Economic Analysis:
Cost Benefit Analysis Study for Coastal Bend Water Supply Options

Autocase
Economic Advisory

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Acronym Glossary

CAC - Criteria Air Contaminants

CBA - Cost-Benefit Analysis

CBRWPG - Coastal Bend Regional Water Planning Group

BCR - Benefit-Cost Ratio

CAPEX - Capital Expenditures

CO2 - Carbon Dioxide DOT -

Department of Transportation

eGRID - Emissions & Generation Resource Integrated Database

EIA - Energy Information Administration

EPA - Environmental Protection Agency

FEMA - Federal Emergency Management Agency

GCGV - Gulf Coast Growth Ventures

GHG - Greenhouse Gas kW -

Kilowatt

kWh - Kilowatt-Hour [Unit of Energy]

MGD - Million Gallons per Day

MT - Metric Tons

NOx - Nitrous Oxide

NPV - Net Present Value

NREL - National Renewable Energy Laboratory

O&M - Operations and maintenance

POCCA - Port of Corpus Christi Authority

PSU - Practical Salinity Unit

RO - Reverse Osmosis

SABIC - Saudi Basic Industries Corporation

SO2 - Sulfur Dioxide

SPMWD - San Patricio Municipal Water District

Sq ft - Square Feet

Sq m - Square Meters

STWA - South Texas Water Authority
TBL - Triple Bottom Line

TBL-BCR - Triple Bottom Line Benefit-Cost Ratio

TBL-CBA - Triple-Bottom-Line Cost-Benefit Analysis

TBL-NPV - Triple-Bottom-Line Net Present Value

TCEQ - Texas Commission on Environmental Quality

TDS - Total Dissolved Solids

TAMU - CC - Texas A&M University Corpus Christi

TWDB - Texas Water Development Board

Executive Summary

Purpose:

The intent of this study is to depict the process and results from an economic business case evaluation of bay and seawater desalination and alternative water supply options to inform discussions with stakeholders and support outreach within the Texas Coastal Bend region and beyond. This business case analyzes recommended strategies including the financial cost evaluation and the monetized value of social and environmental costs and benefits.

Background:

Water demand has grown rapidly and could jump substantially more as the growth in the petrochemical and industrial manufacturing sectors in the Coastal Bend region continues unabated. While the Corpus Christi region has been a longstanding hub of petroleum refining, advances in fracking and the U.S Congressional removal of the export ban of crude oil in 2015 has grown the petrochemical, plastics, and industrial manufacturing industries exponentially. There have been 31 new oil, gas and petrochemical projects built along the Texas and Louisiana coasts since 2016 (Powel, 2018 Houston Chronicle). These facilities often need large volumes of water to operate - for example, while the City of Corpus Christi currently supplies 95 million gallons of water per day (MGD) to the region, the Gulf Coast Growth Ventures (GCGV) facility (a joint venture between ExxonMobil and Saudi Basic Industries Corporation) needs 20 MGD. This represents a 21% increase for the entire system with this one facility - or the equivalent of the annual consumption of 120,000 residents (representing nearly a quarter of the roughly 498,000 people in the Corpus Christi Metropolitan Statistical Area).

Baywater Desalination:

While there are several options to secure a stable long-term supply of fresh water, the City of Corpus Christi and the Port of Corpus Christi have been most aggressively investigating seawater desalination, with intake and/or discharge inside Corpus Christi Bay, an EPA-designated estuary of national significance. Given their location, the term baywater desalination is used throughout the report.

Desalination is a process wherein saline water, such as from a sea or brackish water source is treated to reduce the level of total dissolved solids, salts, and minerals to make the water suitable for human consumption or for industrial processes that require high quality water. It intakes much higher volumes of water in the process, and discharges a concentrated brine effluent (salt and chemicals) back into the system. While brackish desalination is commonplace, there are only three large scale seawater desalination plants in the United States, one in Florida and two in California. All three facilities withdraw water from and discharge into open seas. The Tampa Bay Seawater Desalination Plant intakes and discharges into Tampa Bay, which is an open hydrologic system as compared to the closed hydrologic system of Corpus Christi Bay. Unlike any of the proposed Corpus Christi Bay plants, the Tampa Bay plant is also adjacent to a power generation facility where the brine discharge is blended with this cooling water to achieve only a minor salinity difference (roughly 1% more saline). Many of the concerns voiced over desalination facilities proposed in the Coastal Bend region stem from the closed water system in the Corpus Christi Bay area. Given this location and the low flow of water in the bay, this could cause detriment to the entire marine ecosystem. Damage to animal and plant life (ecotoxicological) is expected from the chronic exposure to effluent chemicals, the low oxygen levels, high temperatures, and high salinity.

Primary Information Source:

A primary source of the water supply strategies and underlying data for this enhanced economic business case study was the Coastal Bend Regional Water Planning Area Region N - 2021 Regional Water Plan (2021 Region N Water Plan) - a comprehensive technical water supply alternatives report commissioned by the Coastal Bend Regional Water Planning Group (CBRWPG - one of 16 state authorized planning bodies of the Texas Water Development Board, TWDB, comprised of local interdisciplinary members). It comprehensively evaluated alternative water supply strategies, costs, and recommended solutions (both supply increase and demand reduction). Figure 1 below shows the sources of supply for major water users in the Coastal Bend Region.

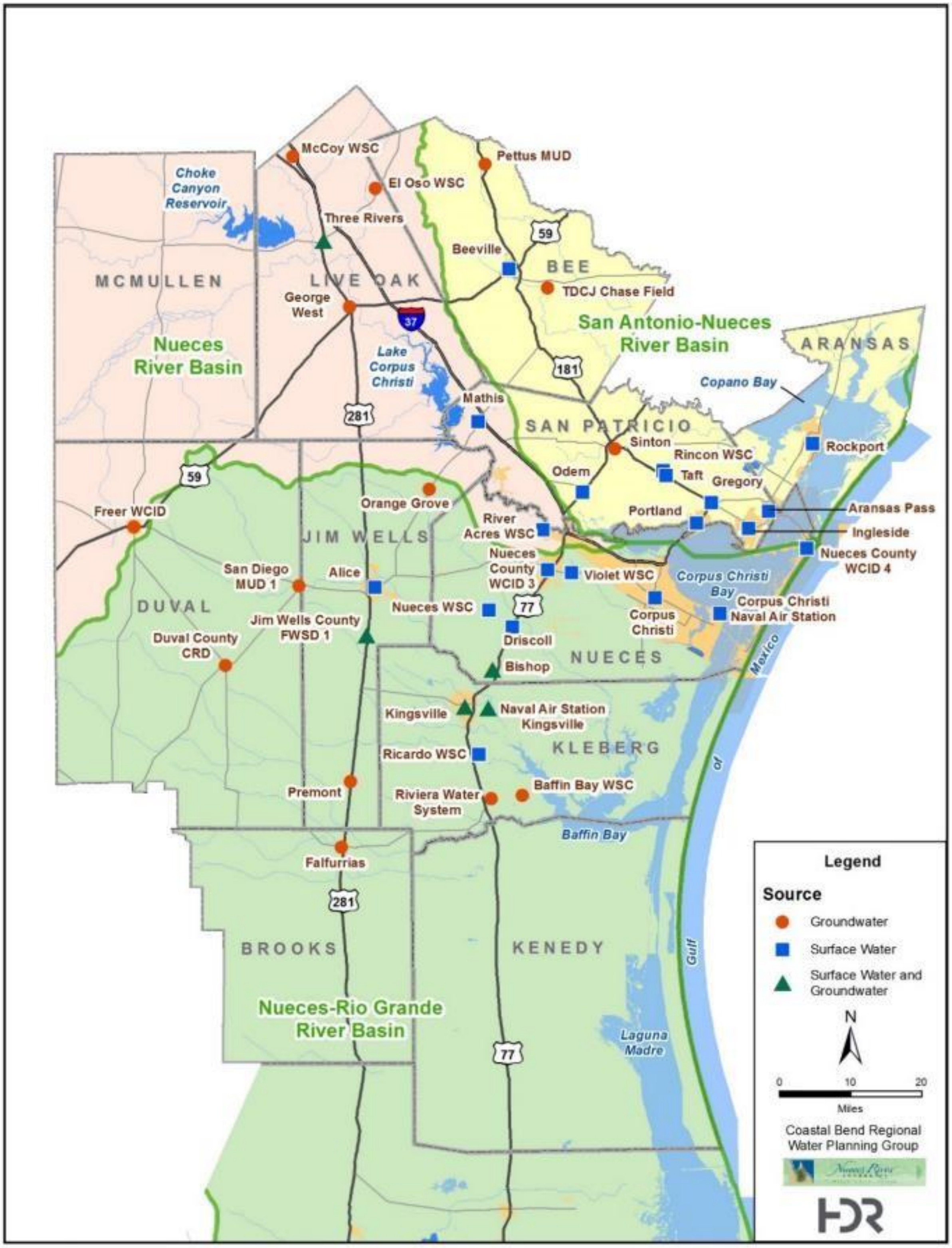

Figure 1: Sources of supply for major water users in the Coastal Bend Region (source 2021 Region N Water Plan, Fig. 1.6)

Water Supply Characteristics and Demand Projections:

The City of Corpus Christi is the largest wholesale water provider in the Coastal Bend Region - the region depends mostly on surface water sources for municipal and industrial water supply use and groundwater supplies for irrigation, mining, and in rural municipal areas that are not served by the Corpus Christi Regional Water Supply System. Under the City of Corpus Christi Water Management auspices are the seven counties within the Coastal Bend area - Aransas, Bee, Jim Wells, Kleberg, Live Oak, Nueces, and San Patricio.

TWDB estimates total water use in the region could increase from 187,788 ac-ft/yr (167.5 MGD) in 2010 to 276,492 ac-ft/yr (246.7 MGD) in 2070, which shows a 47% increase in demand – primarily due to the industrial growth expected in the region. However, the share of demand from industrial activities has been growing rapidly because of the pace of new industrial facilities. If that pace continues, there will be additional heavy demands for water supplies.

Manufacturers in the Coastal Bend Region are food processing, chemicals, petroleum refining, stone and concrete, fabricated metal, and electronic and electrical equipment. Chemicals and petroleum refining are the largest and biggest water users within the manufacturing group, accounting for about 60% of all manufacturing water use. According to the Texas Water Development Board (TWDB), in 2010, the manufacturing sector used 44,820 ac-ft/year (40 MGD) but by 2020 manufacturing water use was projected to nearly double to 88,634 ac-ft/year (79.1 MGD) - a 97.7% jump.

In contrast, the TWDB projected that municipal water use would increase from 111,854 ac-ft/year MGD (99.8) in 2010 to 115,366 ac-ft/year (102.9 MGD) in 2020 - a 3.1% increase. Municipal water demand includes households, commercial establishments (i.e. restaurants, car washes, hotels, laundromats, and office buildings), fire protection, public recreation and sanitation.

Even though the TWDB projected a 97.7% increase between 2010 and 2020 in manufacturing water use, it only projected an 11% increase between 2020 and 2030 and no further increases through 2070. The figure below highlights the overall water demand of the two major user groups - municipal and manufacturing from 2010 to 2020.

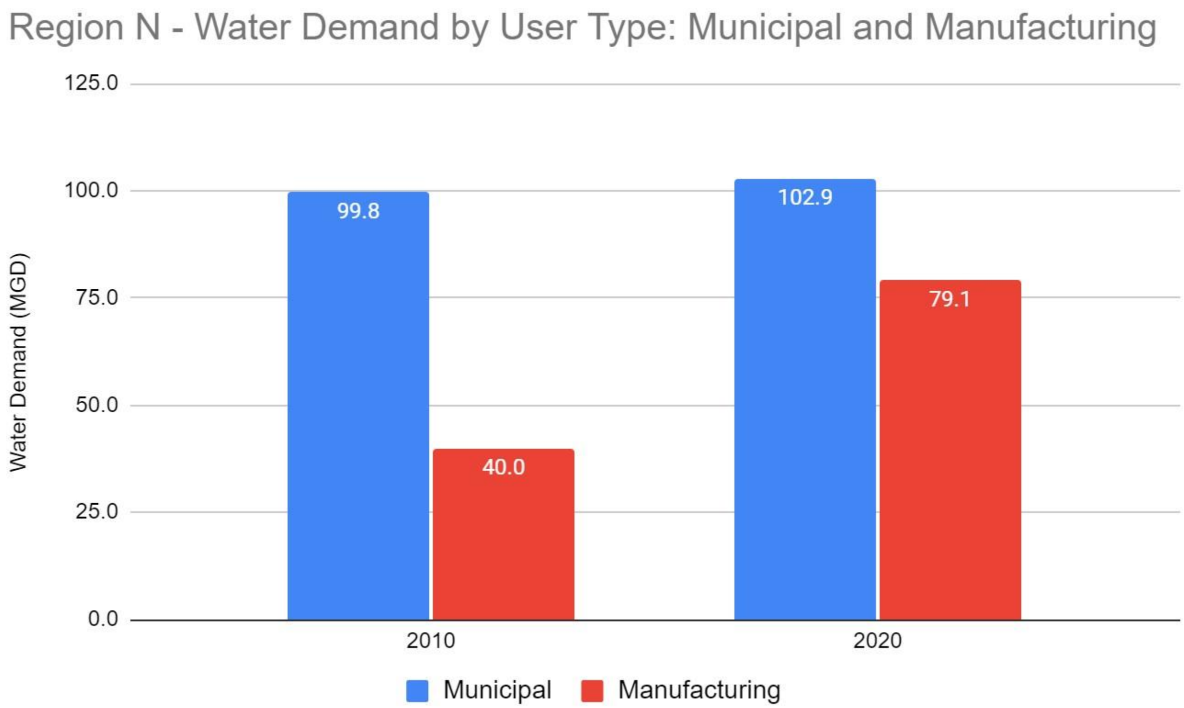

Figure 2: Water use for municipal and manufacturing for 2010 and 2020 (MGD)

Water Strategies Evaluated:
The 2021 Region N Water Plan identified a selection of possible solutions to address expected water shortages - real projects with sponsors - for this supply-demand imbalance and rigorously evaluated them. This economic cost benefit analysis is limited to a handful of key strategies identified in the 2021 Region N Water Plan. The alternatives were selected by the project team for this economic analysis as strong representative alternatives with different sourcing characteristics, groundwater, surface, and sea and baywater. Four of the strategies were recommended in the Water Plan, and the fifth - the floating solar - was added by the project team as an alternative worth evaluating and investigating in more detail. That alternative came to light in discussions with the project team as a viable option for the Choke Canyon Reservoir and/or Lake Corpus Christi, which should be under consideration given available technologies, the substantial power generation capacity potential, and an existing source of water which can be conserved through evaporation reductions.

The water supply strategies evaluated as a part of this study include:

1. **Water supply from the Gulf Coast Aquifer: Evangeline/Laguna Treated Groundwater & Water Conservation Strategies**: Under this scenario, 25 MGD of groundwater water will be supplied by the Gulf Coast Aquifer - Evangeline/Laguna Treated Groundwater project. In addition, 5 MGD of water will be conserved locally using a mix of best management practices that include efficiency of supply, reduce water losses/leak detection, reuse, meter accuracy, educational programs, landscape conservation, etc.
2. **Baywater desalination: La Quinta Channel:** The La Quinta desalination plant being considered by the City of Corpus Christi is expected to have an initial capacity of 20 MGD with a full capacity of

40 MGD. It is located on Corpus Christi Bay, east of the inlet to Nueces Bay. Note, the Port of Corpus Christi Authority (POCCA) has also submitted a permit application with TCEQ for a different site in La Quinta Channel.

