Process Design Basis and Narrative
Port of Corpus Christi Industrial Seawater Desalination
Harbor Island

December 2017

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Introduction

The Port of Corpus Christi Authority (PCCA) is developing a project to provide a sustainable supply of potable water for the Corpus Christi area that is not dependent upon rainwater. The proposed system will provide up to 50 million gallons per day (MGD) of permeate through the process of desalination. The purpose of this project is to develop a basis of design in sufficient detail to complete the Texas Commission on Environmental Quality (TCEQ) Industrial Wastewater (TPDES) Permit Application. The proposed facility will have discharges of the following effluents:

- Reject from the membrane desalination process, which is high in Total Dissolved Solids (TDS); and
- Supernatant and filtrate from sediment and sludge dewatering.

The proposed facility will be located on Harbor Island. The plant intake will consist of seawater pumped from one of the adjacent channels. Pre-treatment will include removing sediment in the form of total suspended solids (TSS). The plant will use several clarification and filtration pretreatment processes for this purpose. The final treatment step will be membrane desalination using Reverse Osmosis. The low TDS permeate will then be treated to reduce corrosiveness, chlorinated, and distributed for potable water use. The suspended solids will be concentrated into a dried sludge for offsite disposal. The dewatering filtrate, thickener supernatant and the membrane reject are the subject of the Industrial Wastewater Permit Application.

Project Objective

The overall Project Objective is to develop a sustainable supply of potable water for the Corpus Christi area that is not dependent upon rainwater. This Process Design Basis and Narrative provides information in support of the TPDES Industrial Wastewater Permit application.

Proposed Pre-Treatment and Treatment Unit Processes

The following unit processes will be utilized in the desalination facility:

- Intake screens to remove large particulate from seawater
- Intake clarification with chemical coagulation to remove algae and suspended solids
- Strainers to remove fine debris
- Ultrafiltration to remove fine TSS
- Reverse Osmosis to remove TDS
- Calcite filters to add alkalinity to the permeate to reduce its corrosiveness
- Chlorination
- Distribution pumping

- Energy recovery
- Discharge of the membrane brine or reject under a TPDES permit
- Thickening of the clarifier underflow
- Consolidation of the ultrafiltration membrane backwash solids with thickened clarifier underflow
- Dewatering of consolidated sludge streams
- Discharge of the thickener supernatant and dewatering filtrate under a TPDES permit

Process Narrative

Seawater will be drawn into the plant from a channel adjacent to Harbor Island through coarse screens that will keep large material from entering the pre-treatment processes. The screen will reject captured solids as industrial solid waste into a dumpster. Sodium Hypochlorite (NaOCl) will be added as required to clear marine growth from the screens. The water will enter a rapid mixing unit where one or more treatment chemicals are added. It will then enter the Clarifier Center well, where flocculent is added. It will then flow into the main clarifier tank, where suspended solids will settle. The settled solids will be removed periodically as underflow to the Sludge Thickener. The clarifier effluent will flow to the Settled Water Clearwell, where NaOCl may also be added for oxidation of manganese and for partial disinfection.

From the Settled Water Clearwell, flow will pass into the strainer where solids and debris will be removed as necessary to protect the Ultrafiltration (UF) membranes. The Strainers will be backwashed to the Sludge Thickener. NaOCl may also be added to the strainers, as required. Particles exceeding a diameter greater than 0.001 μm will then be removed by passing the water under high pressure through the UF membranes. This process is semi-continuous, with some UF units in forward flow and others in Backwash or Cleaning mode. Backwash flows will be sent to the UF Reject Tank and then stored for processing in the Sludge Thickener. UF Permeate will be sent to a Clearwell where NaOCl will be added, if required.

From the Clearwell, water will be pumped through Cartridge Filters, the last unit to protect the Desalination reverse osmosis (RO) skids. The RO units will then remove particles larger than 0.1 nm. Pumps taking suction from the Clearwell will apply high pressure to force the seawater through the RO membranes, leaving the TDS behind. The process will be semi-continuous, with some RO units in forward flow and others in Reject or Cleaning mode. RO Permeate will be passed through a calcite filter to add alkalinity and reduce the corrosivity of the product water. The water will then be chlorinated and placed into one of two Permeate Storage Tanks for distribution as potable water. The RO reject will be discharged to a Brine Tank, and then pumped to Outfall 001.

