Appendix A – Economics

Matagorda Ship Channel, Port Lavaca, Texas

Feasibility Report and Environmental Impact Statement,
Review of Completed Projects,
Calhoun and Matagorda Counties

May 2018

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List of Acronyms

Acronym	Definition
AEO	American Energy Outlook
AAEQ	Average Annual Equivalent
AFRA	Average Freight Rate System
BLT	Bulk Loading Tool
bpd	Barrels per Day
CPA	Calhoun Port Authority
CAGR	Compound Annual Growth Rate
CCSC	Corpus Christi Ship Channel
DWT	Deadweight Ton
EGM	Economic Guidance Memorandum
EIA	Energy Information Administration
ETTC	Estimated Total Trip Cargo
FY	Fiscal Year
FWPC	Future With Project Condition
FWOPC	Future Without Project Condition
HMST	HarborSym Modeling Suite of Tools
IDC	Interest During Construction
LOA	Length Overall
MSC	Matagorda Ship Channel
MLLW	Mean Lower Low Water
MR	Medium Range
NED	National Economic Development
OMRR&R	Operations, Maintenance, Repair and Replacement

OPEC	Organization of Petroleum Exporting Countries
OD	Origin Destination
PX	Panamax
PADD	Petroleum Administration for Defense District
PT	Petroleum Tanker
PDT	Project Delivery Team
RECONS	Regional Economic System
RPEC	Regional Planning and Environmental Center
SD	Standard Deviation
SPX	Sub-Panamax
TSP	Tentatively Selected Plan
TPI	Tons Per Inch
USACE	U.S. Army Corps of Engineers
ULCC	Ultra Large Crude Carrier
UKC	Underkeel Clearance
VLCC	Very Large Crude Carrier
WCSC	Waterborne Commerce Statistical center
WTS	World Trade Services

1 Introduction

This appendix presents the economic considerations and evaluations performed to arrive at the tentatively selected plan for the Matagorda Ship Channel feasibility study. The purpose of this appendix is to explain how the National Economic Development (NED) benefits for each alternative were calculated and display the net NED benefits as compared to cost for each with-project alternative. Together with the Deep Draft Navigation Planning Center of Expertise, the economic analysis for this feasibility study was performed by the Regional Planning and Environmental Center (RPEC) located at Fort Worth District U.S. Army Corps of Engineers (USACE) in conjunction with the USACE Galveston District Project Delivery Team (PDT).

1.1 STUDY PURPOSE

The Calhoun Port Authority (CPA) proposes to widen and deepen the existing Matagorda Ship Channel (MSC) in Calhoun County, TX to allow for larger vessels with more efficient loading practices to access facilities at the Port of Port Lavaca/Point Comfort (the Port). The purpose of this project is to reduce transportation costs and increase operational efficiencies of maritime commerce movement through the Port. HarborSym, a deep draft navigation economics model which will be discussed further in Section 4.1, was used to model the existing as well as the future with- and without-project conditions. This study, among its other objectives, identifies and evaluates economic improvements that will:

- Allow the current fleet to load deeper and more efficiently;
- Accommodate the design vessel (mid-size Aframax tanker), which is not currently calling at the Port due to channel width restrictions;
- Increase efficiency of the channel by allowing two-way traffic of certain vessel types in a channel that has historically been limited to one-way;

1.2 DOCUMENT LAYOUT

The report is organized in the following fashion:

- **Section 1** explains the purpose of the report and the document layout;
- **Section 2** describes the existing conditions at the Port of Point Comfort;
- **Section 3** details the expected future conditions, including the commodity; forecast, and the design vessel;
- **Section 4** presents the transportation cost savings benefit analysis;
- **Section 5** will explore sensitivities to consider the effects of uncertainties on the project;
- **Section 6** examines the multiport analysis;
- **Section 7** describes the socioeconomics of the study area;
- **Section 8** will describe the regional economic development impacts of the project.

2 Existing Conditions

To determine the benefits of a widening and/or deepening project benefiting the Matagorda Ship Channel, existing conditions must be established. Existing conditions are defined in this report as those conditions that would exist within the study area at the time of the study.

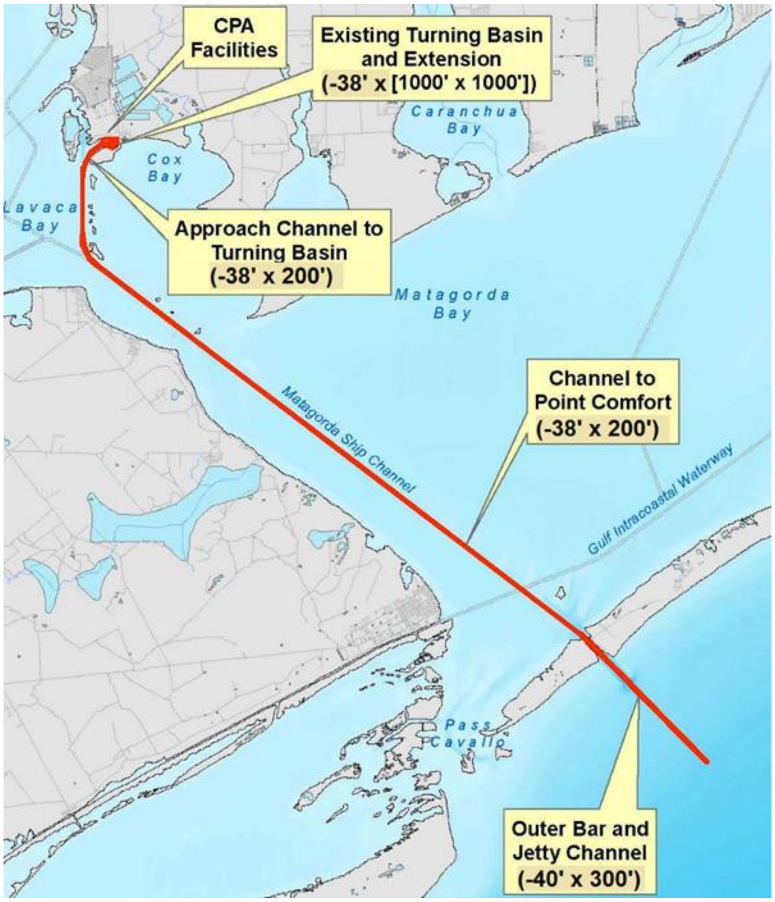
2.1 Project Description

The Matagorda Ship Channel is a 26-mile deep draft navigation channel that runs through Matagorda and Lavaca Bays, connecting the U.S. Gulf of Mexico to Port of Port Lavaca/Point Comfort in Calhoun County, Texas, and providing south Texas with direct, deep-draft access to global trade markets.

Figure 2-1. Study Location

The MSC was constructed in 1962 as a 200-foot wide by 38-foot deep Mean Lower Low Water (MLLW) open bay channel. The channel configurations and dimensions are displayed in Figure 2-2.

Figure 2-2. Matagorda Ship Channel Configuration



The channel was built for a 25,000-30,000 deadweight ton (DWT) design vessel. Today, vessels up to 80,000 DWT use the channel. As such, the channel dimensions limit shippers' ability to efficiently load the vessels and/or use vessels with the most cost effective dimensions. The largest ship that is able to enter the channel is one with a 109' beam. The largest vessel to regularly call at the Port is a 750' long by 106' wide Panamax vessel. Due to the narrow width of the channel, larger classes of vessels cannot call, even with tug assist. Within the harbor, tugs are only used for berthing and un-berthing. The channel dimensions are detailed in Table 2-1.

Table 2-1. Matagorda Ship Channel Sections and Dimensions

Channel Section	Authorized Depth[1] (ft)	Width (ft)	Length (mi)
Outer Bar (Entrance) & Jetty Channel	40	300	3.2
Channel to Point Comfort	38	200	20.9
Approach Channel to Turning Basin	38	200	1.1
Point Comfort Channel to Turning Basin	38	1,000	1,000 ft
Point Comfort Turning Basin Extensions (North & South)	38	300	1,279 ft

[1] **Authorized depth referenced as MLLW (converted from Mean Low Tide)**

2.1.1 Hinterland

A port's hinterland is defined as the geographic areas where port commerce originates and terminates. Historically, the majority of commodity throughput on the MSC is either consumed or produced by local industrial plants. Historical users of the deep-draft channel include Alcoa World Alumina, L.L.C. (Alcoa), INEOS Nitriles, Formosa Plastics Corporation (Formosa), Invista, and J.R. Simplot. A majority of imports by these port users are raw materials used to produce the finished products, which are exported from the Port of Point Comfort.