3. **Baywater desalination: Inner Harbor:** The Inner Harbor desalination plant is being considered by the City of Corpus Christi with an initial capacity of 10 MGD and full capacity of 30 MGD. It is located along the Main Turning Basin, near the outlet to Corpus Christi Bay.
4. **Baywater desalination: Harbor Island:** The desalination plant at Harbor Island, inside the Corpus Christi Bay system, is being investigated by the Port of Corpus Christi Authority (POCCA) with an expected capacity of 50 MGD. The Harbor Island project site is located on the Corpus Christi Ship Channel near Port Aransas, on a former fuel tank storage area that is currently vacant.
5. **Floating solar panels: Choke Canyon Reservoir:** Floating solar panels (also known as floatovoltaics) covering 24,000 acres on Choke Canyon to reduce surface-level water evaporation and supply freshwater to the region, as well as generate utility-scale renewable energy that may be sold back to the grid and offset fossil fuel based energy production from the grid. This option represents a demonstrative solution (albeit at a large-scale) to speak to emerging technologies that should be further investigated given the ability in this case to extend the life of an existing supply source, while driving substantial recurring power revenues.

The proposed desalination plants and solutions listed have different water supply capacities; however, the total water supply required as a part of the study is maintained at 30 million gallons of water per day (MGD) to provide a uniform comparative set of results.

Analysis Details:

Cost benefit analysis (CBA) is an established economic approach for comparing the benefits and costs of a given project. It provides a systematic evidence-based economic business case approach to quantify and attribute monetary values to the direct financial impacts through a life cycle cost analysis, as well as broader social, environmental, and equity impacts resulting from an investment. The approach expands the traditional financial reporting framework to take into account social and environmental performance using empirical data and peer-reviewed literature. It’s the same process federal departments are required to use in major regulatory changes and grant programs.

It’s important to note that the economic analysis holds two key parameters consistent for each alternative:

1. Water supply from each strategy is set to 30 million gallons of water per day (MGD) equivalent; and
2. Operations/supply of that 30 MGD commences in 2030 and continues until 2060 (the end of the analysis study period).

This timeline is reflective of the year by when the desalination plants would be expected to come online from 2030 - given the comparative interest in evaluating different water supply options, the economic analysis timeline was set from 2030-2060. This is in line with the useful life for seawater desalination plants which are estimated at 25-30 years (Voutchkov, 2011) . Within this timeframe, the project team conducted a comparison of financial, social, and environmental cash flows across different water supply options to understand the long-term impacts and trade-offs amongst the five alternatives.

Capital costs, as well as all other ongoing cost elements for the project are incorporated into the project cash flows in terms of an annual cost of water value as calculated in the 2021 Region N Water Plan using the Texas Water Development Board Uniform Costing Model for all of the alternatives except the floating solar, as this wasn't included in 2021 Region N Water Plan. Floating solar life cycle costs and power generating characteristics (including power production and degradation rates) are sourced from the Department of Energy's National Renewable Energy Laboratory (NREL).

In addition to the life cycle cost analysis, this report also focuses on the environmental, habitat, and ecosystem considerations for each of the alternatives within the CBA framework. With desalination plants, the effect of brine discharge in the Bay will increase salinity and likely have negative effects on the local diversity of species. Corpus Christi Bay has a variety of species that are categorized as endangered and are vulnerable to changes in salinity levels. The list of species used as a part of this study have been selected on the basis of the most important commercially fished species in the bay in terms of metric tons and revenues; this has been collected from a fisheries database from NOAA (2020). Additionally, salinity levels required by different species to maintain abundance, as well as the expected decline in species abundance from changes in salinity, were accounted for. This was accomplished by consulting with Texas A&M University Corpus Christi (TAMU-CC, Dr. Paul Montagna) to collect the best available scientific data, peerreviewed research and valuation methodologies on the effect of salinity changes in the Bay.

Permit applications and environmental assessment reports for desalination plants demonstrated significant differences of opinion on the expected level of salinity change in the Bay. Hyperhaline level of salinity has been defined by Montagna et al., (2021) as the highest level of salinity with a Practical Salinity Unit (PSU) of 40 and above. PSU is an industry standard to evaluate salinity levels in regions and effectively compare them. The changes in salinity are evaluated across four regions in Corpus Christi Bay in line with Montagna et al (2021). The change in salinity is converted to a change in the diversity index (an index that represents the abundance or change in abundance of key species in the region) (Montagna et al., 2021). A change in diversity index and tonnage of fish population is evaluated in terms of the commercial value these species provide to the community (NOAA, 2021). The species evaluated as a part of the study are the Atlantic Croaker, Sheepshead Minnow, White and Brown Shrimp, Blue Crab, and Pinfish.

Analysis Results:

The section below outlines the results from the cost benefit analysis for the project. The results are segmented into two core cash flow components - financial and social/environmental impacts.

- Financial cash flows include the life cycle costs associated with the different scenarios such as capital costs, energy costs, interest costs, and annual maintenance costs, as well as the revenues from renewable energy generation.
- Social/environmental impacts include the cash flows associated with reduced water consumption from conservation measures, reduced emissions from renewable energy generation, energy consumption differences across the different water supply scenarios, and the changes in level of threat to endangered species from changes in salinity levels.

The results have been represented in terms of present values for each impact category, with a negative value representing costs over the life cycle, and positive value representing benefits or revenues for each alternative over the life cycle of 30 years from 2030 to 2060, evaluated in 2022 dollars. A scenario analysis with four additional scenarios is included in the results section in the main report. These scenarios vary key parameters in capital costs and bay salinity for the desalination alternatives. The scenario shown below was deemed as the best-representative option to highlight in the Executive Summary given the conservative assumptions built into its parameters.

Results are presented in Net Present Value (NPV) outcomes. NPV is the present value of benefits net of costs over the project study period, which are discounted into current dollars at a rate of 3%. NPV is the principal measure of an investment's economic worth:

- NPV > 0, means benefits are larger than costs.
- NPV < 0, means costs are larger than benefits.

Table 1: Cost Benefit Analysis Absolute Results - 30 Year Study Period Discounted at 3% - 30 MGD Equivalent Water Supply Alternatives

Net Present Value Discounted at 3% (in millions)					
Impact category	**Evangeline + Water Conservation**	**Inner Harbor Desalination**	**La Quinta Desalination**	**Harbor Island Desalination**	**Floating Solar**
Financial					
Life Cycle Costs (low cost)	-$786	-$1,232	-$1,135	-$1,129	-$18,942
Renewable Energy Revenues	$0	$0	$0	$0	$27,383
Social & Environmental					
Societal Value of Water Conservation	$66	$0	$0	$0	$0
Habitat Value - Hyperhaline (PSU level of 40)	$0	-$62	-$74	-$98	$0
Energy Consumption - Emissions (Carbon (GHG) & Air Pollutant (CAC))	-$37	-$160	-$154	-$166	-$41

Renewable Energy Production - Emissions (Carbon (GHG) & Air Pollutant (CAC))	$0	$0	$0	$0	$23,375
Financial	**-$786**	**-$1,232**	**-$1,135**	**-$1,129**	**$8,441**
Social & Environmental	**$29**	**-$222**	**-$228**	**-$265**	**$23,334**
Total Net Present Value	**-$757**	**-$1,454**	**-$1,363**	**-$1,394**	**$31,775**

**Hyperhaline highest salinity - low capital cost scenario (using a Practical Saline Unit projection of 40 and above, as well as where possible, aligning the costs with the 2021 Region N Water Plan)*

When taking a life cycle perspective over a 30 year study period starting in 2030, with 30 MGD of annual withdrawals held constant for each of the different scenarios, the analysis shows substantial impacts to the region. Further along in the report in the results section, these analysis outcomes have also been segmented under different cost and salinity scenarios to provide a range of results (due to long-term project uncertainties). The cost scenarios have been derived from TWDB loan applications adjusted from the estimates in the 2021 Region N Water Plan report, and the salinity scenarios have been set using high levels of historical salinity in the Bay, as well as an increase in salinity along the (practical salinity unit) PSU scale.

The key findings include:

- **Without the high rate of growth in the petrochemical and industrial manufacturing industries, the Coastal Bend Region would not need such large volumes of additional water supply.**
- For the four alternatives that have come from the 2021 Region N Water Plan strategies evaluated in this report, **the lowest net financial cost is the Evangeline Groundwater plus Water Conservation Measures.**
- **The desalination scenarios are the most expensive** with high capital costs as compared to water conservation and pumping water from the Evangeline Aquifer.
- **The desalination scenarios also represent disbenefits to the local region from negative impacts to the local habitat.** The high brine discharge in the brine may be expected to escalate the salinity levels in the Bay area - reducing the viability of a healthy ecosystem for the local fish population. Some species are commercially significant, and a declining population has an effect on the community revenues - this has been estimated in the cost benefit evaluation. The impacts of the proposed desalination plants on just six key fish species will cost the region between $1.18 million to $6.03 million every year. There are at least seven other valuable fish species that could be affected by the increased salinity in the Bay system.
- Additionally, **desalination plants are responsible for significant emissions from energy consumption from the local grid** for the desalination process and pumping of water. The desalination plants would emit more than quadruple the amount of air pollution compared to the groundwater option and floating solar panels would decrease air pollution.
- The analysis shows **the floating solar scenario shows merit as the only option to produce positive life cycle costs (net revenues above costs), as well as net positive externalities (creates positive social and environmental impacts relating to conserving existing water supply and producing clean power)**. The scale of the floating solar is substantially larger than the other options given the area of coverage needed to prevent evaporation losses with a 30 MGD potential of supply;

while the scale to this scenario is somewhat implausible, it's meant to be an illustrative example of the potential of this technology as a viable alternative - likely at a smaller scale with other water supply sources.

The full report provides detailed methodologies, assumptions, qualitative analysis, and key findings for the reader to explore the nuances and research material used by the project team to conduct this study.

Technical Report

Introduction and Overview

Autocase Economic Advisory - a specialty economics evaluation consultancy and economics analytics SaaS developer - was engaged to provide this enhanced economic cost benefit evaluation, along with support from sub-consultant Maritimatix - a data science and analytics company. This report outlines the background, analytical approach, economic methodologies, economic business case outcomes, and data associated with an evaluation of water supply options for the Texas Coastal Bend region.

The Texas Coastal Bend region, consists of a 11 counties - Aransas, Bee, Brooks, Duval, Jim Wells, Kenedy, Kleberg, Live Oak, McMullen, Nueces, and San Patricio - in a water-stressed area lacking a long-term freshwater supply to meet the region's demands (2021 Region N Water Plan). With 75% withdrawal of the regional surface water supply expended across the Colorado River, Lake Texana, Choke Canyon Reservoir, and Lake Corpus Christi, the region needs to find alternative future sources.

Water demand is expected to jump substantially if the growth in the petrochemical and industrial manufacturing sectors in the Coastal Bend region continues, with roughly an increase of 14% of municipal use from 2020 to 2070. While the Corpus Christi region has been a longstanding hub of petroleum refining, the advent of fracking has grown the petrochemical, plastics, and industrial manufacturing industries exponentially in the Coastal Bend. This has threatened the water security of the region as the Corpus Christi City Council voted to supply massive industrial users with water resources that had been developed for municipal use. The Port of Corpus Christi and industrial corporations are planning to create the world's largest industry hub in the area that includes new hydrogen, ammonia, and carbon capture facilities that require massive amounts of water that the region currently lacks. For example:

- Occidental and Mexichem opened a $1.5 billion plastics plant in Ingleside in 2017.
- Other large scale industrial manufacturing facilities, such as Steel Dynamics $1.9 billion flat roll steel mill near Sinton, operational in 2021.
- The largest ethane steam cracker plant in the world, sponsored by ExxonMobil and Saudi Basic Industries Corporation (SABIC), under the local name of Gulf Coast Growth Ventures (GCGV's), has also opened up a $10 billion plant on 1,300 acres, operational in 2021.

These facilities need large volumes of water to operate - the City of Corpus Christi currently supplies 95 million gallons of water per day (MGD) to the region and the GCGV facility uses 20 MGD, which represents a 21% increase for the entire system with this one facility - or the equivalent of the annual consumption of 120,000 residents (there are roughly 498,000 people in the Corpus Christi Metropolitan Statistical Area).

While there are several options to secure a stable long-term supply of fresh water, the City of Corpus Christi and the Port of Corpus Christi Authority (POCCA) have been separately investigating bay and seawater desalination most aggressively. In April 2020, the City instructed the administration to apply for a Texas Water Development Board (TWDB) loan for the Inner Harbor Ship Channel baywater desalination facility. The $222.5 million TWDB loan was approved and in September 2020, Corpus City Council voted to pursue an application for water discharge permits and water rights permits to build a baywater desalination plant at Inner Harbor. An additional application was filed for the La Quinta Ship Channel site by the City. The Port of Corpus Christi Authority (POCCA) had also applied for two permits for desalination facilities in the same region in 2018, one on Harbor Island and the other in the La Quinta Ship Channel.

In February 2021, after receiving hundreds of complaints on POCCA's Harbor Island permit, the Texas Commission on Environmental Quality (TCEQ) referred the matter to the State Office of Administrative Hearings (SOAH) for a contested case hearing before two administrative law judges (ALJ). The judges recommended to TCEQ that they deny POCCA's discharge permit application. In May 2021, TCEQ Commissioners voted unanimously to remand the application back to the SOAH, concluding that the Port had not shown that its proposed desalination permit was protective of the environment or aquatic life, including criteria by which potential larval flow disruption would be considered.

However, in the Fall of 2021, the EPA sent a letter to POCCA and TCEQ asserting its authority to review the Permit being sought by POCCA on Harbor Island as well as the other pending desalination Permit applications. The EPA said in the letter that it is its job to ensure that stateissued permits "are consistent with the requirements of the Clean Water Act and protective of water quality and aquatic life." In December 2021, the EPA notified TCEQ that the proposed desalination plant should be classified as a major facility. As such, the facility would need a major facility permit, requiring a study of less environmentally damaging alternatives. Additionally, as a major facility, the TCEQ is required to provide the EPA with an opportunity to review and comment on it.

In February 2022, the State Water Implementation Fund for Texas (SWIFT) received an application from the Port of Corpus Christi for a $500 million loan for the Harbor Island project, which is substantially higher than the $222.5 million the City of Corpus Christi had previously applied to from SWIFT for the Inner Harbor Project. Corpus Christi City Council approved a resolution asking the Port of Corpus Christi to withdraw its application for a nearly $500 million loan from the state of Texas, and any attempts to be a water producer. POCCA announced in April 2022 that it was no longer pursuing the loan. In May 2022, Mayor Paulette Guajardo and the City Council authorized contract preparation to purchase property for the plant along the Inner Harbor. The cost of the land was approved at $5.4 million and the money will come from the loan approved by the TWDB in 2020.

In June 2022, SOAH and state judges issued a recommendation that the POCCA's application for Harbor Island be approved by TCEQ, with specific conditions imposed to protect aquatic life. EPA officials said that, if TCEQ issued a discharge permit without responding to its objections, the EPA's position would be "that it is not a validly issued final National Pollutant Discharge Elimination System Permit." However, despite this warning from EPA, the TCEQ Commissioners approved this permit on September 22, 2022.

In June 2022, the POCCA and the City continued their public quarrel over the desalination facilities - as there are competing permits, where the city is focused on obtaining a permit to build the Inner Harbor plant, while the port is seeking the same for a plant on Harbor Island, as well as both seeking permits at two different locations at the La Quinta Channel. Council members scrutinized the port commissioners on their recent decisions, leadership and communication with City leaders concerning the Port's efforts to obtain desalination permits. City leaders accuse the Port of being unclear about its intent to obtain the permits, saying the port or a third party opening a desalination plant would hurt the City's business model as the sole water provider. In October 2022, the TCEQ approved the water intake permit for the Inner Harbor plant.

Many stakeholders feel like greater scrutiny is warranted to better understand the true financial costs, and wider social and environmental impacts associated with desalination, as well as the need to explore more rigorously and openly the other available water supply options that could meet current and future water demand in a more cost-effective and environmentally friendly manner.

There are also serious concerns that the cost estimates for construction and ongoing operations are underrepresented for bay and seawater desalination, driving water utility rates significantly higher than currently projected. This is in addition to the expected detriment from the brine effluent, and the impacts from operations will reap on the local ecosystem. Other possible solutions, such as water conservation measures, and withdrawal from the Evangeline Aquifer, have preliminary rate and cost estimates which may be lower than desalination. Other emerging technologies, such as floating solar photovoltaic (PV) capping, which reduces evaporation rates and generates renewable energy, limit the need to secure alternative sources in the future.