Solids and sludge from the Clarifiers, Strainers, and UF Reject will be passed into a Mix Tank where Coagulant may be added, as required, to increase the diameter of the solids and then into a Sludge Thickener. A Flocculent may be added to the center well of the Thickener to enhance solids separation. The Supernatant overflow will pass over the Thickener weirs to the Outfall Storage Tank. Underflow from the thickener will be pumped into a Belt Filter press (BFP) for dewatering. Solids will be taken off site via truck. BFP Filtrate flow will flow to the Outfall Storage Tank where it will combine with the Thickener Supernatant for discharge to Outfall 001.

A Block Flow Diagram of the process is shown in **Figure 1**. The corresponding water balance is shown in **Table 1**. The water balance shows that the intake of the facility will be 150.7MGD to produce 50 MGD of Permeate. The water balance is based on the following design assumptions:

- 5% sludge removal in the clarifier;
- 3% backwash at the strainers;
- 90% permeate recovery in the UF system;
- 55% of RO feed routed through energy recovery;
- 40% permeate recovery in the RO system;
- 50% decant from the thickener; and
- 60% filtrate recovery from the filter press.

Flow Basis and Material Balance

A summary of the projected Wastewater Stream Concentration is show in **Table 2** below. The projected effluent concentrations are based on published sample data for Corpus Christi Bay and the design assumptions identified previously for the water balance. Constituent concentrations for average effluent conditions are derived by assuming 40% recovery of RO permeate, while maximum constituent concentrations are derived by assuming 50% RO permeate recovery. Note that the treatment system is designed to remove suspended solids and associated total organic carbon.

Outfall 001

Diffuser

Outfall 001 will consist of a diffuser oriented parallel to the shoreline, approximately 300 ft away. The design basis assumes a 48-inch buried HDPE discharge pipe will feed the diffuser from the on-shore pump station. The approximate diffuser location is shown in **Figure 2.** While the exact design details of the diffuser have yet to be finalized, a typical diffuser configuration is shown in **Figure 3.** The characteristics of diffuser will be defined during system design to achieve target mixing performances.

Modeling

Diffuser performance was modelled using CORMIX (version 10.0GT). A report describing the modeling program is included as **Appendix A**. Modeling results demonstrate a significant factor in achieving good mixing is locating the diffuser at sufficient water depth. Models were run at water depths of approximately 63 feet.

Significantly better effluent mixing is predicted by the model for 50% RO recovery than for 40% RO recovery for varying diffuser designs. This difference is likely due to the increased density of the effluent at higher recovery rates. Diffuser performance can change significantly across a range of flows for a particular set of design parameters. CORMIX shows that good mixing performance can be achieved when the diffuser effluent is characterized by a certain flow profile, referred to by the CORMIX model as “flow class”. As shown in the modeling report, the modeled effluent at the boundaries of the mixing zones for the various diffuser designs achieved percentages below 2.5% at the ZID, 1.5% at the aquatic life mixing zone, and 1.0% at the human health mixing zone. The diffuser will be designed to achieve these target levels of mixing performance as determined through modeling across the range of flow rates.

Natural Salinity Variation

The following discussion about the variability of salinity levels in Corpus Christi Bay is based on the U.S. Environmental Protection Agency document included in **Appendix B.**

Natural salinity levels within the Bay system vary widely and are largely controlled by sources of freshwater inflows entering into the bays and estuaries consisting of rain, groundwater, and the largest contributor, surface water from rivers and streams. The Nueces River is one of the largest contributors of freshwater into the local bays and estuaries.

Natural fluctuations in freshwater inflows into the Bay can have an immense impact on organisms within the Bay system. For example, if a long drought persists and creates a situation of very little freshwater inflow into the Bay, it may cause hypersaline (high salt) conditions that in turn affect bay shrimp catches which need a certain salinity range in order to mature in healthy numbers. On the other extreme, there may be an abundance of freshwater inflow after an extended heavy rain event that causes eutrophication (high nutrient conditions), triggers large algal blooms that deplete oxygen and light within the water column, and negatively affect fish and plants living in the Bay system.