New users of the channel, all of which had facilities under construction at the start of this feasibility study, include three energy companies, NorthStar Midstream (NST), NGL Energy Partners LP (NGL), and Arrowhead Offshore Pipeline, L.L.C. (Arrowhead). NGL completed construction and began operations in 2017, and the remaining two energy companies are scheduled to complete construction by 2018. All three companies will ship crude oil and condensate from nearby sources via the Matagorda Ship Channel.

These companies will be discussed in detail in section 2.2.

2.1.2 Eagle Ford Shale

Discovered in 2008, the Eagle Ford Shale in South Texas spans northeast from the United States-Mexico border to just below Houston. The formation is approximately 50 miles wide by 400-miles long, covering a 23-county, mostly rural, area. The shale produces natural gas, condensate, oil, and natural gas liquids, adding billions of dollars annually to the South Texas economy and supporting thousands of jobs. Operators expect that the shale play will continue to be developed for decades (http://eaglefordshale.com/). Eagle Ford Shale's proximity to the Port of Port Lavaca/Point Comfort, shown in Figure 2-3, positions the Port to be an efficient exporter of commodities produced by the Shale.

Figure 2-3. Location of Eagle Ford Shale

2.1.3 *Petra Nova Project*

The Petra Nova Project, pictured in Figure 2-4, came online in 2016 and is the world's largest post-combustion carbon capture facility that is installed on an existing coal-fueled power plant. The proven carbon capture process utilized by the project captures carbon dioxide emissions produced by the power plant as part of the Clean Coal Power Initiative Program (CCPI). Once captured, the oil is compressed and transported 80 miles via pipeline to the West Ranch oil field near Vanderbilt, Texas, only 15 miles from Point Comfort. At the oil field, the compressed carbon dioxide will be used in a process called Enhanced Oil Recovery (EOR) to recover previously unreachable oil and then will be stored permanently underground. Oil production at the West Ranch oil field is expected to increase from 300 barrels per day (bpd) to 15,000 as a result of the project.[1]

Arrowhead Offshore, discussed further in Section 2.2.3, is an affiliate of Hilcorp's Harvest Pipeline, a midstream service provider that operates various crude oil and natural gas gathering, storage, transportation, and treatment services. Arrowhead Offshore, a new tenant at Point Comfort, along with its parent company is responsible for moving the oil recovered from the Petra Nova Project by ship and has positioned itself at the Port of Point Comfort based on its proximity to the West Ranch oil field.

[1] NRG Energy, http://www.nrg.com/generation/projects/petra-nova/, accessed November 2017

Figure 2-4. Petra Nova Project

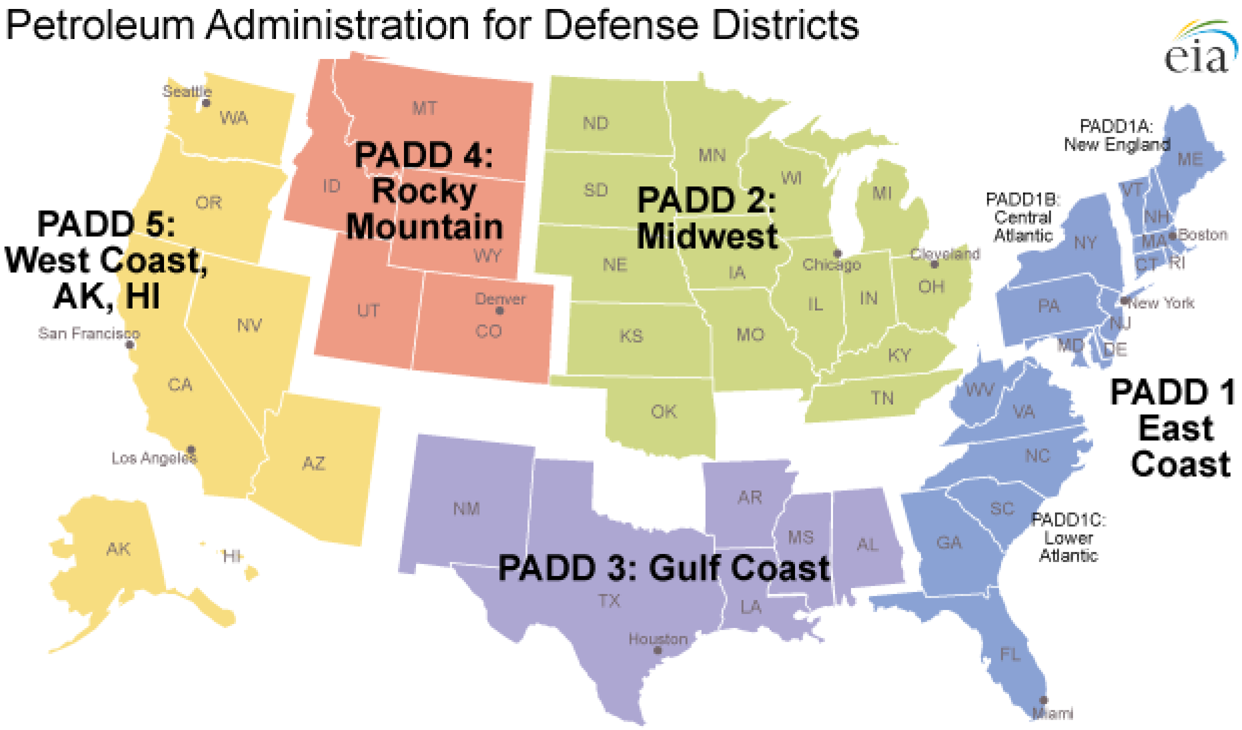
2.1.4 Proximity to Port Corpus Christi

Port Corpus Christi is another deep draft port along South Texas Gulf Coast with similar proximity to the Eagle Ford Shale as the Port of Port Lavaca-Point Comfort (as shown in Figure 2-3. Location of Eagle Ford Shale). The Corpus Christi Ship Channel, which provides access to the port, is a 36-mile, 47-foot (MLLW) channel that handles both international and domestic marine commerce. Like the Matagorda Ship Channel, the Corpus Christi Ship Channel handles liquid chemicals and petroleum products, among other commodities.

To assist with assumptions that will be discussed in detail later in this appendix, Corpus Christi was used as a reference port on which to base some of the economic inputs in both the future with- and without-project conditions. This was considered reasonable based on the close proximity, similar commodities, and the fact that the Corpus Christi Ship Channel's current channel depth is within the range being analyzed for the Matagorda Ship Channel deepening.