This study explores several alternative water supply options, using a full cost accounting total economic impact approach, depicting the expected costs and payment structure for full fiscal transparency for stakeholders, as well as the broader impacts to the community and the environment. Each option has important implications in terms of spill-over effects to the environment – with seawater desalination projected to generate the most substantial externalities not fully borne within the financial costs of the project. An externality is a noninternalized cost or benefit resulting from one economic agent's actions that affects the wellbeing of others. For instance, pollution and other forms of environmental degradation are the result of some production processes and are not reflected in the price of the goods or services being produced. These impacts such as detriment to the Bay ecosystem, carbon and air pollutant emissions, and other impacts need to be transparent to stakeholders and quantified within a total economic value cost benefit analysis framework to measure those impacts explicitly and objectively with best-available scientific data and economic valuation techniques.

The intent of this paper is to depict the process and results from an enhanced economic business case evaluation of seawater desalination and alternative water supply options to inform discussions with stakeholders and support outreach.

Regional Water Characteristics: Supply and Demand

The alternatives and underlying data developed for this analysis were largely sourced from those outlined in the Coastal Bend Regional Water Planning Area Region N - 2021 Regional Water Plan[1] (2021 Region N Water Plan) report, a comprehensive technical water supply alternatives report commissioned by the Coastal Bend Regional Water Planning Group (CBRWPG) by engineering

firm HDR Inc. CBRWPG is one of 16 state authorized planning bodies of the Texas Water Development Board and is comprised of local interdisciplinary members. The alternatives were selected by the project team as strong representative alternatives with different sourcing characteristics, groundwater, surface, and baywater. Four of the strategies were recommended in the 2021 Region N Water Plan, and the fifth - the floating solar - was added by the project team as an alternative worth evaluating and investigating in more detail. That alternative came to light in discussions with the project team as a viable option for the Choke Canyon Reservoir and/or Lake Corpus Christi, which should be under consideration given available technologies, the substantial power generation capacity potential, and an existing source of water which can be conserved through evaporation reductions.

An overview of the Coastal Bend area water supply and demand characteristics is provided below - synthesized from the 2021 Region N Water Plan:

Supply:

The City of Corpus Christi (City), San Patricio Municipal Water District (SPMWD), South Texas Water Authority (STWA), and Nueces County Water Control and Improvement District #3 (Nueces County WCID #3) are the water providers in the Coastal Bend region. The City sells water to two of the other regional water providers — SPMWD and STWA. The City and the SPMWD distribute water to cities, water districts, and water supply corporations for residential, commercial, and industrial customers. The focus of this economic study is the City of Corpus Christi and the Port of Corpus Christi water supply options.

The major surface water supply source is the regional Choke Canyon/Lake Corpus Christi/Lake Texana/Mary Rhodes Pipeline Phase II system (Corpus Christi Regional Water Supply System) through the City of Corpus Christi. The most significant supplies of surface water come from the Nueces River and its tributaries, along with reservoirs in the Nueces River Basin and interbasin transfers from Lake Texana and the Colorado River. Water rights associated with major water supply reservoirs are owned by the City of Corpus Christi and the Nueces River Authority. The Carrizo and Gulf Coast aquifers are two major aquifers that lie beneath the region - the Gulf Coast Aquifer provides about 95% of the groundwater used in the region.

Demand:

Municipal water demand includes households, commercial establishments (i.e. restaurants, car washes, hotels, laundromats, and office buildings), fire protection, public recreation and sanitation. TWDB

[1] https://www-cdn.cctexas.com/sites/default/files/WAT-regional-water-plan.pdf

projects that the increase in water use for the entities in the region is less than their respective increases in population - attributable to a declining per capita water use, which includes conservation built-in the TWDB demand projections. The average annual population growth rate of the region over the 50-year 2020-2070 planning period from the 2021 Region N
Water Plan is 0.46%. Per capita water use in Corpus Christi is projected to decline 10%, from 182 gallons per capita daily (gpcd) in 2011 to 164 gpcd in 2070. TWDB projects municipal use is 115,366 ac-ft/yr (102.9 MGD) in 2020 and 132,248 ac-ft/yr (118 MGD in 2070), a 14% increase.
Municipal and industrial water use accounts for the greatest amount of water demand in the Coastal Bend Region, totaling 88 % of the region's total water use of 145,528 ac-ft/yr/129.8 MGD in 2015. However, the share of demand from industrial activities is growing rapidly given the pace of new facilities and planned industrial investment. The major water demand areas are primarily municipal systems in the greater Corpus Christi area, as well as large industrial (manufacturing, steam-electric, and mining) users located along the Corpus Christi and La Quinta Ship Channels in Nueces and San Patricio Counties. Agriculture is the third largest category of water use in the region. The City of Corpus Christi provides supplies for about 60% of the municipal and industrial water demand in the region (not including supplies to SPMWD or STWA and their customers).

TWDB estimates total water use in the region could increase from 187,788 ac-ft/yr (167.5 MGD) in 2010 to 276,492 ac-ft/yr (246.7 MGD) in 2070, which shows a 47% increase in demand – primarily due to the industrial growth expected in the region.

Manufacturers in the Coastal Bend Region are food processing, chemicals, petroleum refining, stone and concrete, fabricated metal, and electronic and electrical equipment. Chemicals and petroleum refining are the largest and biggest water users, accounting for about 60% of all manufacturing water use. TWDB projects manufacturing use is 88,634 ac-ft/yr (79 MGD) in 2020 and 98,480 ac-ft/yr (87.9 MGD) in 2070, an 11% increase. In 2070, Nueces and San Patricio Counties are projected to account for 95% of the total manufacturing water use in the region.

The projected water demand for future industrial growth appears likely to be vastly understated by Region N. The most recent quarterly report from the Corpus Christi Regional Economic Development Corporation (CCREDC) presented to Nueces County on October 11, 2022 discloses 10 Green/Blue Energy Projects with potential investments of $23.9 Billion and Steel/Metal Fabrication Projects with potential investments of $4.2 Billion in the pipeline for locating in the region. Due to Non-Disclosure Agreements with prospective industries, the CCREDC will not disclose the entities or the water demands that may be required by each. In addition, there has been a number of Applications for Chapter 313 Value Limitations filed in the past 6 months with school districts within the Region N Service area involving expansions of current industrial operations, as well as hydrogen, ammonia, and carbon capture projects that will drive the demand for water much higher than predicted. The Chapter 313 tax incentive program applicants can be found on the Texas Comptroller's website:
https://comptroller.texas.gov/economy/local/ch313/agreement-docs.php

Supply Shortages:
2021 Region N Water Plan assumed further industrial build out and other demand growth and identified anticipated water supply shortages throughout the 50-year planning cycle - in 2020 a shortage of 13,530

ac-ft/yr (12 MGD) exists within the Region and increases to a shortage of 49,363 ac-ft/yr (44 MGD) by 2070. A small portion of this shortage is associated with treatment plant capacity constraints and is not necessarily a raw water shortage. Current O.N. Stevens WTP improvements are in progress to increase treatment plant capacity, roughly an additional 32,030 ac-ft/yr/yr, and the remainder of the shortages coming from water supply constraints (not treatment capacity). Given the demands and existing contracts, the City's shortages are applied to Nueces County manufacturing and San Patricio County manufacturing. Also, the City won't have the supply needed to provide the full contracted purchases by SPMWD after 2020 – set to 73,800 ac-ft/yr (65.8 MGD). Therefore, SPMWD shows increasing water supply shortages from 2030 through 2070. SPMWD's shortages are applied to San Patricio County manufacturing, and this shortage is included in the City's shortage total. If there's greater industrial growth, it will drive greater demand and potentially larger shortages which would need to be addressed.

Solutions:
Numerous water management strategies were identified by the Coastal Bend Regional Water Planning Group (CBRWPG) as potentially feasible to meet water supply shortages. Each strategy was evaluated and compared to criteria adopted by the CBRWPG. The Coastal Bend Regional Water Plan includes recommended water management strategies that emphasize water conservation and reuse; maximize utilization of available resources, water rights, and reservoirs; develop drought-tolerant supplies; engage the efficiency of conjunctive use of surface and groundwater; and limit depletion of storage in aquifers. This economic analysis study uses the recommended strategies for four supply options – Evangeline/Laguna Treated Groundwater and three desalination facilities (La Quinta Channel, Inner Harbor, and Harbor Island) – and has added one additional option developed by the project team in the floating solar solution.

Alternatives Evaluated:

This economic analysis is limited to a handful of key strategies identified in the 2021 Region N Water Plan. The alternatives were selected by the project team as strong representative alternatives with different sourcing characteristics, groundwater, surface, and ocean. Four of the strategies were recommended in the Water Plan, and the fifth - the floating solar - was added by the project team as an alternative worth evaluating and investigating in more detail.

It's important to note that the economic analysis holds two key parameters consistent for each alternative:

1. Water consumption is set to 30 MGD for local demand; and
2. Operations/supply of that 30 MGD commences in 2030 and continues until 2060 (the end of the analysis study period).

This timeline is reflective of the year by when the desalination plants are expected to come online. Before this timeline, from 2022 - 2030, the project team has chosen a set of operational characteristics that are representative of the status quo. Given the intent of this analysis is to evaluate the aforementioned supply alternatives, with the desalination facilities planning to be online starting in 2030, the study evaluates impacts within a 2030-2060 timeframe. Within this analysis period, the project team conducted a comparison of financial, social, and environmental cash flows across different water supply options to understand the long-term impacts and tradeoffs amongst the five alternatives.

Capital costs, as well as all other ongoing cost elements for the project are incorporated into the project cash flows in terms of an annual cost of water value as calculated in the 2021 Region N Water Plan using the Texas Water Development Board Uniform Costing Model for all of the alternatives except the floating solar, as this wasn't included in Water Plan. Floating solar life cycle costs and power generating characteristics (including power production and degradation rates) are sourced from NREL.

The supply options covered as a part of the study are:

1. Water supply from the Gulf Coast Aquifer: Evangeline/Laguna Treated Groundwater & Water Conservation Strategies.
2. Seawater desalination: La Quinta Channel
3. Seawater desalination: Inner Harbor
4. Seawater desalination: Harbor Island
5. Floating solar panels on the Choke Canyon Reservoir

A scenario analysis with four additional scenarios is included in the results section. These scenarios vary key parameters in capital costs and bay salinity for the desalination alternatives.

Evangeline Aquifer & Municipal Water Conservation

The 2021 Region N Water Plan outlines characteristics around the groundwater and water conservation measures. This option combines these two strategies to support the 30 MGD of additional supply. Coastal Bend Region uses groundwater for irrigation, mining, local consumption, industrial use, etc. using two major aquifers that lie beneath the region: the Carizzo and the Gulf Coast aquifers. Besides these two major aquifers there are three minor aquifers within the Coastal Bend Planning Region that are expected to have a combined reliable yield of 187,096 ac-ft/yr/166.9 MGD of water per year by 2070. As Option 1, the Evangeline aquifer is expected to contribute 25 MGD to the water supply. The remaining 5 MGD requirements will come from a mix of urban water conservation options. The Evangeline / Laguna LP Groundwater project includes groundwater production of up to 25.4 MGD across 23,000 acres in San Patricio County. The tested water quality results have shown TDS and chloride levels at acceptable TCEQ drinking water standards of 792 and 269 mg/L respectively (2021 Region N Water Plan).

The 2021 Region N Water Plan identifies the primary environmental concerns with the usage of groundwater from the Evangeline aquifer in San Patricio County; this relates to the development of well fields and pipelines required for conveyance and delivery. The Evangeline project includes well fields of 18 water wells and requires minimal treatment for delivery to SPMWD and future industries. Each of the wells have a depth of 1,000 feet with a pumping rate of 1,200 gallons per minute. There are three pipeline options included as a part of the project.

According to the Coastal Bend report, due to the relatively small acreage of areas involved in developing infrastructure to pump, and convey water from the aquifers, this water supply option is not expected to have substantial habitat and diversity impacts besides those of encroachment of infrastructure on land that is otherwise used as for agricultural purposes. The pumping of groundwater is expected to reduce the base flow of water in downstream reaches, thereby contributing to increasing water scarcity. However, the core of the alternatives within this study have focused on different sources of water supply and not a substantial reduction in water consumption. The Evangeline/ Laguna groundwater supply option is the only scenario that has some reduction in water consumption through a mix of conservation measures. The benefit of reduced water consumption has therefore been attributed to this alternative; otherwise, the other alternatives have overall water supply as consistent at 30 MGD. Additionally, groundwater pumping and decrease in groundwater levels could potentially also result in minor land surface subsidence; however, the level or direct effects of subsidence are not well documented as a part of scientific literature.

To keep uniformity across the design scenarios, it is assumed that all scenarios begin in the year 2030, as that is the expected timeline for the desalination plants to come online. A key consideration for the comparison between the different alternatives is the cost involved in infrastructure building and life cycle maintenance / implementation. The cost details for the Evangeline and water conservation scenario have been taken from the 2021 Region N Water Plan. The cost for the Evangeline Aquifer involves the cost of water purchase, treatment and pumping to the region, as well as annual operations and maintenance costs involved in the upkeep of the water supply. Capital costs for this scenario include the cost of the primary pump station, transmission pipeline, well fields, the water treatment plant upgrades, and other facilities. Soft costs include engineering and feasibility studies, legal and financing costs, environmental studies, land acquisition costs, and interest during the construction period. Annual operation and maintenance costs include those for pipelines, wells, storage tanks, intakes and pump stations, maintenance of treatment plants, energy costs, and the purchase of raw water. These costs have been modified into annual life cycle costs that represent a converted annualized life cycle cost value. Water conservation measures are also expected to have a cost to the municipality in terms of a variety of conservation measures. Detailed descriptions of these costs have been included later on the report in the methodology section.

Desalination design options

Seawater and baywater desalination is a process wherein water from the gulf or bay is treated to reduce the level of total dissolved solids, salts, and minerals to make the water suitable for human consumption or for industrial processes that require high quality water. The water in the Bay has a range of 30,000 – 50,000 parts per million of total dissolved solids (TDS). A typical desalination process has been shown in the figure below:

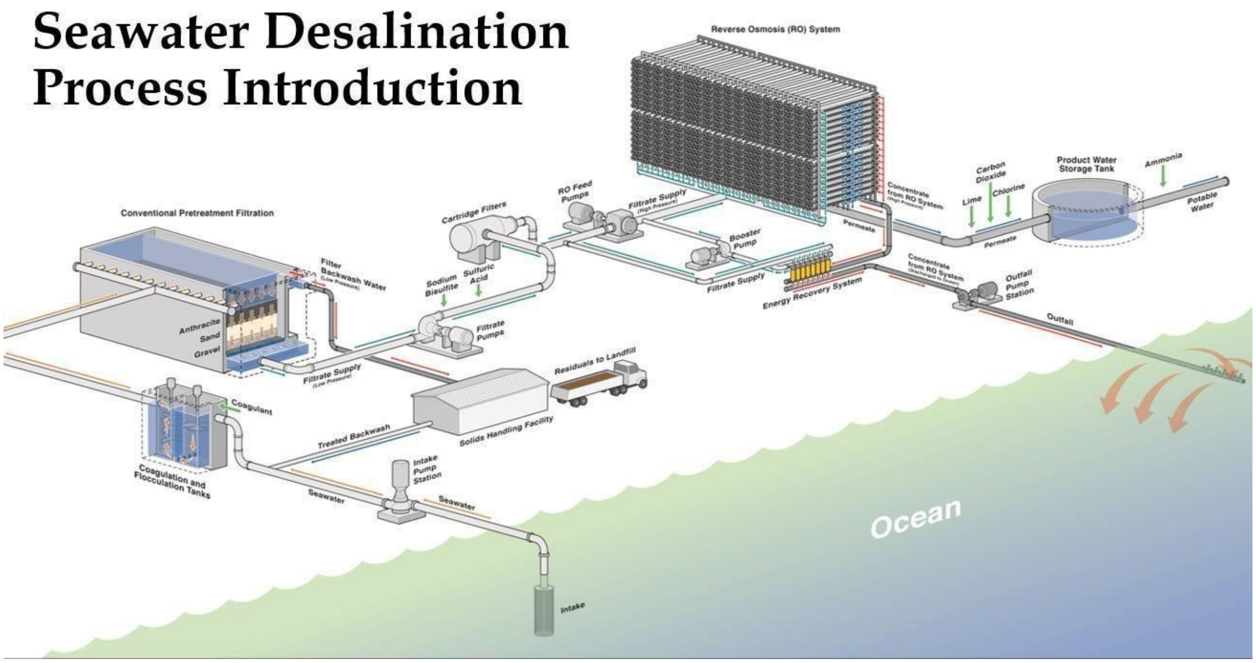

Figure 3: Reverse osmosis desalination process (Source: Freese & Nichols) *this image represents an open ocean intake/discharge which none of the proposed plants in the Coastal Bend would have*

The plants in the Bay will use reverse osmosis (RO) to reduce the mineral content of water. This process uses a semi-permeable membrane that limits the passage of salts from the saltwater side to the freshwater side of the desalination membrane. As a part of this process, the brine or concentrated salt water is collected as a waste stream, as well as residues from chemicals used during the pretreatment process. RO plants globally make up approximately 47% of the global desalting capacity and generate water supply ranging from a few gallons to 35 MGD.