Data obtained from the TCEQ for Buoy 16492 (located in Corpus Christi Bay) demonstrate this natural variation in ambient salinity. This data set, shown in **Figure 4** below, shows a historic salinity variation between 3.06 and 40.9 parts per thousand. Since the proposed effluent modeling demonstrates the system effluent will increase the ambient concentration less than 1% beyond the aquatic life mixing zone, this increase is considered insignificant versus the natural variation and will not lead to the degradation of local water quality.

Table 1: 50 MGD Desalination Facility Water Balance

Stream #	Stream Description	Design Flow (MGD)
01	Seawater Intake	150.7
02	Screened Seawater	150.7
03	Clarifier Feed	150.7
04	Settled Seawater from Clarifier	143.2
05	Clarifier Sludge to Thickener	7.5
06	Settled Seawater to Strainers	143.2
07	UF Feed from Strainers	138.9
08	Strainer Backwash to Thickener	4.3
09	UF Permeate	125
10	UF Reject	13.9
11	UF Permeate Feed to RO	125
12	RO Feed HP Pump Flow	56.3
13	RO Permeate	50
14	RO Permeate from Calcite Filters	50
15	Water to Distribution Pumps	50
16	RO Reject Thru ERU	75
17	RO Feed Thru ERU	68.8
18	RO Reject to Disposal	75
19	Waste from UF Reject Tank	13.9
20	Combined Wastes to Rapid Mixer	25.7
21	Combined Wastes to Thickener	25.7
22	Thickener Decant to Outfall Tank	12.9
23	Thickener Slurry to Filter Presses	12.9
24	Filter Press Filtrate to Outfall Tank	7.7
25	Filter Cake Solids to Landfill	5.1
26	Outfall to Disposal	20.6

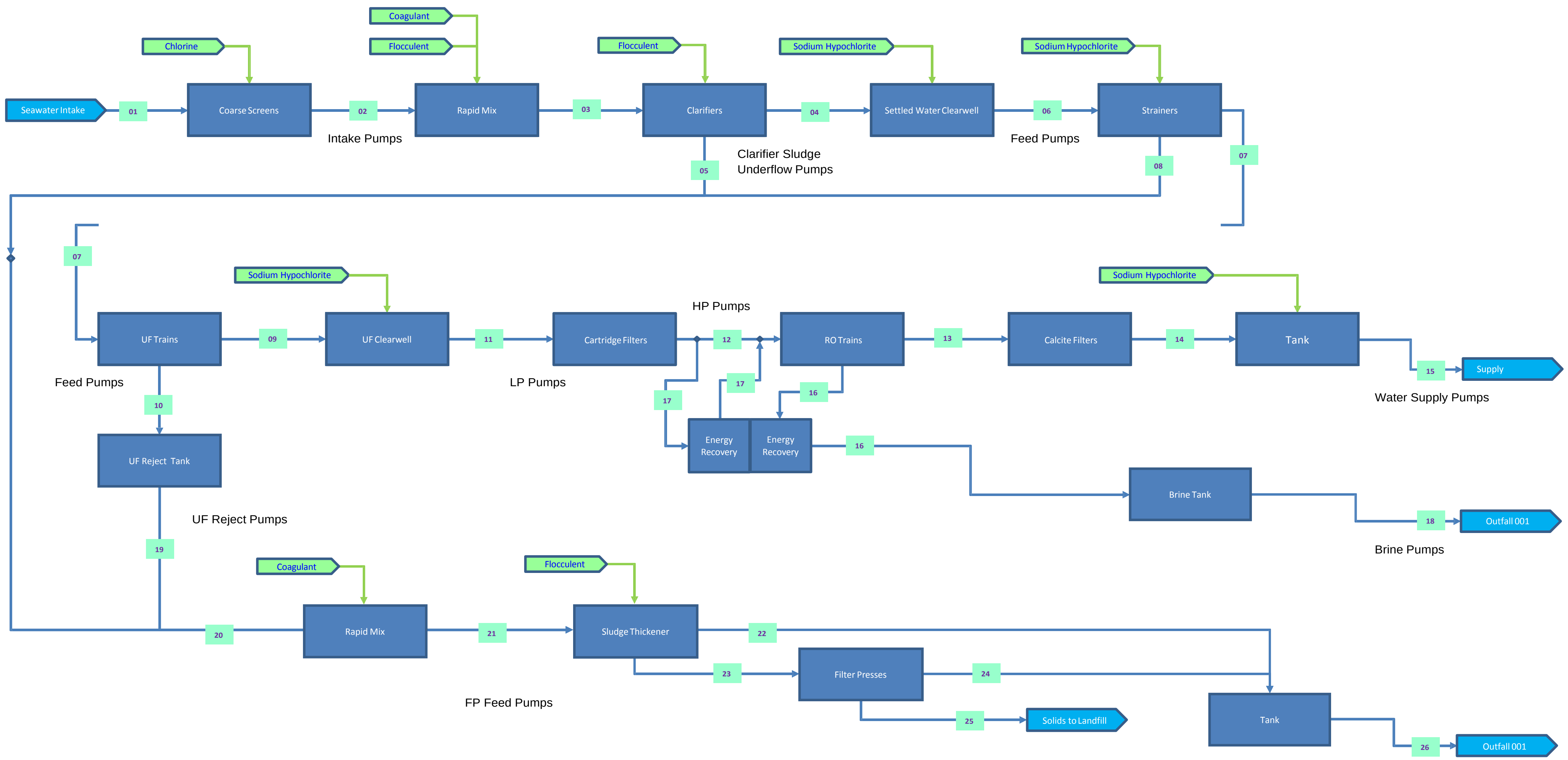
Table 2: 50 MGD Desalination Facility Design Basis Source Water and Effluent Constituent Concentrations