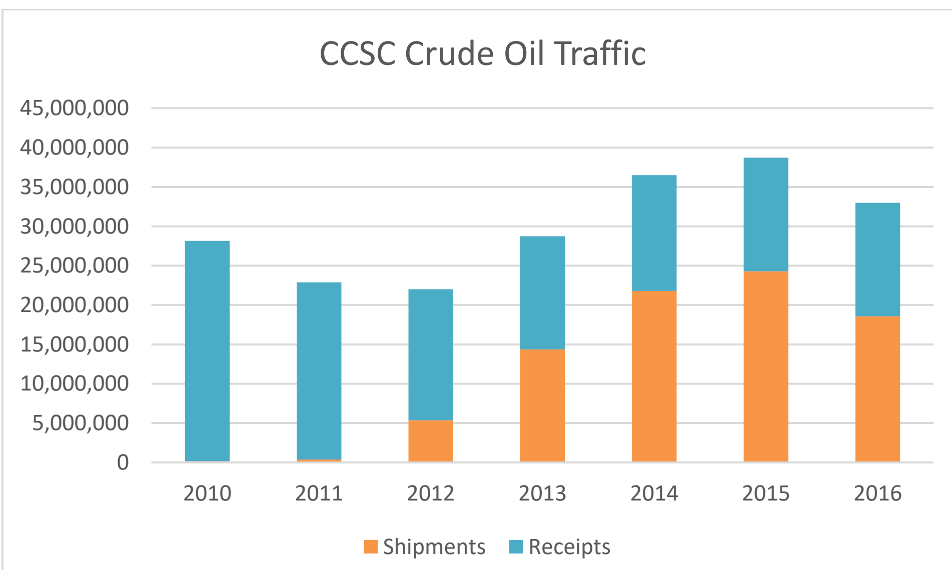
Due to their placement along the Gulf of Mexico, the Port of Point Comfort and Port Corpus Christi are part of Petroleum Administration for Defense District (PADD) 3. PADDs are geographic aggregations of the 50 States into five districts: PADD 1 is the East Coast, PADD 2 the Midwest, PADD 3 the Gulf Coast, PADD 4 the Rocky Mountain Region, and PADD 5 the West Coast, as shown in Figure 2-5. The PADDs help in assessing regional petroleum product supplies as well as allow data users to analyze patterns of crude oil and petroleum product movements throughout the nation. Again based on their proximity, the Port of Point Comfort and Port Corpus Christi are part of the same PADD, making it reasonable to assume that petroleum products shipped from these locations would be similar in terms of growth rates, vessel use, vessel loading, etc.

Figure 2-5. U.S. Petroleum Administration for Defense Districts



Since 2011, significant effects stemming from the discovery of the Eagle Ford Shale have been recorded in Port Corpus Christi's domestic petroleum product tonnage figures, particularly in the crude petroleum commodity category. Figure 2-6 displays the increase in shipments experienced at Port Corpus Christi in recent years. The Eagle Ford Shale, along with the Permian Basin, continues to be a source of oil for Corpus Christi.

Figure 2-6. Corpus Christi Crude Oil Throughput Tonnage



2.1.5 Facilities and Infrastructure

All deep-draft docks within the port are owned by the Calhoun Port Authority (CPA) with the exception of the Alcoa docks, which are privately owned.

2.1.5.1 Multi-Purpose Dock - The Multi-Purpose Dock provides port users the capability to handle project cargoes, heavy equipment, roll-on/roll-off and certain dry bulk shipments moving by ship or by barge. The ship berth can accommodate a variety of general purpose and specialized ocean-going vessels. The full length of the 711-foot bulkhead is fendered. A 60' by 380' concrete apron is surrounded by approximately three acres of open storage area for project staging or cargo consolidation.

2.1.5.2 Liquid Cargo Terminal - The Port Authority operates three liquid cargo ship docks that provide substantial flexibility for loading and unloading chemical, petroleum-related and other liquid bulk products. The primary facility is a 1,100-foot pier with two ship berths and multiple loading arms to accommodate the specific needs of individual commodity shippers. The piers are capable of handling vessels up to 810’ in length and was built so that berths can be deepened when ship channel improvements are made in the future. A third liquid cargo berth is located at the east end of the multi-use general cargo dock. The liquid cargo ship terminal is equipped with generous pipe rack capabilities, remote control firefighting systems, continuous video monitoring, hazardous materials containment systems, and storm water collection systems.

2.1.5.3 Dry Bulk Dock - The port's Dry Bulk Dock went into full operation in 2011. This modern public deep draft dock was designed primarily for bulk materials unloading. The cargo handling system includes a spiral conveyor unloading tower that travels on dock rails to access each cargo hold and feed a continuous conveyor system that extends to nearby industrial sites. However, the dock was built to accommodate the import of bulk feedstock for one of the channel users. Since the dock’s completion, the user’s feedstock source changed from dry bulk to natural gas. As of 2017, the dock is being used for liquid bulk. It is capable of handling vessels up to 740 feet in length.

2.1.5.4 General Cargo Facilities - The Port Authority provides facilities for efficient handling of break bulk, containerized and heavy-lift cargoes. The general cargo Dock can accommodate vessels of up to 750 feet in length. The terminal includes a 25,000 square foot dockside warehouse and transit shed. Rail service is available to the rear of the warehouse. Also available are open storage areas and truck scales. Cargo handling equipment is available. The port also operates a nearby barge dock with outloading conveyor. There is direct highway access to the general cargo facilities via multiple highways.

2.2 Industrial Users

2.2.1 NorthStar Midstream

The NorthStar Midstream Point Comfort facility was built in 2011 and acquired by NorthStar Midstream in 2015. NorthStar Midstream provides storage and transportation for energy products including crude oil and condensate.

The facility is currently under construction, which is expected to be complete by 2018. Expansions plans include 500,000 to 700,000 barrels of storage, loading and unloading of ships and ocean-going barges, inbound/outbound rail, and clean products storage. Current infrastructure includes six high-speed truck unloading stations, two 6,000 barrels/hour loading pumps, and 50,000 barrel crude storage tank.

In May 2016, the company announced that they acquired a 21-mile pipeline that originates in Point Comfort and terminates near Edna, TX. The company intends to use the pipeline to transport up to 100,000 barrels per day of crude oil from the Eagle Ford Shale to the terminal in Point Comfort, which will allow for efficient and timely marine transportation services and an extensive array of end-market customers.

2.2.2 NGL Energy Partners LP

NGL Energy Partners (NGL) announced in October 2016 that it acquired a crude oil and condensate marine terminal project and related assets from Pelorus Terminal, Point Comfort, LLC. The terminal is located in Point Comfort, Texas and will allow for the export of crude oil and condensate via the Gulf of Mexico. It will include 350,000 barrels of storage capacity, truck unloading bays, and capability of unloading inland and ocean-going vessels from three of the Port’s docks. The facility is expected to have 30,000 barrels per day truck receipt capacity and 20,000 barrels per hour marine loading capacity. The Point Comfort facility is operational as of April 2017.

2.2.3 Arrowhead Offshore Pipeline, L.L.C.

Arrowhead Offshore Pipeline, L.L.C. (Arrowhead) is an affiliate of Hilcorp’s Harvest Pipeline, a midstream service provider that operates various crude oil and natural gas gathering, storage, transportation, and treatment services. Arrowhead’s Point Comfort Pipeline Project will be operational in 2018. Once operational, it will allow the transportation of crude oil from Jackson County, Texas to Point Comfort, Texas via pipeline. The company will move crude oil from the West Ranch oil field, the field associated with the Petra Nova project, to the docks at Point Comfort. The Petra Nova project is capable of producing up to 15,000 barrels per day (bpd) of crude oil to be shipped by Arrowhead.

2.2.4 J.R. Simplot

The J.R. Simplot Point Comfort facility was acquired from Texas Liquid Fertilizer in 2010. It is a liquid fertilizer import facility with 110,000-ton liquid storage tank capacity and a blending facility with an annual capacity of more than 80,000 tons. Finished products are distributed within a 200-mile radius of Point Comfort.

2.2.5 Invista

Invista is a fiber, resin, and specialty intermediates company that produces innovative nylon, spandex, and polyester products. Their chemical plant located in Victoria, Texas, approximately thirty miles from the Port of Port Lavaca-Point Comfort, is a manufacturing facility whose primary business is the manufacturing of intermediates, polyester, and specialty chemicals.

2.2.6 Alcoa

Opening in 1948, Alcoa has maintained and operated several docks and piers for the receipt of bulk material including bauxite, fluorspar, limestone, and processing chemicals at Point Comfort. Alcoa has historically been the largest user of the MSC, typically importing over 4 million metric tons of bauxite annually, and having a rated capacity to produce 2.3 million metric tons of alumina per year. However, as of 2016, production at Alcoa has ceased due to a downturn in the price of alumina. The plant has been in care and maintenance mode since and has not been moving any cargo.

Alcoa's main docks, owned and operated by Alcoa, provide berthing space of up to 875 feet with depths up to 38 feet. The Alcoa Channel, which splits off from the main MSC at Mile 18 at the point where it turns east to the harbor and turning basin (just south of the South Peninsula), provides direct deep-draft access to the Alcoa facilities, and does not enter the Port's harbor/turning basin area.