There are only three large-scale seawater desalination plants in the United States, one in Florida and two in California. According to the Texas Water Development Board, Texas does not yet have any saltwater desalination plants. The largest saltwater desalination plant in the US is the Carlsbad Desalination that uses RO for water treatment, has a capacity of 50 MGD and is located in San Diego County.

In the 2021 Region N Water Plan, five different desalination plants were evaluated, including the City of Corpus Christi, the Port of Corpus Christi Authority, and Poseidon/City of Ingleside. Additionally, Corpus Christi Polymers (CC Polymers), through the bankruptcy purchase of M&G Resins, owns a 10 MGD desalination facility near completion on the Corpus Christi Ship Channel. There are conflicting accounts of the amount of desalinated water potentially produced by this facility. Those accounts range from 10 MGD in presentations to the Corpus Christi City Council, to 22 and 30 MGD in news accounts. The Water Rights Permit granted by the TCEQ limits the allowed diversion (for intake purposes) to 23 MGD. Given the application of reverse osmosis technology, it is unlikely the facility would be able to produce much more than 10 MGD of desalinated water.

In total, there are seven desalination facilities recommended under TWDB's 2022 State Water Plan as recommended projects, excluding the CC Polymers facility.[2] These Include:

- City Of Corpus Christi Seawater Desalination (Inner Harbor) - City of Corpus Christi as sponsor
- City Of Corpus Christi Seawater Desalination (La Quinta) - City of Corpus Christi as sponsor
- Freeport Seawater Desalination - Dow Inc. as sponsor
- Laguna Madre Water District - Seawater Desalination Plant - Laguna Madre Water District as sponsor
- Port Of Corpus Christi Authority Seawater Desalination (Harbor Island) - Port Of Corpus Christi Authority as sponsor
- Port Of Corpus Christi Authority Seawater Desalination (La Quinta Channel) - Port Of Corpus Christi Authority as sponsor
- Poseidon Regional Seawater Desalination Project at Ingleside - Poseidon Water as sponsor

Total preliminary capital costs are listed at $2.84 billion for these facilities.

These facilities intake much more water than they ultimately convert into drinking/industrial water and discharge nearly as much wastewater (brine and chemicals). When taken at full planning capacity, the three desalination facilities included in this analysis - POCCA Harbor Island, City of Corpus Christi La Quinta, and City of Corpus Christi Inner Harbor - will produce 110 MGD of treated water. Based on discharge applications to TCEQ from project sponsors, the intake volumes for these three desalination facilities) is expected to be 395 MGD and discharge volume of roughly 221 MGD.

A major concern with desalination stems from the environmental impacts from the desalination process and the brine effluent discharge. Releasing brine concentrate could potentially affect organisms that are dependent upon a specific range of temperature and salinity. Changes to the ratio and type of salt discharges can cause osmotic imbalances (i.e. osmoregulation is the process of maintaining an internal balance of salt and water in a fish's body) and toxicity. Bay and estuary areas are spawning grounds for critical habitat, migratory birds, and fish species. The inflow and outflow of water in these areas are responsible for maintaining a level of salinity that is conducive for local habitat to thrive. These alterations can affect the abundance of marine life, especially those that are sensitive to alterations in environmental factors.

These concerns are somewhat mitigated in the Florida and California desalination facilities as they discharge into deep, open ocean. It's not an enclosed bay scenario. In the ocean, the salinity can be dispersed quickly, there's high rates of water exchange and mixing, and less accumulation of contaminants. Many of the concerns voiced over desalination facilities proposed in the Coastal Bend region stem from the closed water system in the Corpus Christi Bay area. Given this location and the slow exchange of water with the Gulf of Mexico, this could cause detriment to the entire marine ecosystem.

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[2] https://texasstatewaterplan.org/wmstype/SEAWATER%20DESALINATION

Ecotoxicological harm is expected from the chronic exposure to effluent chemicals, the low oxygen levels, high temperatures, and high salinity. [3]

The Corpus Christi Bay system has been designated as an estuary of national significance by the Environmental Protection Agency by way of the establishment of the Corpus Christi Bay National Estuary Program (CCBNEP). The bay system is one of 28 estuaries that have been designated as an Estuary of National Significance. CCBNEP study area includes three of the seven major estuary systems of the Texas Gulf Coast. These estuaries, the Aransas, Corpus Christi, and Upper Laguna Madre are shallow and biologically productive. Freshwater inflow is very low and the only sources of freshwater drainage to Corpus Christi Bay include the Nueces River and Oso Bay, from Oso Creek.

The waters specifically in the La Quinta Channel and by the shore of Port Aransas are important because they are unique features of the Texas coast - these include marshes, barrier islands and estuaries (where salt water meets fresh water). These features help contribute to the survival of many different types of plants and animals which can include saltwater grass, trout, red drum, shrimps, oysters, pelicans, and many others.

In addition to effects on local habitat, desalination plants are also responsible for significant energy consumption for water treatment and pumping to the region. Fossil-fuel-based energy supply from the grid is responsible for emissions of carbon dioxide equivalents and criteria air contaminants (i.e. chemicals which cause a wide-array of detriment, such as Nitrous Oxides, which contribute to smog, Sulfur Dioxides, which leads to acid rain, and Particulate Matter, which causes respiratory health problems, etc.) that are responsible for degrading local air quality levels. Pumping energy requirements for all plants have been sourced from the 2021 Region N Water Plan cost estimations, as well as through sourcing external literature on average rates of energy consumption on a per volume of water basis (10 kWh/1000 gallons (HDR Engineering, Inc., 2015a, 2016)). Energy total costs and rates are used to estimate the volume of energy consumed. Regional-specific air pollution and carbon dioxide equivalent emission factors from power generation have been captured from the EPA eGRID database. A detailed methodology for the environmental effects is listed later on in the report.

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3 https://repositories.lib.utexas.edu/bitstream/handle/2152/85059/POCC_HI_ERA.pdf?sequence=2&isAllowed=y

The section below highlights the key specifications for each desalination plant in this study (three locations: Inner Harbor, La Quinta, and Harbor Island) as they may be assessed to individually meet the City's need for water supply. The CC Polymers facility is included in the map given its near completion, but not evaluated in this study. While all plants have differing capacities, a consistent capacity of 30 MGD is used for supply to ensure an apples-to-apples basis for costs incurred on a variable basis per volume of treatment and use.

Figure 4: Desalination plants locations (blue dots are locations evaluated in this study, red dots are others seeking permitting)

Inner Harbor

The Inner Harbor desalination plant is being considered by the City of Corpus Christi with an initial capacity of 10 MGD and full capacity of 30 MGD. It is located along the Main Turning Basin, near the outlet to Corpus Christi Bay, and is approximately 12 acres in size. This site area is within the area that was set up as a buffer between Refinery Row and the historically Black Hillcrest neighborhood. The treatment efficiency of the Inner Harbor desalination plant is estimated to be 45% - 50% with finished water quality targeted to be approximately 500 mg/L of TDS (Region N water supply report). The Inner Harbor Plant would treat all of its product water to potable standards and send it through the City of Corpus Christi distribution system, primarily for industrial use (Regional N Water Plan). For the Inner Harbor desalination plant, it is assumed that a 3,500 ft raw water pipeline would be used with a 2,300 ft concentrate discharge pipeline, and a 500 ft product water delivery line. These specifications would be expected to have an effect on the costing for this design scenario (based on information provided by Freese and Nichols in the engineering report used by the 2021 Region N Water Plan to estimate costs and design specifications for each of the water strategies, the data points for which have been covered in the methodology section of this report.

La Quinta

The La Quinta desalination plant being considered by the City of Corpus Christi would be expected to have an initial capacity of 20 MGD with a full capacity of 40 MGD. It would be located on the north side of Corpus Christi Bay, east of the inlet to Nueces Bay, and is approximately 10 acres in size. The City's La Quinta Channel Plant would treat the product water to potable water standards and deliver it to San Patricio Municipal Water District (SPMWD). Additional details on the efficiency, intake, desalination process, and concentrate disposal outfall were not made available as a part of the Coastal Bend report or the City's permit applications. The water supplied by this plant to the SPMWD would be delivered to industrial customers (2021 Region N Water Plan, pg 513). The La Quinta desalination plant would require a 11,800 ft raw water pipeline, 14,500 ft concentrate discharge pipeline, and 2,000 ft product water delivery line, also affecting the costs incurred for setting up the infrastructure and accounted for as part of the study, with details specified in the methodology section.

Harbor Island

The desalination plant at Harbor Island is being considered by the Port of Corpus Christi Authority (POCCA) with an expected capacity of 50 MGD. POCCA is a political subdivision of the State of Texas; the Port being a central point for economic development from ship channel expansion would be a key location for the desalination plant should the growth in petrochemical and industrial facilities increase the need for additional water supplies. The Harbor Island project site would be located on the Corpus Christi Ship Channel near Port Aransas, across 33 acres in a former fuel tank storage area that is currently vacant. It would produce 50 MGD for both municipal and industrial use, utilize Reverse Osmosis (similar to all the other desalination plants) to treat seawater from the Gulf of Mexico, and a proposed diffuser would discharge into the Corpus Christi Ship Channel. A desalination plant at this location would be expected to need a 22 mile (116,160 ft) pipe to the San Patricio County area and a two-mile (10,560 ft) 42'' pipe to Nueces County. This site also currently does not have data published on the concentrate disposal outfall, storage needs, efficiency levels, etc (as per the Coastal Bend Report).

Table 2: Desalination Plant Specifications

Desalination Plants	Capacity	Length of Piping
Inner Harbor	Initial: 10 MGD; Full: 30 MGD	- 3,500 ft raw water pipeline - 2,300 ft concentrate discharge pipeline - 500 ft product water delivery line
La Quinta	Initial: 20 MGD; Full: 40 MGD	- 11,800 ft raw water pipeline - 14,500 ft concentrate discharge pipeline - 2,000 ft product water delivery line

Harbor Island	Expected: 50 MGD;	- 22 mile (116,160 ft) pipe to the San Patricio County - 2 mile (10,560 ft) 42" pipe to Nueces County.

The results from the analysis for the desalination plants include two cost scenarios reported later in the report. In addition to these desalination plants, if the Corpus Christi Polymers desalination plant is built as well, the downstream impacts of increased salinity may be expected to increase, as well as costs, and energy consumption, particularly for the immediately downstream Inner Harbor facility proposed. This has not been modeled as a part of the study. The Port of Corpus Christi La Quinta Plant has also not been included in the analysis due to a different effluent discharge process wherein the brine may be discharged on land instead of the Channel, with few details provided on the specifics.

Floating Solar Panels on Choke Canyon

An additional water supply strategy has been suggested by the project team to offer an alternative to the desalination plants or complementary to other supply strategies. Solar panels will be expected to be constructed either solely on the surface of Choke Canyon Reservoir or Lake Corpus Christi. Historically, such panels have been installed on retention ponds, lakes, and other water bodies in an effort to increase sustainability and reduce the regional carbon footprint by generating renewable solar energy. Altman Plants was responsible for the first floating solar array in Texas, which boasted 750 kW of production capacity. More recently, Third Pillar Solar has been looking into investing $231 million towards floating solar panels in Brazoria County (Houston Business Journal, 2022). Other floating solar panel investments have also taken place primarily in California, Florida, and other areas along the East Coast (Lisa Ogle, 2021). Internationally, Huaneng Power International (HPI) has recently completed building the world's largest floating solar project - the Dezhou Dingzhuang Floating Solar Farm in China - with a capacity of 320 Megawatts (MW) (Electrek, 2022). In June 2022 the US Army at Fort Bragg began operating one of the largest floating solar farms in the US at a 1.1 MW capacity. This represents the first such deployment of 'floatovoltaics' for the Department of Defense and aligns with the military branch's climate strategy to increase the use of renewable energy. Currently, the largest floating solar facility in the US is under construction in New Jersey, with a 8.9 MW capacity from 16,000 solar panels to sit atop the Canoe Brook Water Treatment Plant reservoir (The Hill, 2022[3]). The US has lagged behind many other global jurisdictions in floating solar panels, but the opportunity is there - a 2018 study from NREL estimated that 10% of the nation's annual electricity production could come from installing floating solar installations on the roughly 24,000 human-made reservoirs in the U.S. (The Hill, 2022).

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[3] https://thehill-com.cdn.ampproject.org/v/s/thehill.com/changing-america/sustainability/energy/3564585why-put-solar-panels-on-the-surface-of-water/amp/?amp_gsa=1&amp_js_v=a9&usqp=mq331AQIKAGwASCAAgM%3D#amp_tf=From%20%251%24s&aoh=16584010153043&csi=0&referrer=https%3A%2F%2Fwww.google.com&ampshare=https%3A%2F%2Fthehill.com%2Fchanging-america%2Fsustainability%2Fenergy%2F3564585-why-put-solarpanels-on-the-surface-of-water%2F

The floating solar array can be expected to reduce evaporation from the surface of Choke Canyon such that the water conserved will be supplied to the city in place of the water from desalination plants or other sources. For simplicity of analysis, this report assumes that these panels will be placed on the Choke Canyon Reservoir. Since there is no official design scenario covering this option that has been presented in official reports, the project team has undertaken research using publications from NREL to estimate the upfront capital costs, annual ongoing operations and maintenance costs, energy generation from the panels that may be subsequently be sold back the grid, and the extent of solar panels required for the reduced evaporation of water that will be used to supply water to the region for the equivalent of 30 MGD.

Since 30 MGD of additional water supply is targeted for each of the options, there is a substantial number of solar panels required, which end up covering almost 90% of the surface area of Choke Canyon reservoir - a sum total of 98 million square meters (24,200 acres). This was estimated using an average evaporation rate of 4.96% (using historical evaporation levels from Texas reservoirs - specifically Choke Canyon), and gallons of water evaporated per day with a comparative drawn between the surface area of the reservoir, and the volume that needs to be covered everyday to reduce evaporation levels by 30 MGD. To evaluate the costs and energy generation of these floating panels, a combination of research from NREL and PVWatts has been used. PVWatts uses location specific characteristics to estimate the kWh of energy generation and system size capacities. The project team has estimated a solar panel system capacity of 19.5 kW that is expected to cover 130 sq meters (1,400 sq feet) per panel, and has a solar power capacity of 0.15 kW per square meter. Across the area of panels required, this generated a total power capacity of over 14 million kW. Using costing estimates from NREL at $1,290/kW, the expected capital cost is estimated at $19.14 billion, with annual operations and maintenance at $15.5/kW per year.