Parameter		Source Water Quality Design Basis[1]	Average Outfall 001 Effluent[2]	Max Outfall 001 Effluent[3]
Flow, mgd		150.7	96	125
Sodium (Na)	mg/L	11,600	18,500	21,800
Calcium (Ca)	mg/L	1,700	2,720	3,200
Magnesium (Mg)	mg/L	1,400	2,240	2,640
Potassium (K)	mg/L	368	590	690
Barium (Ba)	mg/L	0.04	0.06	0.1
Strontium (Sr)	mg/L	6.8	11.0	12.7
Iron (Fe)	mg/L	1.5	2.4	2.8
Bicarbonate (HCO3)	mg/L	145	230	270
Chloride (Cl)	mg/L	23,000	36,700	43,200
Sulfate (SO4)	mg/L	3,000	4,800	5,660
Nitrate (NO3)	mg/L	2.0	3.1	3.6
Fluoride (F)	mg/L	2.0	3.2	3.7
Silicon Dioxide (SiO2)	mg/L	5.0	8.0	9.4
Boron	mg/L	6.0	8.0	8.9
Total Dissolved Solids (TDS)	mg/L	41,252	66,000	77,460
pH	S.U.	7.5	7.5	7.5
Temperature	°C	14-32	14-32	14-32
Total Organic Carbon (TOC)	mg/L	4	1	2
Total Suspended Solids (TSS)	mg/L	30	15.0	30.0

Note:

1. The source water quality design basis data are based on sample data for Corpus Christi Bay listed in the Freese and Nichols report, "Variable Salinity Desalination Demonstration Project: Technical Memorandum No. 2, VSD Plant Siting Analysis", April 26, 2016.
2. Average constituent values based on 40% RO permeate recovery.
3. Maximum constituent values based on 50% RO permeate recovery.

Process Flow Diagram



Port of Corpus Christi
Proposed Desalination Plant
Harbor Island Site
Corpus Christi, Texas

PROCESS FLOW DIAGRAM

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FIGURE
1

Port of Corpus Christi
Proposed Desalination Plant
Harbor Island Site
Corpus Christi, Texas

