Texas. These efforts have brought attention from the Federal level as Federal officials realize that the potential for providing additional drinking water supplies is becoming just as crucial to Texas as it is to California and other more arid regions. Growth along the nation’s coastline is proceeding rapidly and additional supplies of quality drinking water are needed now and in the future to properly manage that growth.

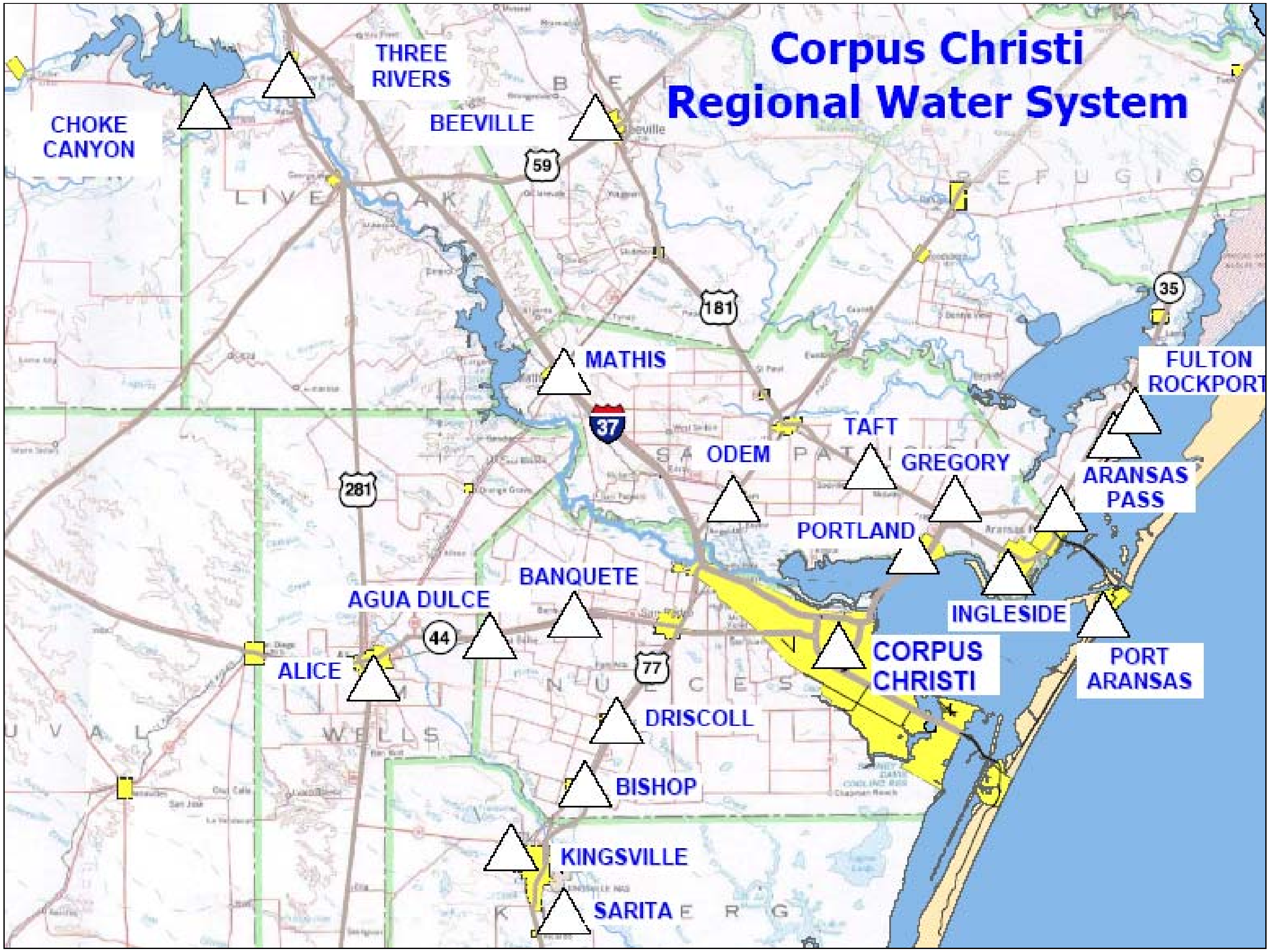
As all of the projects have demonstrated, there are no serious technical impediments to the treatment of seawater and production of potable water. However, there are significant environmental issues that must be addressed to be sure that desalination of seawater is managed to minimize any negative effects and maximize the positive effects. In addition, there are questions concerning the cost of such facilities. It is difficult to compare the costs of producing a water which comes from a drought-proof source whose quality can be specifically engineered to nearly any desired level of dissolved minerals, versus the cost of conventionally obtained surface water that is treated with more conventional treatment technology and whose quantity is subject to current and future droughts of record. There is added value to desalinated water from the reliability of the supply and the quality of the product, and the determination of that incremental value has yet to be quantified.