Using an expected energy output at 1,500 kWh/kW/year, this research generates an annual renewable energy generation at 22.406 million MWh in 2030. The generation is expected to degrade at 0.50% per year owing to diminishing capabilities of the solar panels over time. The project team assumes that the energy generated from these panels are sold back to the grid or region directly at a unit revenue of $0.80 per kWh. Being renewable energy, this is also emissionfree and therefore contributes to lower criteria air contaminants and carbon emissions during the project life cycle, thereby offsetting energy consumption in the region and generating benefits.

Estimates to evaluate the capital costs and maintenance costs for treatment and conveyance infrastructure and emissions have been sourced using the estimates from the existing, current O.N. Stevens' capacity increase scenario (which is at a significantly low cost as compared to the Evangeline and desalination scenarios). This estimates annual costs at $196 per ac-ft/yr of water during debt service and $46 per ac-ft/yr after the debt is covered. Annual pumping and treatment energy consumption is estimated at 12,050 MWh and 17,000 MWh respectively.

Since the water in Choke Canyon Reservoir is fresh water, there is no brine discharge in this scenario within the Bay, thereby avoiding the habitat and species diversity decline costs. In addition, it is expected to generate renewable energy that may be supplied into the grid to generate revenues and replace the fossil-fuel based grid energy, thereby generating significant benefits for the project.

Given the scale of the installation, it's unlikely that this option would be used for the full 30 MGD; however, it could start at a small scale, grow over time, and be used in combination with other supply strategies or demand reductions.

Analytical Framework: Cost Benefit Analysis

The economic analysis framework used in this evaluation is a Cost Benefit Analysis (CBA) framework. This approach is an evidence-based economic method that combines Life Cycle Cost Analysis (LCCA) and CBA techniques to quantify and attribute monetary values to the Triple Bottom Line (TBL) - financial, social, and environmental - impacts of a given project.

Cost Benefit Analysis (CBA) is an established economic approach for comparing the benefits and costs of project or activity alternatives to a recognized and definable baseline. CBA involves identifying, quantifying, monetizing, and summing in dollars terms the possible value of incremental costs and benefits over the life of a project. It provides a systematic evidence-based economic business case approach to quantify and assign monetary values to the direct financial impacts, as well as broader social, environmental, and equity impacts resulting from an investment using empirical data and peer-reviewed literature. The approach expands the traditional financial reporting framework (such as capital, and operations and maintenance costs) to address social and environmental performance outcomes. The approach is reliant on the comparison of a "base case" compared to a selection of "design cases", the latter which has some incremental change, either positive or negative, compared to the base case. CBA evaluates incremental differences between the base case and design case by first quantifying and then monetizing the difference.

CBA is an industry standard decision-support tool used to inform and improve public policy, programs and projects. Essentially, the approach helps prioritize projects in a standardized way, as well as provide insights as to the impacts on various project stakeholders. For example, the US, Europe, and the UK have mandated legislative requirements to use CBA to evaluate policies and policy reforms, and CBA is required for a variety of merit-based federal grant funding programs. Additionally, the World Bank and other multilateral financial institutions, such as the Inter-American Development Bank and Asian Development Bank widely use CBA to help bring about a better allocation of resources, to provide insights into overall societal welfare gains, direct financial impacts, sustainability impacts, and assess project risks.

Key study parameters

The study period for this report is 2030 to 2060, which reflects an 8-year construction period should the proposed desalination be permitted, constructed and come online. Annual cash flows (benefits and costs) are accounted for throughout the entire study period. To discount the future cash flows into today's dollars, a discount rate of 3% was selected for the analysis. By utilizing the real discount rate across the economic analysis, annual cash flows are not required to be inflated as this discount rate is net of expected annual inflation.

The Evangeline groundwater, water conservation, and desalination plants strategies have costing information that has been supplied from the 2021 Region N Water Plan. The life cycle costs for the floating solar panel scenario uses NREL (2020) and PV Watts to estimate the cost of the solar panels. The cost incurred to treat and pump the freshwater to the region is assumed to be status quo as of current day and uses estimates from the O.N. Stevens WTP capacity expansion cost estimation, also reported in the Region N Water Plan.

A scenario analysis with four additional scenarios is included in the results section in the main report. These scenarios vary key parameters in capital costs and bay salinity for the desalination alternatives.

Interpreting results

Results are presented in Net Present Value (NPV) outcomes. NPV is the present value of benefits, net of initial capital costs over the project study period, which are discounted into current dollars at rates of 3%. NPV is the principal measure of an investment's economic worth:

- NPV > 0, means benefits are larger than costs.
- NPV < 0, means costs are larger than benefits.

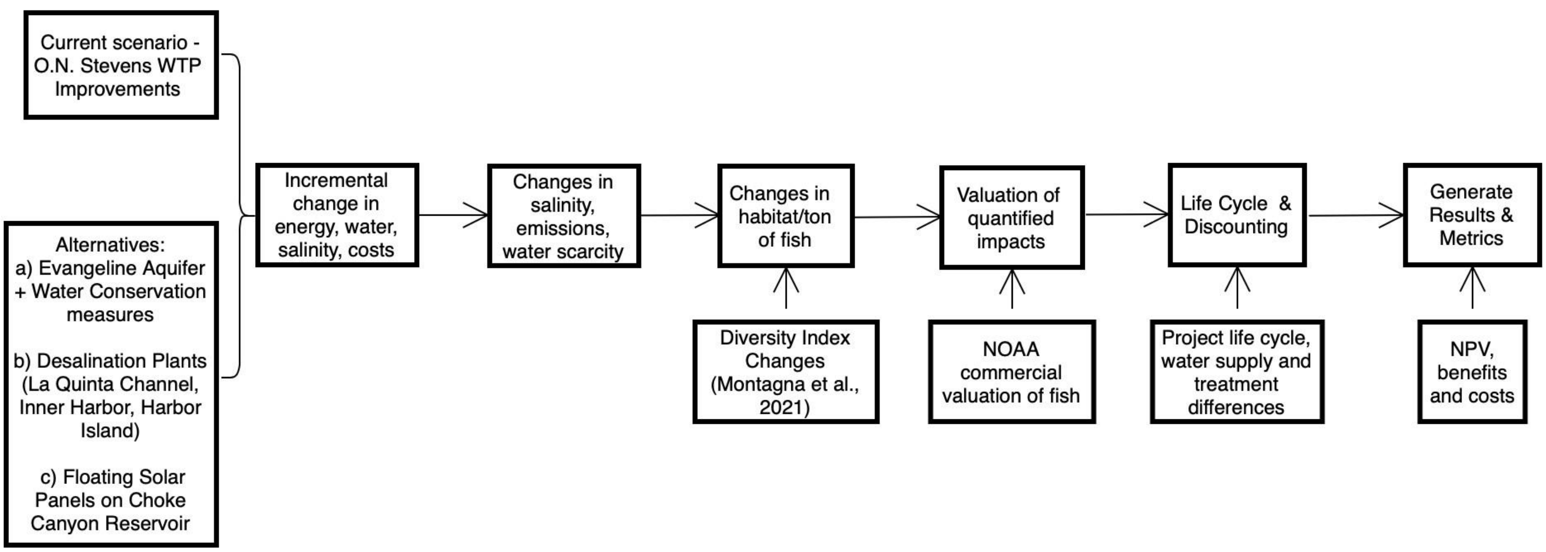

Figure 3: Valuation pathway for the cost-benefit analysis study

Results overview

The section below outlines the results from the cost benefit analysis for the project. The results are segmented into two core cash flow components - financial and social/environmental impacts.

- Financial cash flows include the life cycle costs associated with the different scenarios such as capital costs, energy costs, interest costs, and annual maintenance costs, as well as the revenues from renewable energy generation.
- Social/environmental impacts include the cash flows associated with reduced water consumption from conservation measures, reduced emissions from renewable energy generation, energy consumption differences across the different water supply scenarios, and the changes in level of threat to endangered species from changes in salinity levels.

When taking a life cycle perspective over a 30-year study period starting in 2030, with 30 MGD of annual withdrawals held constant for each of the different scenarios, the analysis shows substantial impacts to the region.

The results have been represented in terms of present values for each impact category, with a negative value representing costs over the life cycle, and positive value representing benefits or revenues for each alternative over the life cycle of 30 years from 2030 to 2060, evaluated in 2022 dollars. These results are built off the assumption of following the costing elements (where provided) from the Region N Water Plan and a hyperhaline level of saline in the bay; while this is taking a conservative approach on the costing side, a set of scenarios with varying costs and saline levels can be found in the following section.

Table 3: Cost Benefit Analysis Absolute Results - 30 Year Study Period Discounted at 3% - 30 MGD Equivalent Water Supply Alternatives (hyperhaline highest salinity - low capital cost scenario)

Net Present Value Discounted at 3% (in millions)					
Impact category	Evangeline + Water Conservation	Inner Harbor Desalination	La Quinta Desalination	Harbor Island Desalination	Floating Solar
Financial					
Life Cycle Costs (low cost)	-$786	-$1,232	-$1,135	-$1,129	-$18,942
Renewable Energy Revenues	$0	$0	$0	$0	$27,383
Social & Environmental					
Societal Value of Water Conservation	$66	$0	$0	$0	$0
Habitat Value - Hyperhaline (PSU level of 40)	$0	-$62	-$74	-$98	$0
Energy Consumption - Emissions (GHG and CAC)	-$37	-$160	-$154	-$166	-$41
Renewable Energy Production - Emissions Reduction (GHG and CAC)	$0	$0	$0	$0	$23,375
Financial	**-$786**	**-$1,232**	**-$1,135**	**-$1,129**	**$8,441**
Social & Environmental	**$29**	**-$222**	**-$228**	**-$265**	**$23,334**
Total Net Present Value	**-$757**	**-$1,454**	**-$1,363**	**-$1,394**	**$31,775**

Key findings:

- Without the high rate of growth in the petrochemical and industrial manufacturing industries, the Coastal Bend Region would not need such large volumes of additional water supply.
- For the four alternatives that have come from the 2021 Region N Water Plan strategies evaluated in this report, the lowest net financial cost is the Evangeline Groundwater plus Water Conservation Measures.
- The desalination scenarios are the most expensive with high capital costs as compared to water conservation and pumping water from the Evangeline Aquifer.
- The desalination scenarios also represent disbenefits to the local region from negative impacts to the local habitat. The high brine discharge in the brine may be expected to escalate the salinity levels in the Bay area - reducing the viability of a healthy ecosystem for the local fish population. Some species are commercially significant, and a declining population has an effect on the community revenues - this has been estimated in the cost benefit evaluation. The impacts of the proposed desalination plants on just six key fish species will cost the region between $1.18 million to $6.03 million every year. There are at least seven other valuable fish species that could be affected by the increased salinity in the Bay system.
- Additionally, desalination plants are responsible for significant emissions from energy consumption from the local grid for the desalination process and pumping of water. The desalination plants would emit more than quadruple the amount of air pollution compared to the groundwater option and floating solar panels would decrease air pollution.
- The analysis shows the floating solar scenario shows merit as the only option to produce positive life cycle costs (net revenues above costs), as well as net positive externalities (creates positive social and environmental impacts relating to conserving existing water supply and producing clean power). The scale of the floating solar is substantially larger than the other options given the area of coverage needed to prevent evaporation losses with a 30 MGD potential of supply; while the scale to this scenario is somewhat implausible, it's meant to be an illustrative example of the potential of this technology as a viable alternative - likely at a smaller scale with other water supply sources.

The results also highlight the need in exploring multiple sources to reduce the demand/supply gap - for example, if 5 MGD is achieved through conservation and 5 MGD is achieved through decreased evaporation as a result of floating solar, then less would be needed from the Evangeline Aquifer. Furthermore, given that the price of solar panels continues to decrease, floating solar could be incrementally scaled up with lower upfront capital investment.

Scenario analysis

The results for the study have been segmented into a scenario analysis to account for uncertainty in the valuation of benefits and costs. Uncertainty in valuation can be derived from a multitude of factors including but not limited to changes in available information, expected environmental conditions, regulations, budgets, etc. In this study there are two factors expected to have a degree of uncertainty over the 30 year period.

1. A change in long-term salinity from brine discharge in the Bay
2. The costs associated with the installation and running of desalination plants in the Bay

The Coastal Bend region of Texas has seen an increase in salinity due to long-term climatic changes (the hotter and drier climate in the Southwest) (Seager et al., 2007). The change in climatic and long-term conditions include a reduction in mixing of freshwater, an increase in evaporation, and an increase in industrial brine discharge from the introduction of desalination plants in the Corpus Christi Bay. The increase in salinity may also be perpetuated by an increase in baywater temperatures. The brine discharge from the desalination process is expected to have a higher salinity level than that found in the Bay waters surrounding the discharge point. While direct disposal of this brine may be an economical option for the plant, the denseness from salt levels in brine makes the discharge flow and then sink to the bottom of the Bay water - below the less-dense ambient water thereby forming a stratified cap over the bottom sediment (Person et al., 2007). More than the salt levels in the brine, the difficult conditions that deter mixing of water are responsible for eco-toxicity and hypoxic (low oxygen conditions that create conditions where there are algae blooms, and deterioration of natural habitat) conditions for aquatic life in the Bay. The level of mixing is affected by natural forces of plume flow, wind mixing and currents. The slower the mix with overlying water, the more intense is the depletion of available dissolved oxygen near the bottom sediment - thereby perpetuating an environment that creates hypoxis
(low oxygen that can harm aquatic life) (Person et al., 2007). Due to uncertainty in the level, rate, intensity at which hypoxic environments may be created within the Coastal Bay over 30 years with regular brine discharge, the project team has set up two discrete levels of salinity:

1. Salinity levels in the bay reaching hyperhaline levels with a PSU value over 40
2. Salinity levels in the bay reaching historically high levels of salinity during the dry season with a PSU value of 34.9 (historical salinity data collected as a part of Montagna et al, 2021).

In addition to uncertainty in salinity, the project team has also allowed for uncertainty in a key driver in the study's results, the life cycle costs associated with the installation and maintenance of desalination plants. In February 2022, the State Water Implementation Fund for Texas (SWIFT) received an application from the Port of Corpus Christi for a $500 million loan for the Harbor Island project, which is substantially higher than the $220 million the City of Corpus Christi had previously applied to from SWIFT for the Inner Harbor Project. POCCA announced in April 2022 that it was no longer pursuing the loan. The $500 million loan was higher than that of estimates from the Region N Water Plan. The Region N water Plan uses a uniform costing model (HDR, 2018) to estimate the annual costs with and without debt service. While the project team does not have access to the full model, assumptions from the user guide have been taken to estimate a high level cost estimate for desalination plants with a higher budget for facilities, and corresponding increases in annual maintenance and other costs. The additional scenarios for the study are therefore:

- **Scenario 2: Low-cost scenario with historical high levels of salinity:** The low cost scenario includes the reported annualized costs from the 2021 Region N Water Plan for each of the desalination plants. A high historical level of salinity follows a scenario where the salinity levels in the Bay may be expected to reach a PSU level of 34.9. This has been set in accordance with the highest levels of salinity historically observed in the Bay.
- **Scenario 3: High-cost scenario with hyperhaline salinity:** The high cost scenario includes estimated capital costs using a municipal budget of $500 million (cost of facilities), as well as the soft costs associated with the expenses for engineering, feasibility, land acquisition the reported

capital costs (these approximations have been estimated using the Region N Water Plan as the reference study). A hyperhaline salinity level follows a scenario where the salinity levels in the Bay may be expected to reach a PSU level of 40. This has been set as an uncertain scenario wherein salinity levels may increase from the current euhaline (where the level of salinity is at a PSU of approximately 30-32) to hyperhaline levels.

- **Scenario 4: High-cost scenario with historical high levels of salinity:** The high cost scenario includes estimated capital costs using a municipal budget of $500 million (cost of facilities), as well as the soft costs associated with the expenses for engineering, feasibility, land acquisition the reported capital costs (these approximations have been estimated using the Region N Water Plan as the reference study). A high historical level of salinity follows a scenario where the salinity levels in the Bay may be expected to reach a PSU level of 34.9. This has been set in accordance with the highest levels of salinity historically observed in the Bay.