2.2.7 INEOS

In 2005, INEOS Nitriles acquired the Green Lake, Texas nitriles production facility as part of its $9 billion acquisition of BP's Innovene subsidiary. The facility relies on the Port for the delivery of raw material and distribution of finished products through the use of deep draft vessels, and is connected directly to the Port by pipelines. INEOS has recently expanded its Green Lake Plant through the construction of a fourth reactor, which is located adjacent to the existing acrylonitrile facilities in Green Lake, Texas. With this project, the plant has been expanded by approximately 15 percent to a 544,000 ton capacity.

2.2.8 Formosa

Formosa owns and operates a 1,600-acre petrochemical complex located in Point Comfort. Starting with a project completed in 1994, Formosa has invested over $2.5 billion into the expansion of chemical and plastics production facilities at Point Comfort. All of Formosa's polyethylene resins, marketed under the trade name Formolene, are produced at the Point Comfort plant. Chemical feedstock and other raw materials are shipped to the Port via deep draft vessels and are delivered to the plant through direct pipeline connections from the Port.

2.3 Historical Commerce

Historically, the three main commodity groups handled by the Matagorda Ship Channel are Crude Materials, Chemicals and Related Products, and Petroleum/Petroleum Products. The Crude Materials category is made up almost exclusively of aluminum ore shipped to the Alcoa docks in the form of bauxite. The rest of the tonnage handled within the Port of Point Comfort is in the form of liquid bulk. Annual throughput tonnage levels by commodity for the latest available years of Waterborne Commerce (WCSC) data (2004-2016) are displayed in Figure 2-7, below. Within this timeframe, the average throughput tonnage moved via the MSC was 9.2 million metric tons with the greatest amount of tonnage (11.3 million metric tons) being moved in 2004. Despite a decline in tonnage spurred by the 2008 global economic recession, tonnage levels have steadily increased until 2016 when a cease in production by Alcoa caused a drop in tonnage levels. Figure 2-8 isolates the liquid bulk tonnage from the crude materials tonnage that is attributed to Alcoa. Changes to the commodity profile in the Port of Point Comfort will be addressed in the following section.

Figure 2-7. MSC Tonnage by Commodity (Receipts and Shipments 2004-2016)

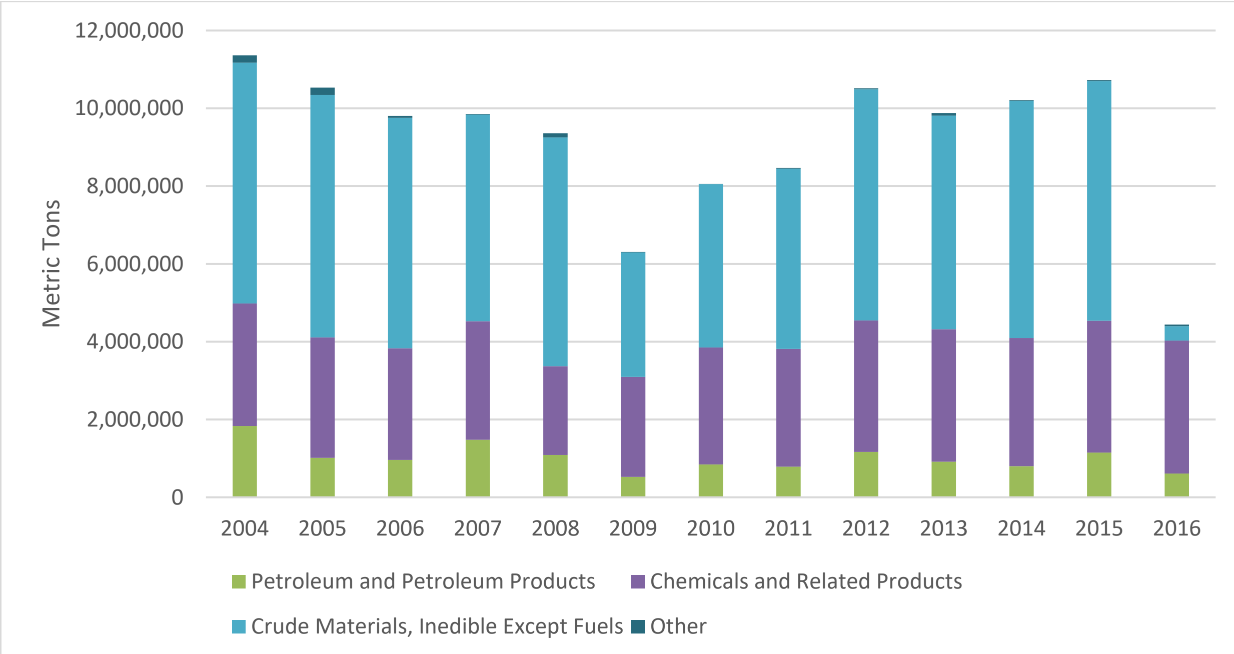
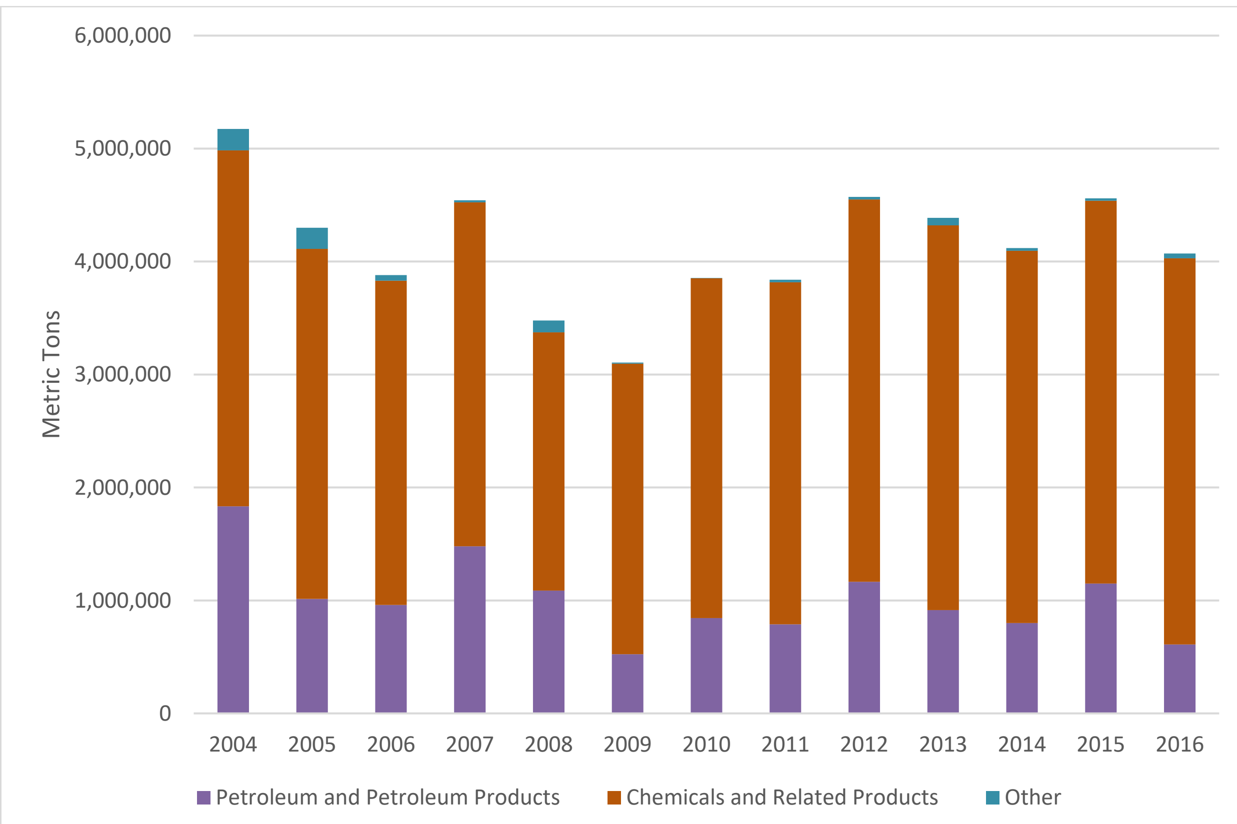


Figure 2-8. MSC Liquid Bulk Tonnage Levels (Receipts and Shipments, 2004-2016)



2.4 Existing Commerce

The composition of Point Comfort's commodity profile has changed in recent years. These changes began in 2015, when the first energy user acquired land at the Port, and continued with the addition of two more energy companies in 2016. Also in 2016, the primary user of the Matagorda Ship Channel, Alcoa, ceased production due to the decline in the price of alumina.