APPROXIMATE DIFFUSER LOCATION

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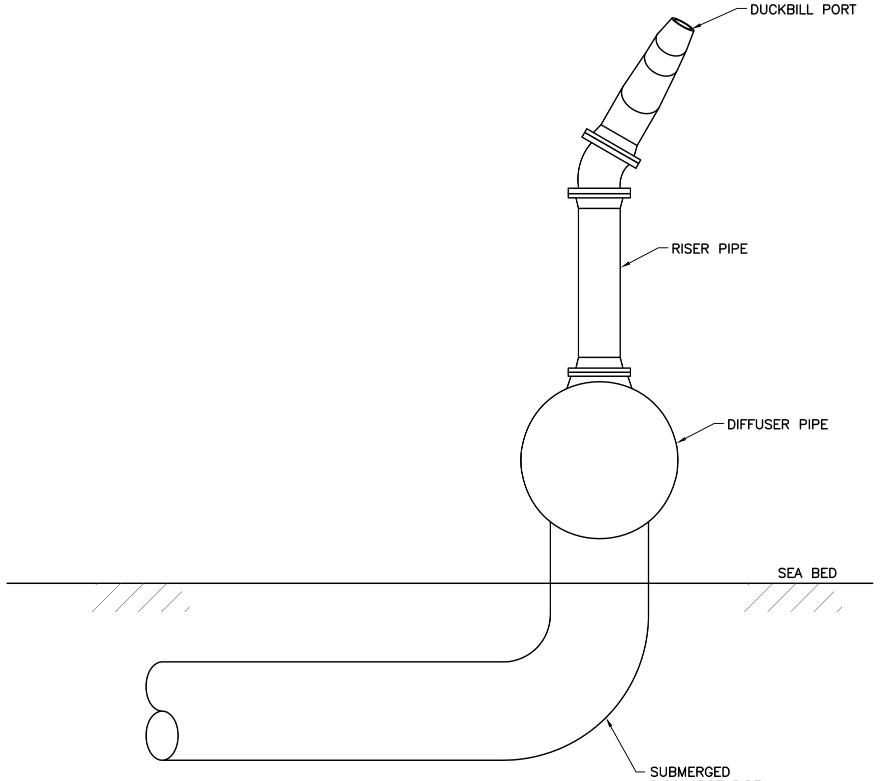
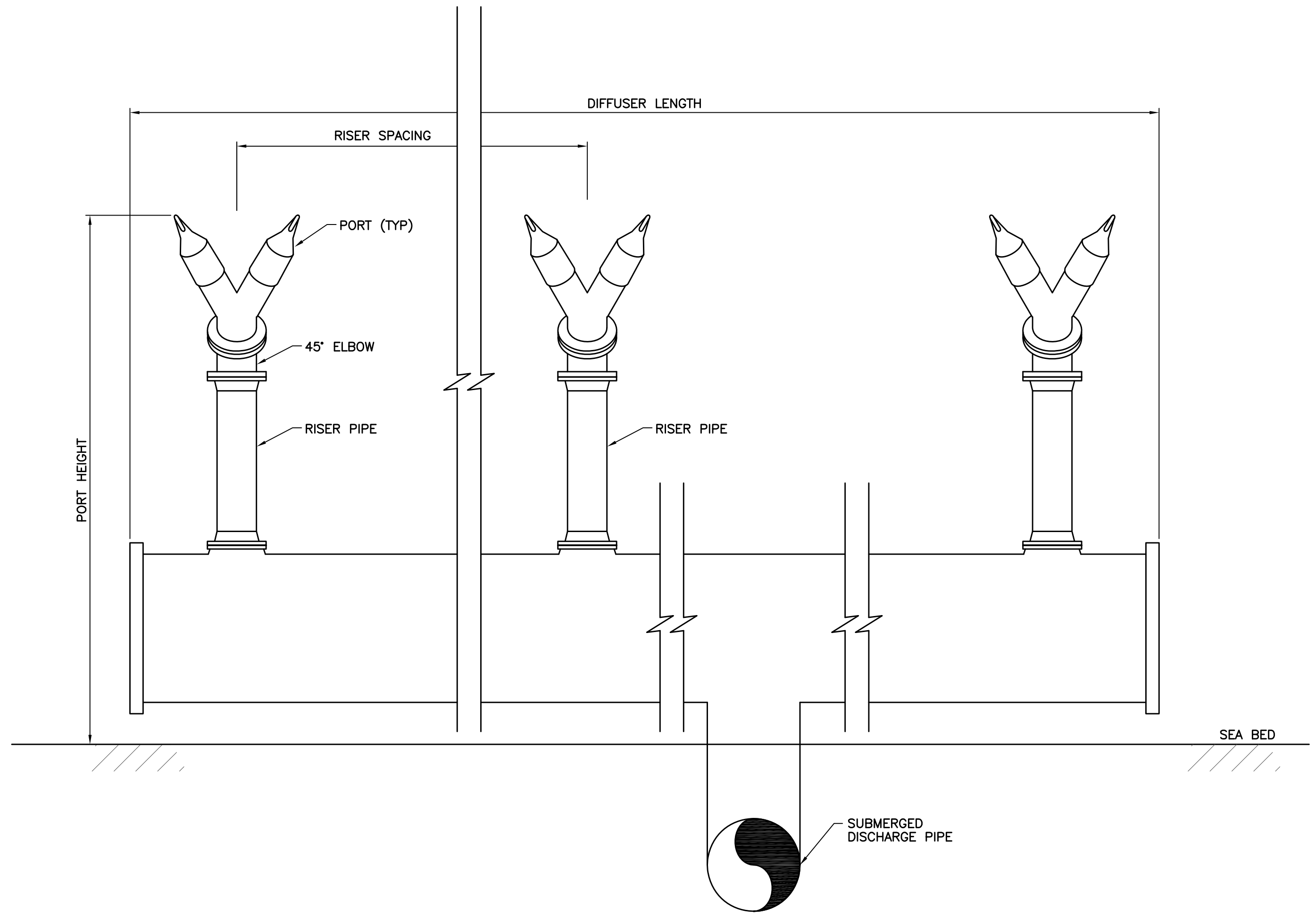
FIGURE
2