Table 4: Cost Benefit Analysis Absolute Results (historically levels of salinity - low capital cost scenario)

Net Present Value Discounted at 3% (in millions)					
Impact category	Evangeline + Water Conservation	Inner Harbor Desalination	La Quinta Desalination	Harbor Island Desalination	Floating Solar
Financial					
Life Cycle Costs (low cost)	-$786	-$1,232	-$1,135	-$1,129	-$18,942
Renewable Energy Revenues	$0	$0	$0	$0	$27,383
Social & Environmental					
Societal Value of Water Conservation	$66	$0	$0	$0	$0
Habitat Value - Historically High Salinity (PSU level of 34.9)	$0	-$19	-$32	-$55	$0
Energy Consumption - Emissions (GHG and CAC)	-$37	-$160	-$154	-$166	-$41
Renewable Energy Production - Emissions Reduction (GHG and CAC)	$0	$0	$0	$0	$23,375
Financial	**-$786**	**-$1,232**	**-$1,135**	**-$1,129**	**$8,441**
Social & Environmental	**$29**	**-$179**	**-$185**	**-$222**	**$23,334**
Total Net Present Value	**-$757**	**-$1,412**	**-$1,320**	**-$1,351**	**$31,775**

Table 5: Cost Benefit Analysis Absolute Results (hyperhaline highest salinity - high capital cost scenario)

Net Present Value Discounted at 3% (in millions)					
Impact category	Evangeline + Water Conservation	Inner Harbor Desalination	La Quinta Desalination	Harbor Island Desalination	Floating Solar
Financial					

Life Cycle Costs (high cost)	-$786	-$1,650	-$1,645	-$2,089	-$18,942
Renewable Energy Revenues	$0	$0	$0	$0	$27,383
Social & Environmental					
Societal Value of Water Conservation	$66	$0	$0	$0	$0
Habitat Value - Hyperhaline (PSU level of 40)	$0	-$62	-$74	-$98	$0
Energy Consumption - Emissions (GHG and CAC)	-$37	-$160	-$154	-$166	-$41
Renewable Energy Production - Emissions Reduction (GHG and CAC)	$0	$0	$0	$0	$23,375
Financial	**-$786**	**-$1,650**	**-$1,645**	**-$2,089**	**$8,441**
Social & Environmental	**$29**	**-$222**	**-$228**	**-$265**	**$23,334**
Total Net Present Value	**-$757**	**-$1,872**	**-$1,873**	**-$2,354**	**$31,775**

Table 6: Cost Benefit Analysis Absolute Results (historically levels of salinity - high capital cost scenario)

Net Present Value Discounted at 3% (in millions)					
Impact category	Evangeline + Water Conservation	Inner Harbor Desalination	La Quinta Desalination	Harbor Island Desalination	Floating Solar
Financial					
Life Cycle Costs (high cost)	-$786	-$1,650	-$1,645	-$2,089	-$18,942
Renewable Energy Revenues	$0	$0	$0	$0	$27,383
Social & Environmental					
Societal Value of Water Conservation	$66	$0	$0	$0	$0
Habitat Value - Historically High Salinity (PSU level of 34.9)	$0	-$19	-$32	-$55	$0
Energy Consumption - Emissions (GHG and CAC)	-$37	-$160	-$154	-$166	-$41
Renewable Energy Production - Emissions Reduction (GHG and CAC)	$0	$0	$0	$0	$23,375
Financial	**-$786**	**-$1,650**	**-$1,645**	**-$2,089**	**$8,441**
Social & Environmental	**$29**	**-$179**	**-$185**	**-$222**	**$23,334**
Total Net Present Value	**-$757**	**-$1,830**	**-$1,830**	**-$2,311**	**$31,775**

Cost Benefit Analysis: Impacts and Methodologies

The impacts for the analysis have been divided into two overarching categories of financial and social & environmental impacts. Financial impacts include the annual cash flows expected to be incurred as a part of the project. Social and environmental impacts refer to the indirect costs and benefits, externalities accrued to a project that may not form a part of a traditional set of financial cash flows, but should still be considered to have a holistic view of the project impacts given the external impacts produced. Each methodology also has a structure and logic diagram - a cause and effect mapping of the impact category valuation approach - that follows the legend below:

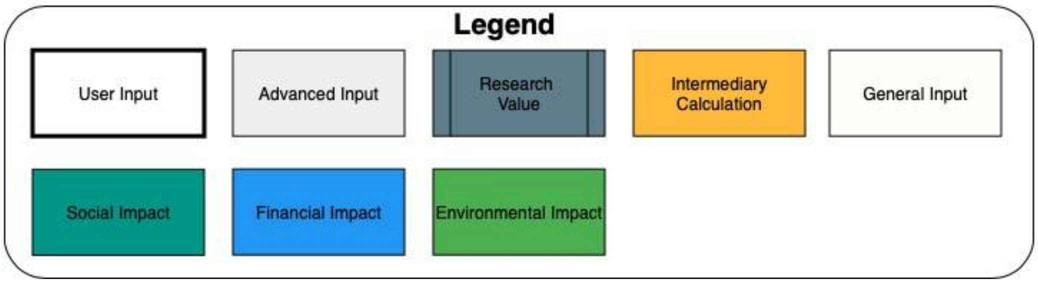

Figure 5: Structure & Logic diagram color legend

Financial

Financial cost impacts for the project are evaluated in terms of annual cash flows with and without debt payments. These financial impacts have been applied to the aquifer, water conservation, and desalination scenarios and sourced from the Regional Water Plan report cost table summaries where the annualized water cost value was used. For the floating panel scenarios, the capital cost has been taken into account as is in terms of an upfront cost. The costs of water treatment, and pumping facilities with debt service have been applied for 30 years after which an interest-free cash flow value has been used. The annual cash flow values account for

- Capital costs
- Debt service costs (this analysis uses annual costs for a period of 20 years while the debt has to be paid, and a lower cost after the 20 year period that reflects the 'After Debt Service' cost of water)
- Annual operations and maintenance
- Energy costs for pumping
- Cost of water treatment and water purchase
- Costs of water supply between the different scenarios and across the timeline
- Other ancillary costs that have been shown in extracted tables in the methodology below

The costs extracted from the 2021 Region N Water Plan report for the Gulf Coast Aquifer, and Desalination plants are as follows.

Evangeline/Laguna LP Treated Groundwater Strategy - Region N Plan With MAG Limits (Option 3)

Item	Estimated Costs for Facilities
Primary Pump Station	$5,803,000
Brine Concentrate Pump Station (5.4 MGD)	$992,000
Transmission Pipeline (36 in dia., 5 mi treated; 1.5 mi brine concentrate)	$9,977,000
Well Fields (Wells, Pumps, and Piping)	$35,051,000
Water Treatment Plant (21 MGD)	$56,990,000
Total Cost of Facilities	**$108,813,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$37,591,000
Environmental & Archaeology Studies and Mitigation	$667,000
Land Acquisition and Surveying (26 acres)	$348,000
Interest During Construction (3% for 2.5 years with a 0.5% ROI)	$10,136,000
Total Cost of Project	**$157,550,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$11,085,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$450,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$170,000
Water Treatment Plant	$10,536,000
Pumping Energy Costs (9456774 kW-hr @ 0.08 $/kW-hr)	$757,000
MRP Energy and Power Capacity Compensation	$207,000
Purchase of Water (24,873 acft/yr @ 480.6 $/acft)	$11,954,000
Total Annual Cost	**$35,159,000**
Available Project Yield (acft/yr)	19,898
Annual Cost of Water ($ per acft)	$1,767
Annual Cost of Water After Debt Service ($ per acft)	$1,210
Annual Cost of Water ($ per 1,000 gallons)	$5.42
Annual Cost of Water After Debt Service ($ per 1,000 gallons)	$3.71

Figure 6: Evangeline scenario cost information (Source: 2021 Region N Water Plan: Table 5D.9.8)

City of Corpus Christi- Inner Harbor 30 mgd Desalination Project (Sept 2018 Prices)

Item	Estimated Costs for Facilities
Transmission Pipeline (raw water piping; brine concentrate disposal x 3)	$51,000,000
Storage Tanks (and Delivery) x 3	$33,000,000
Water Treatment Plant (30 MGD)	$302,911,000
Total Cost of Facilities	**$386,911,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$132,869,000
Land Acquisition and Surveying (26 acres)	$108,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$42,891,000
Total Cost of Project	**$562,779,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$39,598,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$840,000
Water Treatment Plant	$45,437,000
Total Annual Cost	**$85,875,000**
Available Project Yield (acft/yr)	33,604
Annual Cost of Water ($ per acft)	$2,555
Annual Cost of Water After Debt Service ($ per acft)	$1,377
Annual Cost of Water ($ per 1,000 gallons)	$7.84
Annual Cost of Water After Debt Service ($ per 1,000 gallons)	$4.23

Figure 7: Inner Harbor desalination plant scenario cost information (Source: 2021 Region N Water Plan: Table 5D.10.4)

City of Corpus Christi- La Quinta 40 mgd Desalination Project (Sept 2018 Prices)

Item	Estimated Costs for Facilities
Transmission Pipeline (raw water piping/intake; brine concentrate disposal x 2)	$113,000,000
Storage Tanks (and Delivery) x 2	$26,000,000
Water Treatment Plant (40 MGD)	$390,940,000
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$179,829,000
Land Acquisition and Surveying (33 acres)	$138,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$58,568,000
Annual Cost	
Debt Service (3.5 percent, 20 years)	$54,071,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,390,000
Water Treatment Plant	$58,641,000
Available Project Yield (acft/yr)	44,804
Annual Cost of Water ($ per acft)	$2,547
Annual Cost of Water After Debt Service ($ per acft)	$1,340
Annual Cost of Water ($ per 1,000 gallons)	$7.81
Annual Cost of Water After Debt Service ($ per 1,000 gallons)	$4.11

Figure 8: La Quinta desalination plant scenario cost information (Source: 2021 Region N Water Plan: Table 5D.10.6)

Cost Estimate Summary of the Port of Corpus Christi Authority's 50 MGD Desalination Project at Harbor Island (Sept 2018 Prices)

Item	Estimated Costs for Facilities
Primary Pump Station (26.3 MGD)	$12,940,000
Transmission Pipeline (42 in dia., miles)	$56,451,000
Water Treatment Plant (50 MGD)	$478,968,000
Total Cost of Facilities	**$548,359,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$189,103,000
Environmental & Archaeology Studies and Mitigation	$1,163,000
Land Acquisition and Surveying (182 acres)	$2,998,000
Interest During Construction (3% for 3 years with a 0.5% ROI)	$61,184,000
Total Cost of Project	**$802,807,000**
Annual Cost	
Debt Service (3.5 percent, 20 years)	$56,486,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$565,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$324,000
Water Treatment Plant	$71,845,000
Pumping Energy Costs (11835834 kW-hr @ 0.08 $/kW-hr)	$947,000
Total Annual Cost	**$130,167,000**
Available Project Yield (acft/yr)	56,044
Annual Cost of Water ($ per acft),	$2,323
Annual Cost of Water After Debt Service ($ per acft),	$1,315
Annual Cost of Water ($ per 1,000 gallons),	$7.13
Annual Cost of Water After Debt Service ($ per 1,000 gallons),	$4.03

Note: The water treatment plant annual costs from the TWDB uniform costing model includes energy costs associated with use of reverse osmosis membrane treatment to desalinate seawater and produce finished water with TDS levels below the TCEQ regulatory limit.

Figure 9: Harbor Island desalination plant scenario cost information (Source: 2021 Region N Water Plan: Table 5D.10.11)

In addition to these costs, the regional plan has also estimated a range of $46 - $196 per acre foot as a cost for the pumping and treatment of fresh water from Choke Canyon reservoir for the floating solar panel scenario. The capital and maintenance costs for the floating solar panels have been estimated using PVWatts accounting for the reservoir surface coverage requirement, and corresponding number of panels needed to prevent 30MGD of surface water evaporation.

A summary of the costs used for the analysis have been shown in the table below. In addition to the annual cash flows, the financial impact section also accounts for revenues from the floating panels at $0.08 per kWh generated across the panels. The volume of renewable electricity generated has been estimated using historical evaporation rates from Choke Canyon reservoir to estimate the square meters of coverage required. PVWatts data on Corpus Christi specific solar radiation has been used to estimate the annual generation capacity (0.15 kW / sq meter and 1,509 kWh/kW). Annual levels of renewable electricity generated are estimated at 22.406 billion kWh of output that generates an annual revenue of $1.7 billion.

Table 7: Cost analysis inputs for the project scenarios

Inputs	Units	Evangeline	Inner Harbor	La Quinta	Harbor Island	Floating Solar
Water consumption	MGD	25	30	30	30	30
Water consumption from reclamation	gallons / year	9,131,250,000	10,957,500,000	10,957,500,000	10,957,500,000	-
Water consumption from evaporation prevention	gallons / year	-	-	-	-	10,957,500,000
Water consumption from conservation measures	gallons / year	1,826,250,000	-	-	-	-
Solar PV capital costs per kW	$/kW	-	-	-	-	$1,290.00
Solar panel total capital costs	$	-	-	-	-	$19,144,766,186
Solar panel annual maintenance	$	-	-	-	-	$230,034,012**
KW of energy	kW	-	-	-	-	14,840,904
Annual energy generation	kWh	-	-	-	-	22,406,796,890***
Annual costs debt service	$/year	$1,767	$2,555	$2,321	$2,323	$196
Annual costs after debt service	$/year	$1,210	$1,377	$1,362	$1,315	$46
Cost of municipal water conservation	$/year	$503	-	-	-	-

*reflects pumping, treatment and maintenance costs from status quo - O.N. Stevens WTP
** $15.5 / kW for PV maintenance
*** 0.5% degradation rate in solar PV capacity after the first year

Renewable energy revenues

As a part of the solar panel scenario, the municipality is expected to earn revenues from renewable energy sold into the grid at 8 cents per kWh of electricity generated. Details on the estimation of renewable energy generation have been provided in the next section along with emission details.