This section will discuss how existing commodity levels were determined given the dynamic nature of cargo types and levels at the start of this study. In this section, only foreign tonnage will be considered, because the domestic traffic is carried on smaller vessels with relatively shallow drafts and, in general, will not benefit by the deepening project.

2.4.1 Chemical Traffic

Chemical products in the form of liquid bulk have a long history at the Port of Point Comfort. Therefore, historical tonnage was used to develop a baseline tonnage number upon which to forecast growth for chemical tonnage. At the commencement of this study, the latest available data on tonnage levels from the Waterborne Commerce Statistical center (WCSC) was from calendar year 2014. To develop a baseline tonnage level upon which to apply the commodity growth rates, foreign tonnage levels for both imports and exports from calendar years 2012 through 2014 were averaged and labeled as "2015." The 2015 projection for chemical tonnage was 1.76 million metric tons, similar to the actual number displayed in Table 2-2 below.

Also observed in Table 2-2, the Port of Point Comfort is a net exporter of chemical products, typically importing approximately 25% of its foreign chemical tonnage and exporting approximately 75%. Most of the chemicals imported to the Port are used as raw materials for specialty chemicals produced and exported by the Port users.

Table 2-2. Matagorda Ship Channel Throughput Foreign Chemical Tonnage (2007-2016)

Traffic Direction:	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Imports	580,391	376,256	408,051	565,006	537,579	510,347	498,161	501,118	493,987	459,865
Exports	1,397,791	1,026,504	1,374,049	1,277,777	1,340,946	1,372,490	1,280,918	1,131,106	1,144,668	1,293,361
Total	**1,980,190**	**1,404,768**	**1,784,109**	**1,844,793**	**1,880,536**	**1,884,849**	**1,781,092**	**1,634,238**	**1,640,671**	**1,755,241**

2.4.2 Dry Bulk Traffic

Historical dry bulk traffic moved via the Matagorda Ship Channel has been attributed almost exclusively to Alcoa (discussed in Section 2.2.6), an alumina producer with operations in Point Comfort since 1948. As of 2017, there is no cargo moving to or from the plant. This can be attributed to the downturn in the alumina price index in 2015 and the ending of production at the plant in 2016.

Though it is not certain whether or not this cease in production will be temporary or result in permanent closure of the plant, there is no indication that production will resume in the near future. Therefore, in this analysis, dry bulk tonnage is assumed to be zero in both the existing and future conditions and will not be discussed in subsequent sections of this report.

2.4.3 Crude Oil and Condensate Traffic

Crude oil and condensate exports and shipments from the Port of Point Comfort is a new type of commerce at the Port, which as mentioned previously, began in 2015 when NorthStar Midstream (NST) acquired their facility in Point Comfort.

At the start of this study, capacity projections from each facility were collected via interviews with representatives of the companies that will be using the Matagorda Ship Channel to ship petroleum products. The projections were combined to develop a baseline crude oil and condensate tonnage level for the year 2018 (i.e., the first year in which all three facilities will be done with construction and in full operation). To protect proprietary information of these companies, the forecasts from the three companies will remain aggregated in this report.

Using the projections provided by the channel users, three baseline scenarios were developed to estimate the amount of benefitting tonnage that would be moved via the Matagorda Ship Channel in the form of petroleum products (crude oil and condensate). The tonnage levels for these three scenarios, low, medium and high, are displayed in Table 2-2. The high scenario was estimated by obtaining the three users' capacity forecasts, combining them, and multiplying them by 75%. The median scenario is 50% of the high scenario, and the low scenario is 25% of the high scenario. For purposes of this analysis, the median scenario was considered the most likely and is the baseline upon which growth rates, which will be discussed in Section 3.2.4, are applied.

Table 2-3. Projected Baseline Crude Oil & Condensate Tonnage (2018)

2018			
Scenario	**Low** **25% of High Scenario**	**Median** **50% of High Scenario**	**High** **75% of Capacity**
Metric Tons	1,412,444	2,576,546	4,904,751

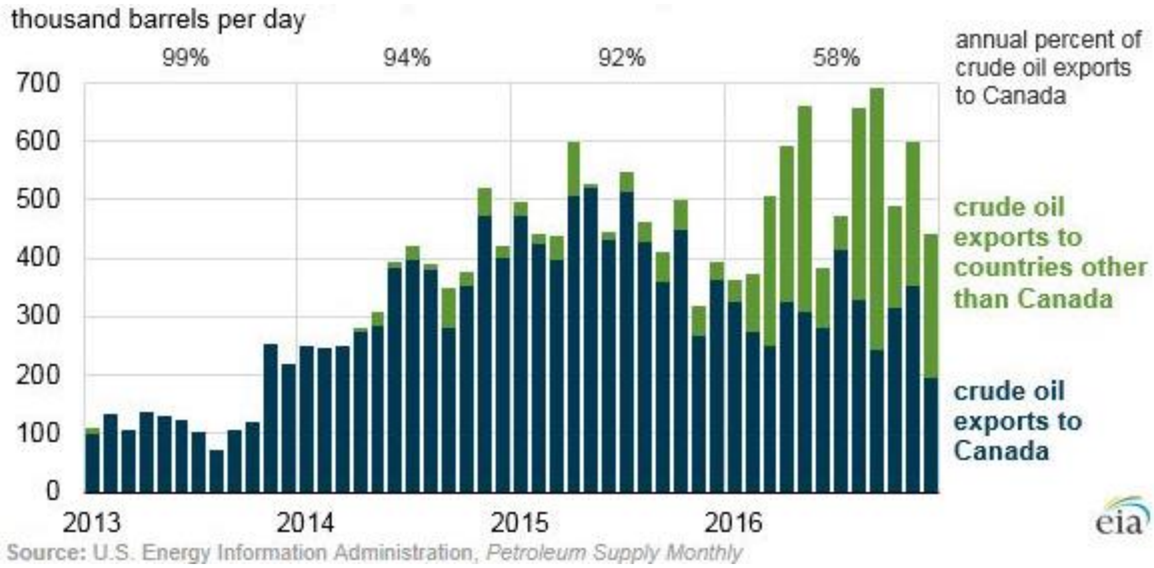
2.4.4 Crude Oil Export History

United States Law has historically prohibited the exportation of crude oil following the 1973 Arab oil embargo. Prior to December 2015, crude oil exports were restricted to: (1) crude oil derived from fields under the State waters of Cook Inlet of Alaska; (2) Alaskan North Slope crude oil; (3) certain domestically produced crude oil destined for Canada; (4) shipments to U.S. territories; and (5) California crude oil to Pacific Rim countries. Under these limited exceptions, the U.S. has been exporting low volumes of crude oil for decades.

Due to the recent drilling technology, U.S. oil production has increased dramatically since 2008. The ban on crude oil exports combined with the increase in U.S. oil production created a surplus of oil in the U.S. This surplus contributed to the rapid decline of oil prices that was observed in 2014. In December of 2015, as a response to lobbyists in favor of ending the ban, the crude oil export ban was lifted.

According to the U.S. Energy Information Administration (EIA) and as depicted in Figure 2-9, in 2016, U.S. crude oil exports averaged 520,000 barrels per day (bpd), 55,000 bpd (12%) above the 2015 level, despite a year-over-year decline in domestic crude oil production. Even though oil exports have increased, growth in U.S. crude oil exports has slowed significantly from its pace from 2013 to 2015, when annual U.S. crude oil production grew rapidly.

Figure 2-9. Monthly United States Crude Oil Exports, 2013-2016



Following the removal of restrictions on U.S. crude oil exports in December 2015, the United States exported crude oil to 26 different countries in 2016, compared with 10 countries the previous year. In 2015, 92% of U.S. crude oil exports went to Canada, which was exempt from U.S. crude oil export restrictions. After restrictions were lifted, Canada remained the top destination but received only 58% of U.S. crude exports in 2016.