SIDE VIEW
N.T.S.



FRONT VIEW
N.T.S.

PORT OF CORPUS CHRISTI
PROPOSED DESALINATION PLANT
CORPUS CHRISTI, TEXAS

TYPICAL DIFFUSER LAYOUT

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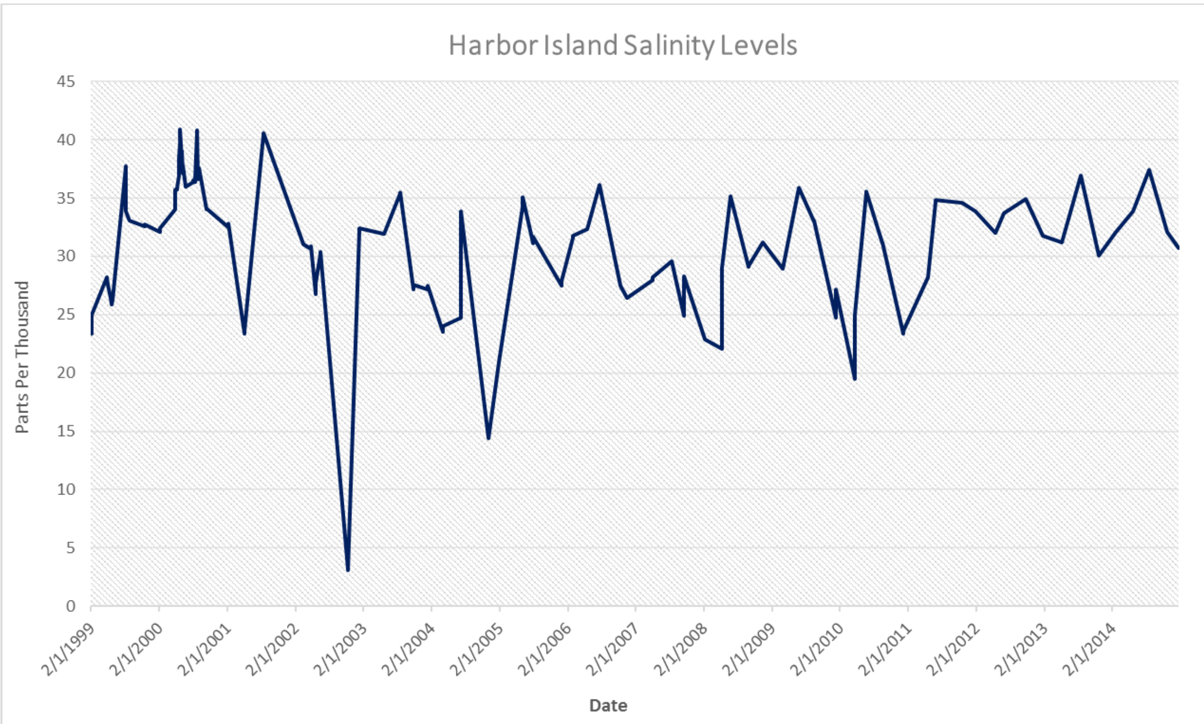
FIGURE
3

Figure 4 – Variability of Salinity Levels Over Time



Note: Data from Buoy 16492

Appendix A

Brine Discharge Mixing Analysis