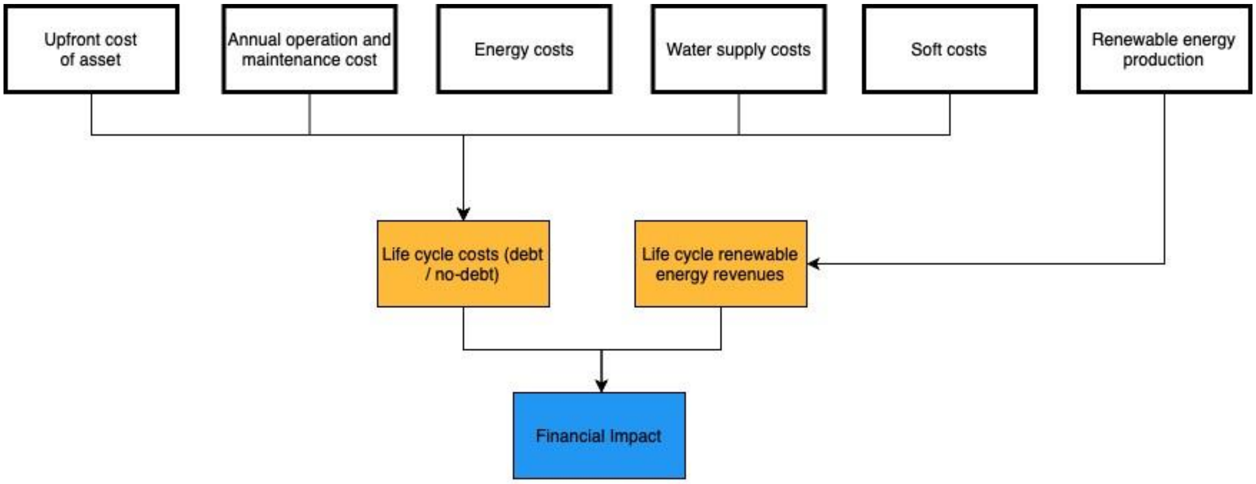

Figure 10: Financial impacts structure & logic diagram

Social & Environmental

Electricity consumption and emissions

Energy consumption in the desalination scenarios creates not only financial disbenefits from energy costs covered in the financial section, but also environmental disbenefits from emissions. The volume of energy is estimated using energy costs estimated by the Regional Water report on the cost of pumping water and a unit energy cost to estimate the kWh of energy consumption. Additionally, energy consumed for water treatment at the plant is estimated using a range of 1015 kWh per 1,000 gallons of water treated at the plants. Emissions from energy are divided into air contaminant emissions and carbon emissions. These are quantified using location-specific and monetized emission factors and social values. While electricity consumption for all scenarios emits pollutants, renewable energy generation from the panels are responsible for reducing emissions as they are expected to directly offset regional grid-based energy consumption. Energy consumption and data used for this analysis has been shown in the table below:

Table 8: Energy consumption and generation inputs used for the emissions analysis

Energy consumption	kWh/ year 2030 onwards (pumping)	kWh/ year 2030 onwards (treatment)*	Total tons of emissions
Evangeline	12,050,000	14,610,000	496,600
Inner Harbor	7,214,700	109,575,000	2.175 million
La Quinta	2,593,500	109,575,000	2.089 million
Harbor Island	11,835,800	109,575,000	2.262 million
Floating solar	12,433,300	17,532,000	558,200

*10kWh / 1,000 gallons for seawater desalination[4]

Table 9: Emissions per pollutant type for each scenario

Emissions	Evangeline	Inner Harbor	La Quinta	Harbor Island	Floating Solar Panels
NO_x	310	1,370	1,320	1,430	-16,700
SO_2	430	1,880	1,950	1,950	-22,800
$PM_{2.5}$	20	100	110	110	-1,270
VOC	5	20		20	-270
CO_{2e}	495,880	2,172,300	20 2,086,300	2,258,200	-26,393,000

The desalination plants would therefore emit more than quadruple the amount of air pollution compared to the groundwater option and floating solar panels would decrease air pollution.

Criteria Air Contaminants Reduction

Electricity consumption from the grid generates emissions and environmental disbenefits from air pollution and affected air quality. For each unit of energy produced and used, air pollution emissions are released into the atmosphere, quantified using emission factors. Emission factors for Corpus Christi Bay are used from the (Electric Reliability Council of Texas) ERCOT grid from the United States Environmental Protection Agency (EPA) eGRID. The social benefit from reducing air pollution emissions is monetized by applying the social cost of each air pollutant to the respective amount of that air pollutant reduced. Autocase uses federal guidance from the Environment Protection Agency (EPA), Federal Aviation Administration (FAA), National Environmental Policy Act (NEPA), ExternE, World Health Organization (WHO) Air Quality Guidelines, and federal, regional departments of transportation to assess the pollutants of interest.

Autocase calculates the environmental benefit for the following air pollutants: NO_x, SO_2, $PM_{2.5}$, and VOCs. Non-baseload, location-specific emission factors per unit of electricity for U.S. locations are gathered from the EPA eGRID (eGRID, 2018a) for NO_x and SO_2 and US EPA National Emissions Inventory (NEI, 2017) for $PM_{2.5}$ and VOCs. Autocase uses social values for criteria air contaminants (CACs) to monetize the impacts of changes in outdoor air pollutant quantities derived from changes in operational energy use. Autocase uses the following sources to build a location specific valuation of CAC emissions: Estimating Air Pollution Social Impact Using Regression (EASIUR) (2015), Environmental Protection Agency (2012), Muller et al. (2007), Rabl & Spadaro (2000), RWDI (2005), Sawyer et al. (2007), Transportation Research Board (2002), U.S. Department of Transportation (2017), Victoria Transport Policy Institute (VTPI) (2011) and Wang et al. (1994). Each of these sources value reduced emissions on four key fronts: health, ecology, visibility and the built environment. Health outcomes may be divided into mortality (loss of life) and morbidity

[4] HDR Engineering, Inc., 2015a, 2016, South Central Texas Regional Water Plan Volume I – Executive Summary and Regional Water Plan: contract report to South Central Texas Regional Water Planning Group.

(negative quality of life due to diseases or illness). We provide an explanation of a few of the key resources used towards each of the above outcomes.

EASIUR is a regression tool used by Autocase that simulates location-specific public health costs per grid, where each grid covers 36x36 square kilometers. Public health costs by EASIUR are calculated in terms of a change in mortality rate and years of life lost (YOLL) per death, monetized using a Value of Statistical Life (VSL). The other sources described above, specifically the U.S. Department of Transportation, VTPI, EPA extend the analysis to include other human health impacts such as chronic bronchitis, emergency room visits, lower and upper respiratory symptoms, and restricted activity days). These health impacts are monetized using a combination of avoided damage-costs and a willingness to pay (WTP) to avoid negative health outcomes. Additionally, other impacts also accounted for are changes in crop yields, changes in visibility, and structural damage.

Carbon Emission Reduction

Electricity consumption from the utility provider and grid is also responsible for emitting GHGs, thereby generating societal costs or disbenefits. For each unit of fossil fuel-based energy produced and used, GHGs are released into the atmosphere, quantified using emission factors. The social cost of emitted GHGs is monetized by applying the social cost of carbon to the amount of carbon dioxide equivalent emissions reduced. Emission reductions are calculated as a part of the floating solar scenario where renewable energy produced offsets electricity required for pumping, conveying, and treating fresh water. The social cost of carbon in the U.S. is taken from the Government's Interagency Working Group on Social Cost of Carbon (2016). The social cost of carbon is a conservative estimate of the negative effects of climate change. The cost of carbon pollution is an estimate of the economic cost of damages relating to health, agricultural losses, property flooding and the value of ecosystem services.

Non-baseload, location-specific emissions factors per unit of electricity are gathered from the United States Environmental Protection Agency eGRID (eGRID, 2018a) - the ERCOT grid for Corpus Christi Bay. Emission factors for natural gas combustion for the U.S. are gathered from the United States Environmental Protection Agency (EPA, 1998).

Renewable Energy Emissions Reduction

This strategy is targeting the installation of floating solar photovoltaics (PV) on the surface of Choke Canyon Reservoir. The project team has targeted that installing floating solar panels will be responsible for reducing the level of evaporation of surface water from the reservoir which will then be used to supply freshwater to the region for water consumption. It is assumed that over 90% of the surface will be covered with floating solar panels to avoid the annual evaporation of 30 MGD (at a rate of 4.96%). Assuming an average solar panel area of 130 square meters, with a 19.5kW panel capacity, and output of 1509 kWh/kW per year, the solar panels generate 22.406 billion kWh of energy per year. Reduction in emissions from this design would be expected as this directly offsets energy consumption from the grid. The same emission factors and social values are used as described in the section above.

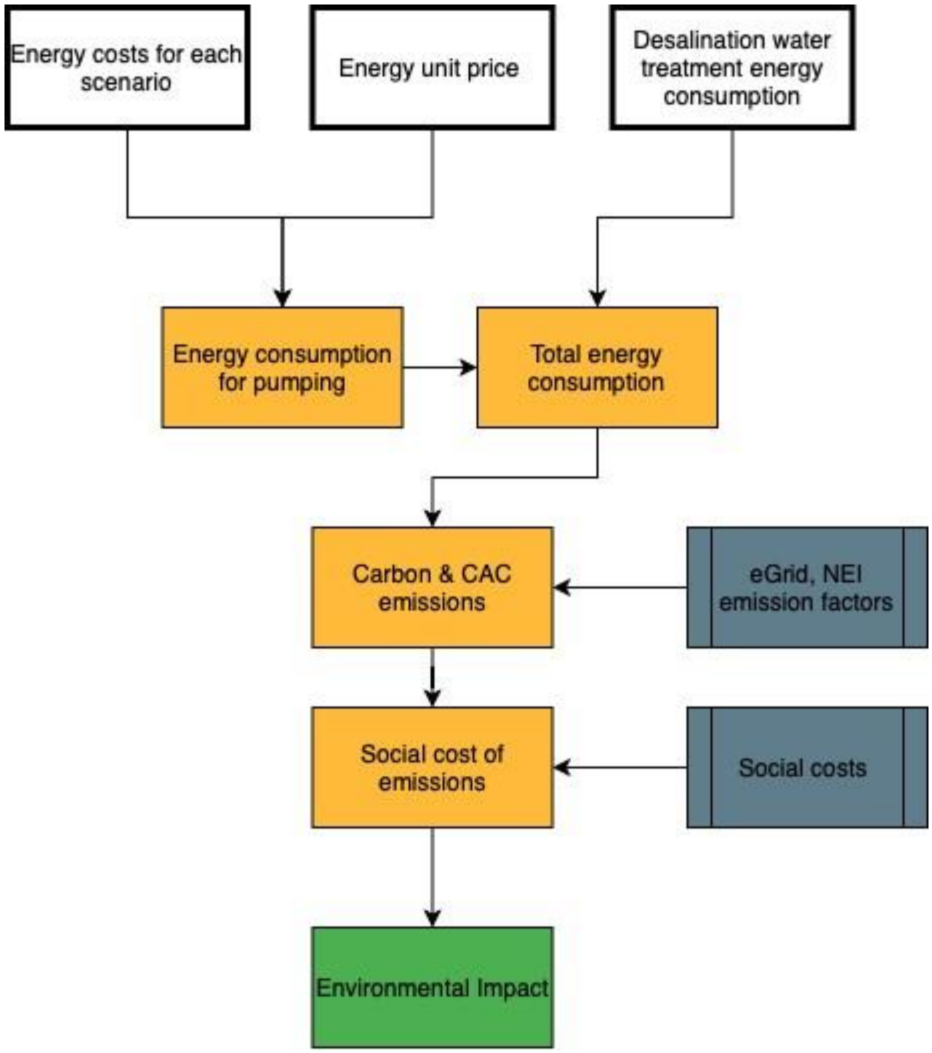

Figure 11: Electricity emissions structure & logic diagram

Social Value of Water from Source Consumption

Consumption of local water as groundwater, freshwater from the reservoir, Bay or Gulf water for desalination is expected to have a disbenefit to society in terms of its effects on scarcity of water, and thereby, an applied social value of water. As a part of this study, the Evangeline/water conservation measures scenario is expected to conserve 5 MGD of water through water efficiencies and regulations across the region, thereby saving 5 MGD of groundwater. Groundwater conservation is responsible for recharging the aquifer, raising the water table, and reducing the burden on water scarcity.

There is a multi-faceted link between natural capital and the final ecosystem services provided by natural resources. Natural capital is the stock of biological and physical resources like air, energy, water, land, and living organisms on earth that perform functions which provide ecosystem goods and services. Ecosystem services represent a direct and indirect set of services provided by natural capital that are responsible for furthering human well-being. Cost benefit analysis uses various frameworks to assess the value generation from natural capital. Some approaches for valuation pathways are suggested as a part of publications from the Economics of Ecosystems and Biodiversity (TEEB) and the Millennium Ecosystem Assessment (MEA), and the EPA's National Ecosystem Services Classification System (NESCS). There are four distinct steps (TEEB) used in the valuation of ecosystem services:

1. Identify the impacts from natural capital
2. Identify and quantify the impacts on ecosystem services in terms of provisioning, regulating, cultural, and support
3. Identify and quantify the corresponding impacts on human and environmental well-being
4. Value the impacts using market and no-market valuation strategies

The impacts on human and environmental well-being are estimated in terms of total economic value (TEV). TEV represents the use and non-use value of a good or service provided. Methods used to estimate the TEV include market price, contingent valuation, avoided costs, willingness to pay, stated preferences etc. For example, water reclamation and conservation strategies are responsible for improving water reliability, and are sometimes measured in terms of the willingness to pay per customer per gallon of future water shortage avoided.

Total indirect economic valuation of social value means finding the willingness to pay when markets do not reflect that information directly. In the case of the social value of water several factors are involved when considering a willingness to pay approach. These factors include water quality, status of water from other resources and other factors that affect the supply of water such as population growth, current potable water and climate change.

Ground and surface water is responsible for enhancing downstream habitat, reducing the risk to endangered species, reducing the risk of subsidence, and enhancing the quality of soil and topography for different-land use. Evidence shows that the valuation of ground water consumption and water table depletion is dependent on the balancing factor of current demand and water use per location, the existing supply of groundwater in the region as well as the recharge of the water table from yearly rainfall (Cutter, 2007). Recharge rates are estimated using evidence from the United States Geological Survey (USGS, 2003; 2010). Different investments into water conservation measures using efficient technology or green infrastructure in the region are responsible for generating a significant social value of water benefit.

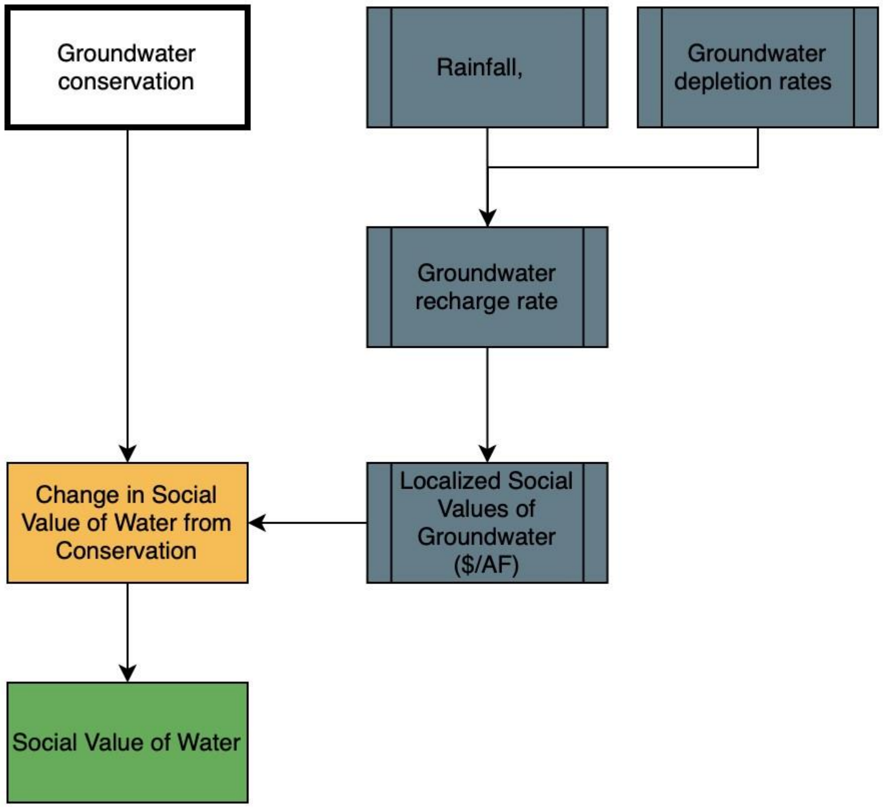

Figure 12: Social value of water structure & logic diagram

Habitat and Diversity Index Effects

A critical component of the analysis outside of costs are the environmental considerations as a part of the project. While the Coastal Bend area is well known for its valuable mineral resources, oil and gas processing and export, and petrochemical industrial activities, it is also responsible for supporting a rich diversity of living natural resources. The Coastal Bend Region provides habitat for numerous endangered and threatened species including birds, amphibians, reptiles, fish, mammals, and vascular plants. Bay and estuary systems rely on the optimal mix of fresh inflow and salt water to maintain the abundance of diversity and environmental conditions for species to thrive.

Concentrated brine effluent is produced during the desalination process. The change in salinity levels from brine discharge into the Bay impacts aquatic life in the Bay. Releasing brine concentrate could potentially affect organisms that are dependent upon a specific range of temperature and salinity. Changes to the ratio and type of salt discharges can cause osmotic imbalances (water mixing and flow) and toxicity. This effect is evaluated as a part of the study in terms of a change in abundance of marine species in the Bay area.