Aside from Canada, European destinations such as the Netherlands, Italy, United Kingdom, and France rank high on the list of U.S. crude oil export destinations. The second-largest regional destination is Asia, including China, Korea, Singapore, and Japan. In 2016, the United States exported to eight different Central and South American destinations, including Curacao, Colombia, and Peru. Assumptions regarding route groups in the existing and future conditions are discussed in Section 3.3.

Figure 2-10 displays a more extensive history of crude oil exports from the United States in terms of thousands of bpd. Again, the effects of the crude oil ban being lifted in December 2015 can be observed in the graph. The volatility in export levels between January 2015 and September 2017 can be attributed to the price of oil during this time frame. Oil prices in terms of the Cushing, OK West Texas Intermediate (WTI) spot prices are displayed in Figure 2-11.

Figure 2-10. U.S. Exports of Crude Oil (Jan 2008 - Sep 2017, thousand bpd)

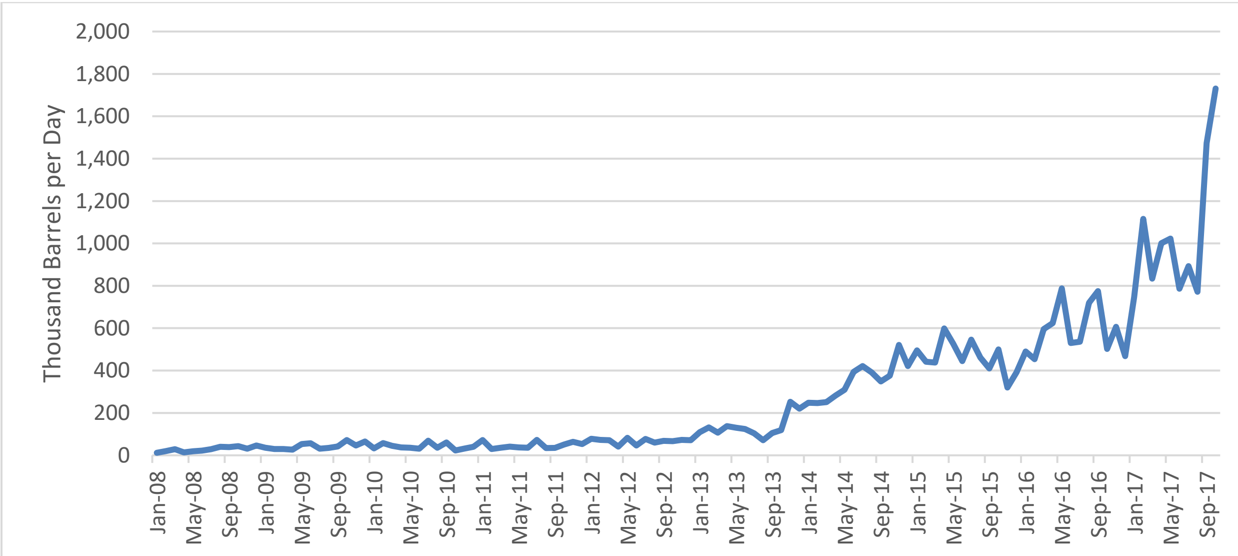


Figure 2-11. Cushing, OK WTI Spot Price (Dollars per bbl)

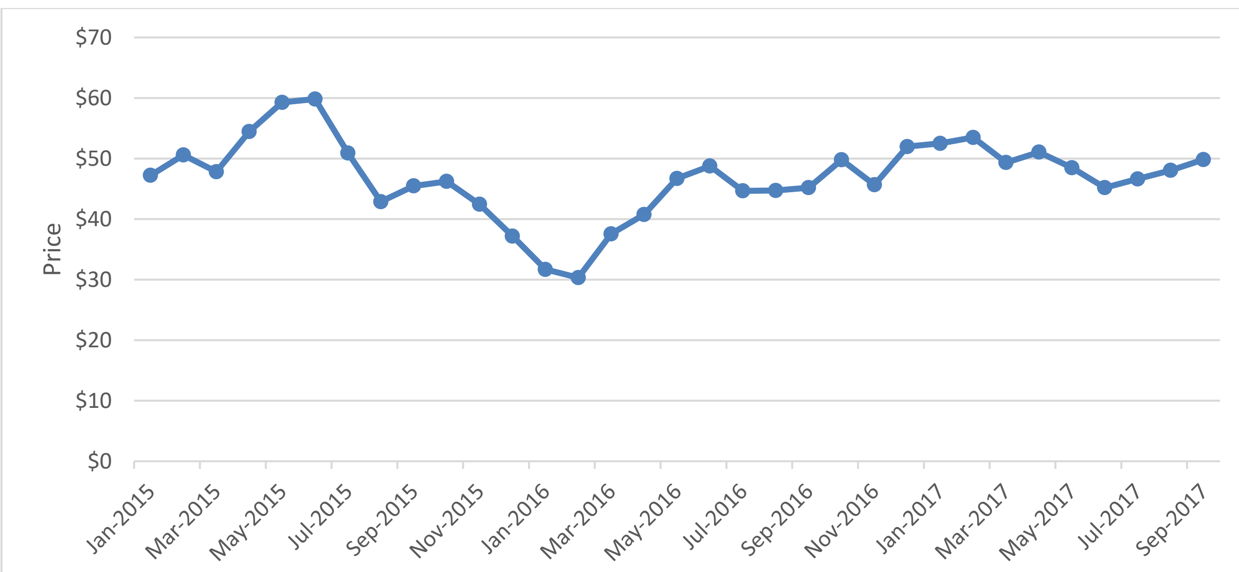
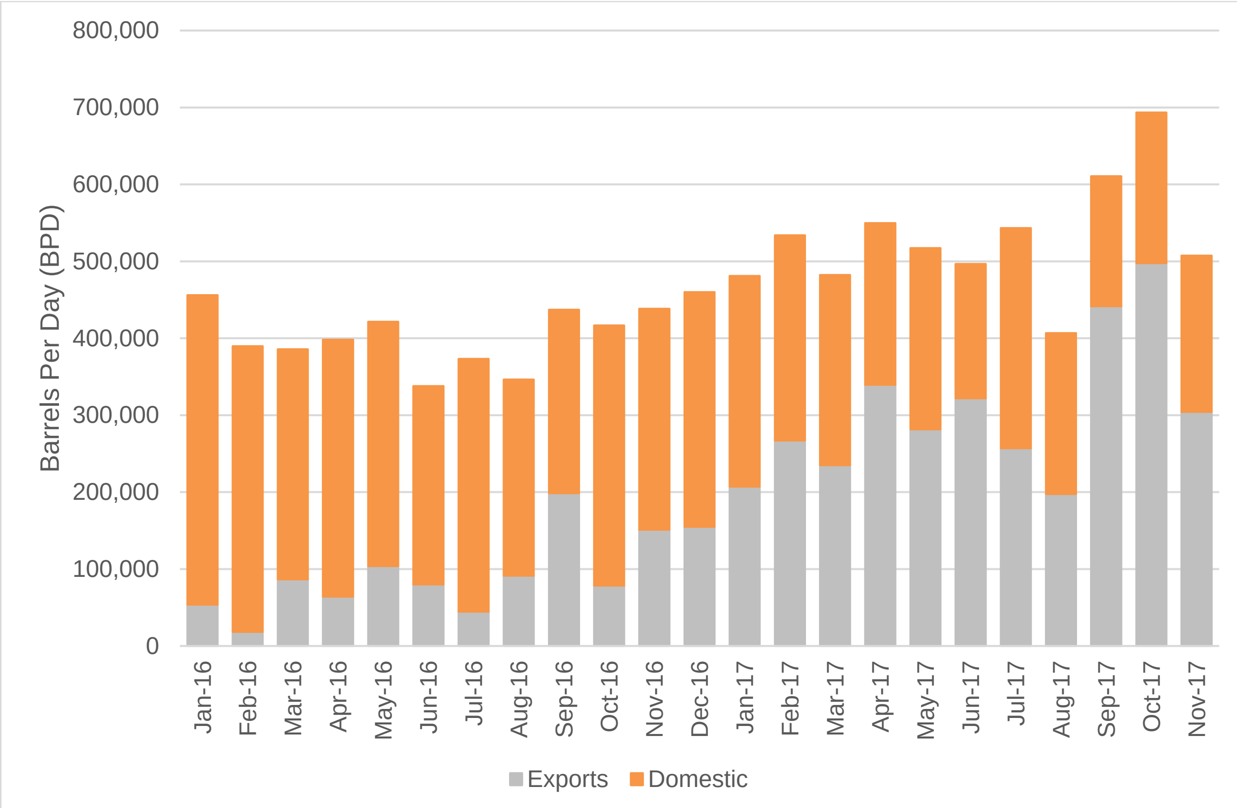