Continuation of the demonstration projects through the pilot plant and data gathering phases is in the best interest of Texas for the following reasons:

- The more widespread and potential applications of membrane processes there are, the more incentive there is for membrane manufacturers to continue to fund research into newer, better, and more energy efficient membranes.
- Membrane technology improvements are applicable to the entire State, as many areas have supplies of brackish groundwater that are now being investigated for conversion to potable supplies through desalination technology. Improvements in membrane life, durability, and susceptibility to fouling and scaling are just as applicable to groundwater desalination as they are to seawater desalination.
- Development of large scale seawater desalination projects at the coast provides a ready source of supply to growing coastal areas, many of which encompass significant industrial capacity that contributes heavily to the economy of the State.
- Development of water supplies at the coast relieves some of the pressure on inland sources of water, both for growth farther inland as well as for environmental flow needs.
- All of the demonstration project investigations had to rely to some extent on worst-case assumptions. These assumptions have resulted in high costs and potential subsidy levels. Pilot plant investigations and direct data gathering provide a means of refining those costs and potentially reducing the subsidy amounts needed.
- An active process of investigation of desalination in Texas helps make the case for Federal funding to support desalination activities throughout the United States with a variety of source water quality.
- Continuation of the demonstration process allows continued debate on the added value of water from a desalination facility.

- The pilot plant and data gathering phase will better define the environmental issues that will be faced and help to gather information on impacts and potential mitigation strategies to minimize those impacts.
- The pilot plants will provide a focal point for public attention and education efforts in desalination technology. Nothing informs the public better than something that can be seen in operation, and the greater the number of pilot facilities that are in operation, the greater the number of members of the general public who will have the opportunity to view them.

Corpus Christi Regional Water System



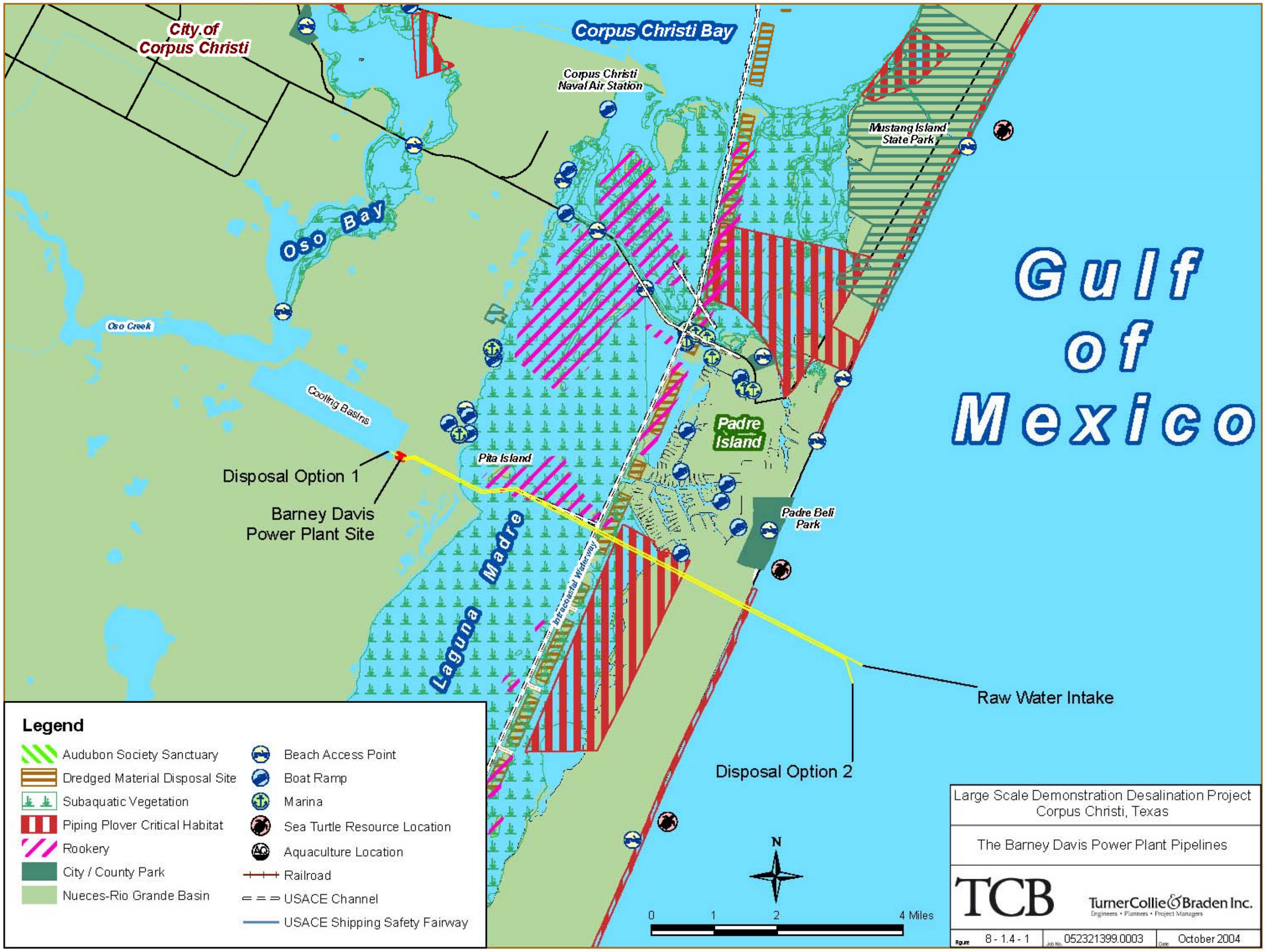


Figure 8-1.4-1 The Barney Davis Power Plant Pipelines

Figure 4-3.1.3-2 General Arrangement of Parkson DAF FloFilters