The evaluation is segmented into three key steps that had their individual research and engagement processes to determine the best valuation approach:

- Changes in salinity levels

- Changes in the volume of fish and other species
- The value associated with the change in species volumes

To evaluate a change in salinity, the current salinity levels are first assessed to get an understanding of the levels of brackishness or salinity in different areas of the Bay. To assess this, we have used historical salinity data from Montagna et al. (2021) to set up a current level of pre-existing salinity in the bay. The paper divides Corpus Christi Bay into four distinct regions and records the historical salinity levels from 1987 to 2016:

- Nueces Bay
- South Corpus Christi Bay
- North Corpus Christi Bay
- Redfish / South Aransas Bay

Overall, for each of the regions, there have been over 1500-2500 samples collected to record an average salinity level. Salinity as a part of this paper has been recorded in terms of Practical Salinity Units (PSU) - an industry standard to evaluate salinity levels in regions and effectively compare them.

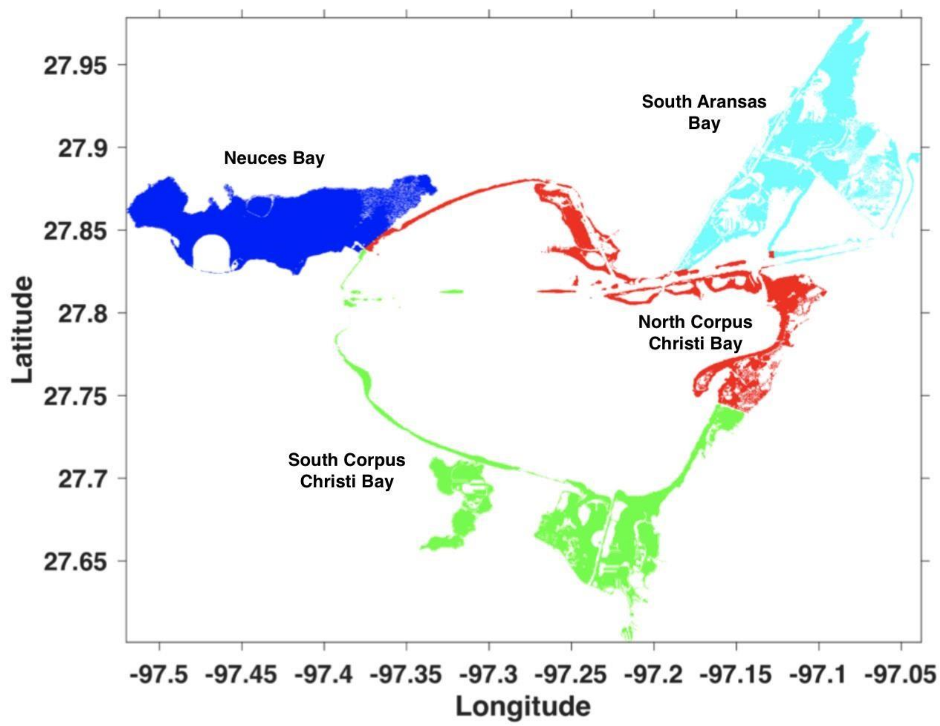

Figure 13: Regions for salinity level analysis (Source: Montagna et al, 2021)

The figure above shows the four regions as recorded as a part of research by Montagna et al., (2021). The color codes are as follows: Redfish and South Aransas Bays (light blue), North Corpus Christi Bay (red), South Corpus Christi Bay (green), and Nueces Bay (blue). The latitude and longitudes for each of these areas have been used to match them to our project sites for desalination plants. The paper also divides salinity into four categories based on the PSU value. These categories and mapping of salinity categories as well as the current levels have been shown in the tables below. To evaluate the effect of brine discharge on the salinity levels in the different bay regions, the project team, in consultation with Dr. Montagna has taken two approaches:

- Evaluate historically highest levels of salinity (PSU of 34.9)
- Evaluate a future perspective of an increase in the category level of coastal salinity modifiers to hyperhaline with a PSU level of over 40 units.

Table 10: Coastal salinity modifiers used as a part of the study

Coastal salinity modifiers	Salinity
Hyperhaline	>40
Euhaline	30-40
Polyhaline	18-30
Mesohaline	5-18
Oligohaline	0.5-5
Fresh	<0.5

Table 11: Change in salinity assumed for the analysis

Salinity levels at project locations	PSU	Category of salinity	Modeled increase in salinity: Hyperhaline*	Modeled increase in salinity: Historically high salinity**
Evangeline	NA	NA	NA	NA
Inner harbor	32.29	Euhaline	7.71 (23%)	2.61 (8%)
La Quinta	30.82	Euhaline	9.18 (29%)	4.08 (13%)
Harbor Island	27.99	Polyhaline	12.01 (42%)	6.91 (24%)
Floating Solar - Choke Canyon	<0.5	Fresh	NA	NA

*Hyperhaline salinity is measured at practical salinity units (PSU) of >40

**Maximum salinity historically was measured at a PSU of 34.9

As a next step, the project team evaluates the effect of changes in salinity on the change in local diversity or habitat. As a part of the project's research and literature review, there is a large list of commercially and socially important species that are currently in the local commercially important species list:

Table 12: List of commercially important species that have monetizable values in the Bay

Endangered species important to the bay	Value per tonne
White Shrimp	$5,602

Brown Shrimp	$4,887
Blue Crab	$2,981
Eastern Oyster	$13,007
Red Snapper	$9,967
Black Drum	$2,697
Yellowedge Grouper	$9,879
Vermillion Snapper	$6,680
Golden Tilefish	$6,610
Atlantic Croaker	$21,076
Blue Catfish	$2,162.
Flounder	$8,782
Mullets	$6,736

The value per ton for the endangered species is provided by the NOAA Fisheries database by using their estimates on the tons of species within the Bay and the total valuation per species type. These values are representative of the recreational and commercial values placed on species and are presented in 2019 dollars.

To evaluate the impact of the change in salinity reported above on the local habitat, the project team has once again used research from Dr. Montagna to estimate a local diversity index. His paper has published linear regression estimates on the effect of salinity on the diversity index. The Shannon diversity index is a measure of the effective number of species in a sample - and is indicative of proportional species abundance. This diversity index in Dr. Montagna's paper has only focused on six species: the Atlantic Croaker, Sheepshead Minnow, White and Brown Shrimp, Blue Crab, and Pinfish. The regression coefficients on the change in diversity index from a change in salinity are reflective of only these species, and have therefore been the species of focus to assign an environmental cost to increases in salinity. *Even with a focus on only six species, the desalination plants still generate a significant detriment from a reduction in the abundance of species. Therefore, with additional research, the environmental costs of desalination may be expected to be much higher in the future.* The output from this model has been shown in the table below under both scenarios. The impacts of the proposed desalination plants on just six key fish species will cost the region between $1.18 million to $6.03 million every year. There are at least seven other valuable fish species that could be affected by the increased salinity in the Bay system.

Table 13: Effect size on the local habitat and diversity index from changes in salinity

Diversity effect	Diversity Index change (Hyperhaline)	Diversity Index change (Maximum historical salinity)	Tons of habitat affected (diversity index - hyperhaline) per year	Tons of habitat affected (diversity index - max salinity) per year
Evangeline, Floating solar	NA	NA	NA	NA
Inner harbor	-0.30322	-0.09401	560	173
La Quinta	-0.36338	-0.15428	672	285
Harbor Island	-0.47941	-0.2703	886	499

Table 14: Annual costs to the region from changes in salinity

Diversity effect	Annual cost to habitat - hyperhaline	Annual cost to habitat - max salinity	30 year cost - hyperhaline	30 year cost - max salinity
Evangeline, Floating solar	NA	NA	NA	NA
Inner harbor	$3.8 million	$1.18 million	$64.46 million	$19.9 million
La Quinta	$4.5 million	$1.94 million	$77.28 million	$32.8 million
Harbor Island	$6.03 million	$3.40 million	$101.95 million	$57.48 million

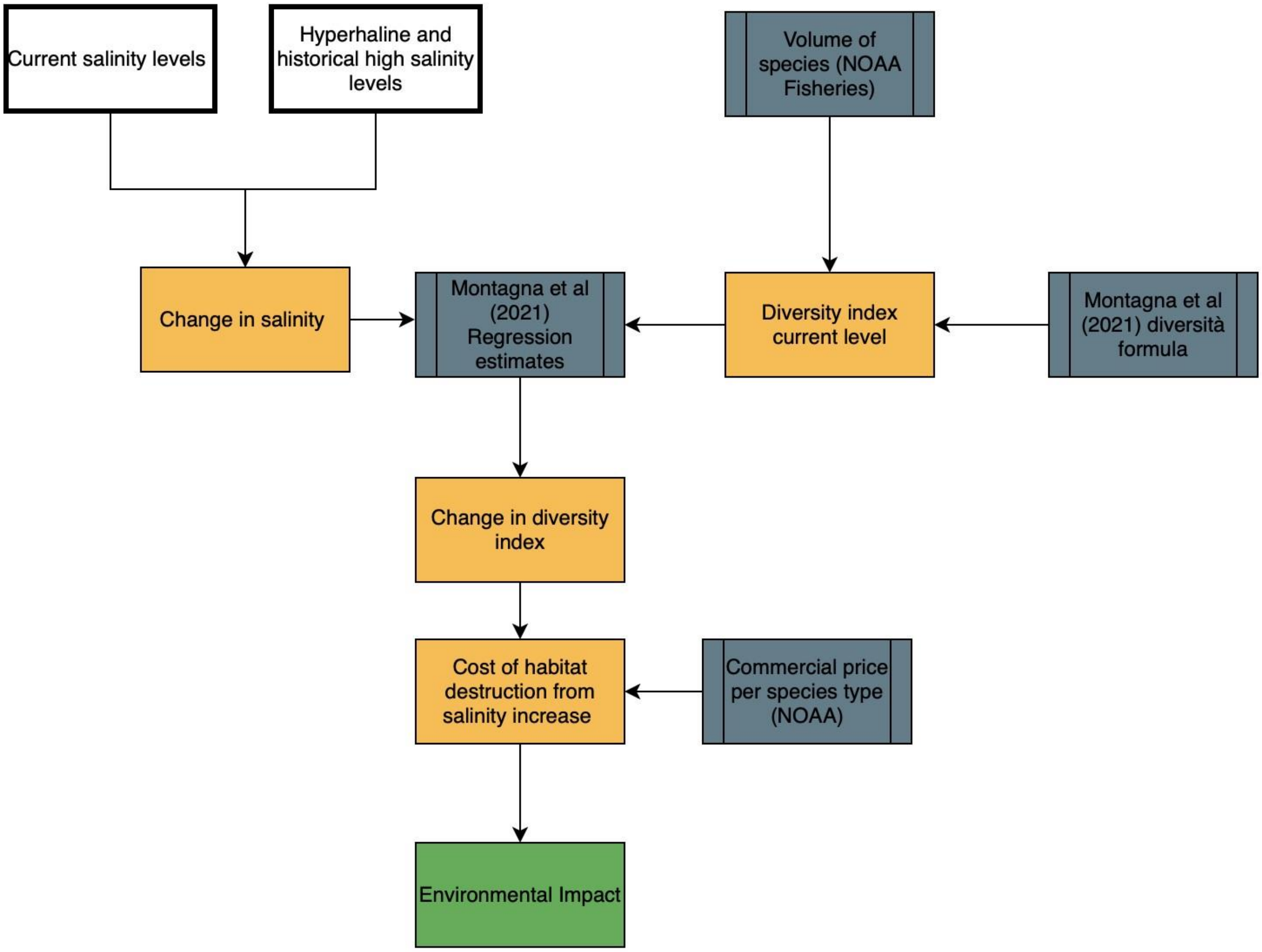

Figure 14: Habitat and diversity impacts structure & logic diagram

Qualitative impacts

In addition to the impacts studied as a part of this analysis, there are impacts that would be relevant to this study, but that have not been addressed due to lack of data and strong literature to support an evidence-based evaluation. A key impact not included as a part of the study is the effect of brine discharge chemicals and temperature on the local water quality. Besides salinity levels, brine discharge is expected to affect the local water quality levels due to the emissions of chlorine, halogenated organics, coagulants acid, cleaning chemicals, and heavy metals. In addition to these chemicals, it may also be expected that with substantial discharge, and potential lack of regulation of brine temperature, it may increase the temperature of the water in the Bay area by 5-15 degrees (Montagna et al., 2021). Since there has not been clear evidence from the applications on the extent to which the discharge of pollutants will be controlled in the Bay, this has not been included within the cost benefit analysis study so as to provide a conservative estimate of the impacts of the desalination plants. According to best available research, the reverse osmosis process may be expected to generate 60 - 70 PSU of salinity, 1-30 ppm of coagulants, and acid with a pH value of 6-7 (Montagna et al., 2021). There is a definite need for additional research to explore the effects of this discharge on the local water quality, and subsequent additional impacts on habitat.

Effects on the water quality may also be expected to generate disbenefits from the community from effects on water use for recreational purposes. However, there isn't sufficient evidence in literature to quantify the magnitude of effect of change in water quality or salinity on recreational outcomes in the Bay area, as well as baseline survey information on the volumes of recreational use in the Bay. In addition to recreational and water quality effects, the habitat impact covered as a part of the study is also a conservative estimation of the effects of salinity on commercially important fish species. With additional future research, a robust study is needed to study the varying salinity effects on all endangered species in the Bay to get the full perspective of the environmental impacts of desalination. This also includes evaluating the intake elements on species and habitat, as well as the processing solids and hazardous waste materials after treatment. Another consideration is helping to inform the issue around who bears the burden of these costs to supply expansion - residential rate payers or industry?

Appendix A: Inputs

General Inputs	Value	Notes / Source / Units
Country	US	
State/Province	TX	
City	Corpus Christi	
Project Name	Water Supply Options for Corpus Christi Bay	
What currency would you like to use for your analysis?	USD	
Construction Start Date	2022	

Construction Duration (years)	2022-2030	2030 is when the desalination plants come live, we assume the status quo until then.
Operation Duration (years)	30 years (till 2060)	
Discount rate	3%	
Emission Factors		Collected from eGrid and NEI
Nox	0.000000379	metric tonnes / kWh
So2	0.000000519	metric tonnes / kWh
Pm2.5	0.000000029	metric tonnes / kWh
VOC	0.000000006	metric tonnes / kWh
CO2	0.0006	metric tonnes / kWh
Social values of pollutants		
Nox	$10,525	$/metric tonnes
So2	$25,779	$/metric tonnes
Pm2.5	$240,205	$/metric tonnes
VOC	$2,421	$/metric tonnes
CO2	$56	$/metric tonnes

Model Inputs	Units	Evangeline	Inner Harbor	La Quinta	Harbor Island	Floating Solar Panels
Water consumption	MGD	25	30	30	30	30
Municipal water conservation	MGD	5	-	-	-	-
City						Corpus Christi
Capital expenditures	$	$157,550,000	$562,779,000	$457,732,000	$802,807,000	$19,144,766,160
Annual debt service (2030-2050)	$/year	1767	2555	2321	2323	$196

Non-debt service cash flows (2050-2060)	$/year	1210	1377	1362	1315	$46
Solar panels maintenance	$/kW/year	-	-	-	-	$15.5
Solar panel annual maintenance	$	-	-	-	-	$230,034,012
KW of energy	kW	-	-	-	-	14,840,904
Annual energy generation	kWh	-	-	-	-	22,406,796,890
Annual costs debt service	$/year	$1,767	$2,555	$2,321	$2,323	$609*
Annual costs after debt service	$/year	$1,210	$1,377	$1,362	$1,315	$609*
Current water supply costing - until 2030	$/year	$565	$565	$565	$565	$565
Cost of municipal water conservation	$/year	$503	-	-	-	-
Energy consumption						
Pumping	kWh	12,050,000	7,214,700	2,593,500	11,835,800	12,050,000
Treatment	kWh	146,100,000	109,575,000	109,575,000	109,575,000	17,532,0000
Salinity current levels	PSU	NA	32.99	30.82	27.99	<0.5
Diversity valuation	$/tonne	$6,810	$6,810	$6,810	$6,810	$6,810

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