Figure 2-12 displays crude oil and condensate shipments from the Port of Corpus Christi between January 2016 and November 2017, after the crude oil ban was lifted. From the figure, it can be seen that crude oil foreign exports gradually outpaced domestic shipments as a result of the ban being lifted. For the last twelve months of available data, foreign exports have accounted for 55% of crude oil and condensate shipped via the CCSC.

Figure 2-12. CCSC Crude Oil and Condensate Shipments (Jan 2016 – Nov 2017, bpd)



Source: Port Corpus Christi

2.5 Existing Fleet

The vast majority of deep-draft tonnage moved via the Matagorda Ship Channel is carried on tankers (petroleum/chemical), with the occasional ocean-going barge. Data on the existing fleet was obtained from the Waterborne Commerce Statistical Center (WCSC) and verified by the Pilot's log provided by the Port of Point Comfort. The data obtained from WCSC was for the three most recent years available, 2013 through 2015, at the time of the analysis. The year 2015 was isolated and used to analyze vessel characteristics, as it was considered to be a reasonable representative year after comparing it to the previous years' data. Where historical data did not exist for a new type of commodity traffic, i.e., crude oil, WCSC data for the Port of Corpus Christi was obtained and used as a proxy for developing the existing fleet. This will be discussed further in Section 2.5.2 below.

As discussed previously, the MSC handles to main commodity types, chemicals and petroleum products. Though there can be overlap in the types of vessels that carry each product, for the purposes of this analysis, chemical and petroleum tankers were treated as two separate vessel types, and were broken out in to classes within those types. The vessels are distinguished based on physical and operation characteristics, including lengths overall (LOA), design draft, beam, and tons per inch (TPI) data.

2.5.1 Chemical Fleet

Chemicals are shipped to and from the Port on vessels ranging from 4,500 to 60,000 deadweight tons (DWTs). For this analysis, these vessels were split in to three categories, or vessel classes, the attributes of which are displayed in Table 2-3 below. Vessels were categorized based on DWT, hence the overlap of attributes such as design draft, beam, and length overall (LOA).

Table 2-4. Chemical Tanker Vessel Class Attributes

Vessel Class Name	Vessel Class ID	DWT Range	Min Design Draft	Max Design Draft	Min Beam	Max Beam	Min LOA	Max LOA
Sub-Panamax 1	SPX1	0-20,000	20'	34'	49'	97'	326'	529'
Sub-Panamax 2	SPX2	20,000-40,000	30'	42'	77'	105'	459'	604'
Panamax 1	PX1	40,000-60,000	36'	44'	101'	108'	577'	673'

The distribution of tonnage by vessel type for chemical imports and exports on the Matagorda Ship Channel is displayed in Figure 2-5. Annually, approximately 45% of tonnage is moved on sub-Panamax 1 (SPX1) tankers, 28% is moved on sub-Panamax 2 (SPX2) tankers, and 31% is moved on Panamax tankers.

Figure 2-13. MSC Chemical Tonnage Distribution by Vessel Type, 2015

2.5.2 Petroleum Product Fleet

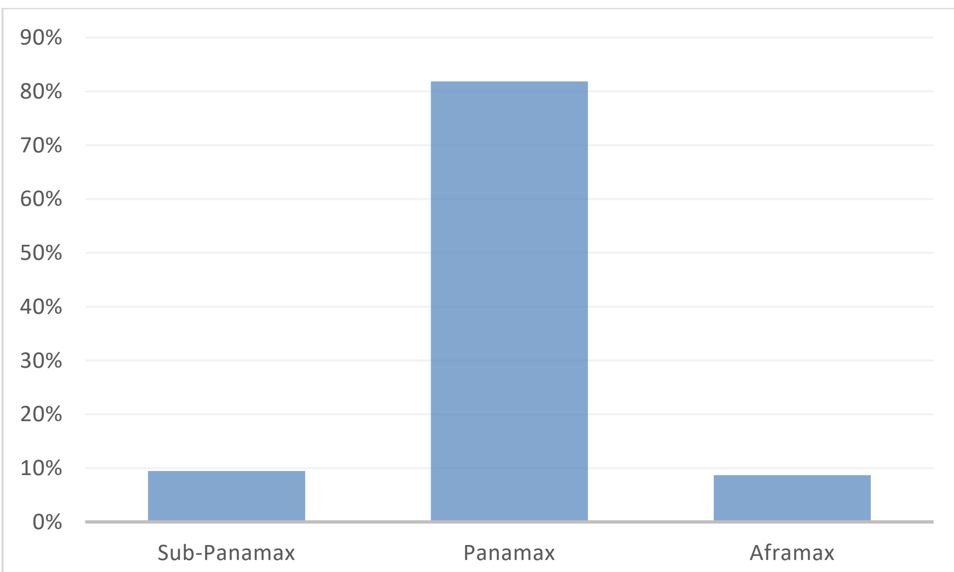
As mentioned previously, petroleum products exports in the form of crude oil and condensate is a new type of traffic at the Port of Point Comfort. Therefore, Port Corpus Christi was used as a proxy to develop a baseline vessel fleet distribution for the new activity in the Port of Point Comfort. Because Point Comfort's users were not anticipating any receipt of crude oil and condensate at the time interviews were conducted, only petroleum product exports from Corpus Christi were analyzed for development of the fleet forecast. Petroleum Products are exported from Corpus Christi on vessels ranging in size from 6,000 to 116,000 DWT. Petroleum tankers were split in to five categories, or vessel classes, for this analysis. The attributes of each vessel class are displayed in Table 2-5. Like with the chemical tankers, DWT was used to categorize the vessels into classes.

Table 2-5. Petroleum Tanker Vessel Class Attributes

Vessel Class Name	Vessel Class ID	DWT Range	Min Design Draft	Max Design Draft	Min Beam	Max Beam	Min LOA	Max LOA
PT Sub-Panamax 1	PT-SPX1	0-20,000	21'	29'	57'	75'	350'	529'
PT Sub-Panamax 2	PT-SPX2	20,000-40,000	30'	43'	78'	104'	462'	605'
PT Panamax 1	PT-PX1	40,000-60,000	33'	45'	86'	105'	557'	655'
PT Panamax 2	PT-PX2	60,000-80,000	41'	48'	104'	121'	656'	752'
PT Aframax	PT-Afra1	80,000-110,000	43'	51'	137'	138'	750'	810'

The distribution of tonnage by vessel size observed in Corpus Christi's 2015 petroleum product exports is displayed in Figure 2-4 below. In 2015, approximately 82% of petroleum product exports were moved on Panamax vessels, 9% were on Aframax, and another 9% were on sub-Panamax.

Figure 2-14. CCSC Petroleum Product Tonnage Distribution by Vessel Type, 2015



In reviewing the data collected by Waterborne Commerce for past years, it was determined that 2015 is an acceptable representative year for Corpus Christi from which a vessel fleet distribution could be extrapolated for Matagorda Ship Channel. However, although 2015 is a suitable year on which to base the existing vessel fleet for Matagorda Ship Channel, it is important to note that the composition of the petroleum product tanker fleet utilizing the Corpus Christi Ship Channel for exports is likely to change. These changes were taken in to account when developing the future vessel fleet forecast and will be discussed in Section 4 of this appendix. A major contributor to the changing vessel fleet can be attributed to the lifting of the crude oil ban at the end of calendar year 2015 that was discussed in Section 2.4.4. According to a September 2017 article from Global Trade Magazine, Port Corpus Christi is the number one exporter of crude oil in the nation. Given the efficiencies of Aframax vessels for exporting crude oil, which will also be discussed in Section 4, it is anticipated that a larger portion of Corpus Christi's petroleum products will be exported on Aframax vessels in the future.

2.6 Shipping Operations

2.6.1 Traffic Rules

Vessel pilots apply traffic rules as necessary to ensure safe travel through harbors. The Matagorda Bay Pilots Association was consulted during this study to provide input on the rules associated with the Matagorda Ship Channel. The current restrictions placed on vessels transiting the Matagorda Ship Channel are:

- All ocean-going traffic is one way;
- Any vessel within 4' of maximum allowable draft is restricted to daylight only;
- Any vessel 195 meters (639 feet) in length is restricted to daylight due to turning basin dimensions;
- No passing of ocean-going vessels;
- No movement of a vessel that is drafting within 4' of maximum allowable draft when current is greater than 4 knots.

In addition to the pilot rules listed above, a sufficient amount of underkeel clearance is required to allow for safe vessel passage. Underkeel clearance is the distance below the ship to the channel floor, and in the case of Matagorda Ship Channel, is a requirement of the shipper and the vessel rather than the pilots. The Matagorda Pilots indicated that, in general, an underkeel clearance of three feet or 10% of loaded draft is typically required by shippers. Review of WCSC data confirmed this practice. Therefore, an underkeel clearance requirement of three feet was used for this analysis.

2.6.2 Tidal Range

Opportunities to increase allowable vessel draft by tidal advantage are limited given the small tidal range in the Gulf of Mexico, which is approximately one foot on a diurnal cycle. Another factor is that the meteorologically-driven tide can be greater than the astronomically driven tide, especially during frequent winter cold fronts that may depress the water level up to three feet. Because the meteorological forcing is more random in nature, using the tidal advantage for navigation of larger vessels is more difficult, and according to the Matagorda Bay Pilots, virtually non-existent. Therefore, tidal advantage is not included in this analysis.

3 Expected No Action and Future With-Project Conditions

3.1 Port Expansions

At the onset of this study, in addition to the crude oil users that whose facilities were under construction and whose throughput tonnage is considered part of existing conditions for the purposes of this analysis, both the Port of Point Comfort and its tenants were in the process of expanding their facilities and infrastructure. These expansions are described below.

3.1.1 Terminal Expansions

The Port of Point Comfort is currently in the permitting stages of a South Peninsula Development Project. The project, pictured in Figure 3-1, includes the addition of four bulk liquid product barge berths and three bulk liquid product docks to be used for the shipment and receipt of petrochemical products, crude oil, and condensate, with the possibility of being used for other liquid products in the future. The docks are designed for an Aframax class vessel with dimensions of 840' length overall (LOA) and 140' beam. The design depth for the liquid bulk docks will be 47' MLLW in the future with- or without-project condition.

The development project is projected to be fully complete by 2020. The first liquid dock and the barge berths are scheduled to be operational in 2019, the second liquid dock in 2020, and the third liquid dock is to be operational based on market demand. Though not included in the HarborSym model, these new developments at the Port support the growth in the throughput tonnage that was forecasted for this analysis and will be detailed in Section 3.2.

Figure 3-1. Calhoun Port Authority South Peninsula Development Project

3.1.2 Formosa Expansion

Formosa Plastics Corporation, a supplier of plastic resins and petrochemicals, has been a user of the Matagorda Ship Channel since 1982. Formosa's Point Comfort facility experienced its first expansion, costing $1.5 billion, in 1994, and a second, $900 million expansion took place in 1998. In 2015, the company's sales totaled about $5.7 billion.

Since 2015, Formosa has been undergoing a third expansion, scheduled to be completed in late 2018. The expansion, pictured in Figure 3-2, will add 800 acres to the plant, bringing the facility's footprint in Point Comfort from 1,500 acres to 2,300 acres. The company, which employees approximately 2,000 full-time employees and 922 contract staff, is projected to add 340 permanent jobs to the region. The growth being experienced by this channel user supports the growth forecasted in the chemicals commodity category, which will be discussed in Section 3.2.3.

Figure 3-2. Formosa Expansion

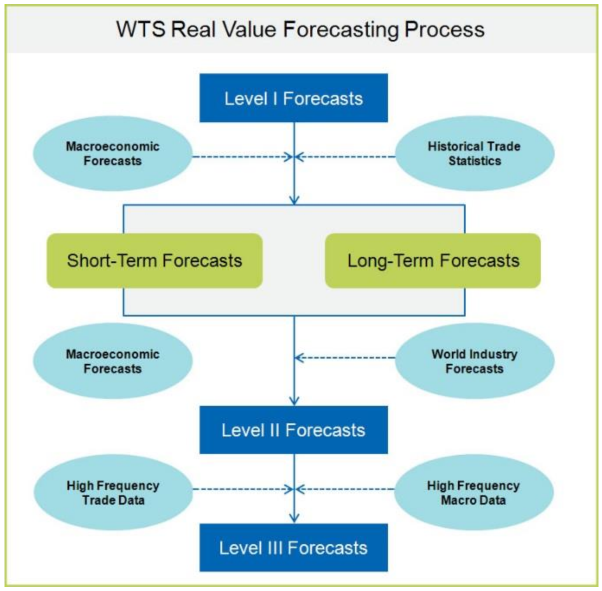
3.2 Commodity Forecast

Commodity throughput was forecasted for benefitting commodities, i.e., chemicals and petroleum products, over a 50-year period (2024-2073). To estimate future tonnage levels, annual growth rates were applied to the baseline tonnage levels for chemicals and petroleum products detailed in sections 2.4.1 and 2.4.3, respectively. The methodology used to obtain and apply the commodity forecasts for the two major commodity groups are detailed in this section. Several sources of data were used to establish the commodity forecasts including historical data, the U.S. Energy Information Administration's Annual Energy Outlook, and a 2015 IHS Global Insight forecast prepared for the Gulf Coast.

3.2.1 Global Insight

IHS Global Insight (Global Insight) provides comprehensive economic, financial, and political coverage of countries, regions, and industries and utilizes models, data, and software within a common analytical framework to support planning and decision making. For trade forecasting, Global Insight's model is based on the IHS World Trade Service (WTS) model. Conceptually, the WTS real value trade model uses a three-level process, shown in Figure 3-3. This multi-stage forecasting uses a combination of bottom-up and top-down approaches.

Figure 3-3. WTS Real Value Forecasting Process



A 2015 Global Insight forecast for the Texas Gulf Coast which was developed for a neighboring port, Port of Houston, was consulted when developing projected growth rates for Matagorda Ship Channel. The forecast was divided in to major commodity categories including petroleum products, chemicals, primary manufactured good, food and farm, manufactured equipment, and crude materials, as well as sub-categories within the major commodity categories.

3.2.2 American Energy Outlook (AEO)

The American Energy Outlook (AEO) is a report on trends and projections for energy use and supply that is published annually by the U.S. Department of Energy's Energy Information Administration (EIA). The AEO is developed using the National Energy Modeling System (NEMS), an integrated model that aims to capture various interactions of economic changes and energy supply, demand, and prices, and it provides modeled projections of domestic energy markets through the year 2050. This forecast used the "reference" case, which assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central view of leading economic forecasters and demographers. As of 2017, given the strong domestic production and relatively flat demand, the AEO projects that the U.S. becomes a net energy exporter (in most cases) between 2017 and 2050.

3.2.3 Chemical Imports and Exports

To begin establishing a growth forecast for chemical products, historical tonnage levels were reviewed. Data collected by the Waterborne Commerce Statistics Center (WCSC) between the years of 1996 and 2014 was obtained and is displayed in Table 3-1. Foreign traffic was isolated, because domestic, barge traffic will not benefit from the channel deepening and widening.

Table 3-1. Matagorda Ship Channel Historic Foreign Chemical Metric Tonnage (1996-2014)

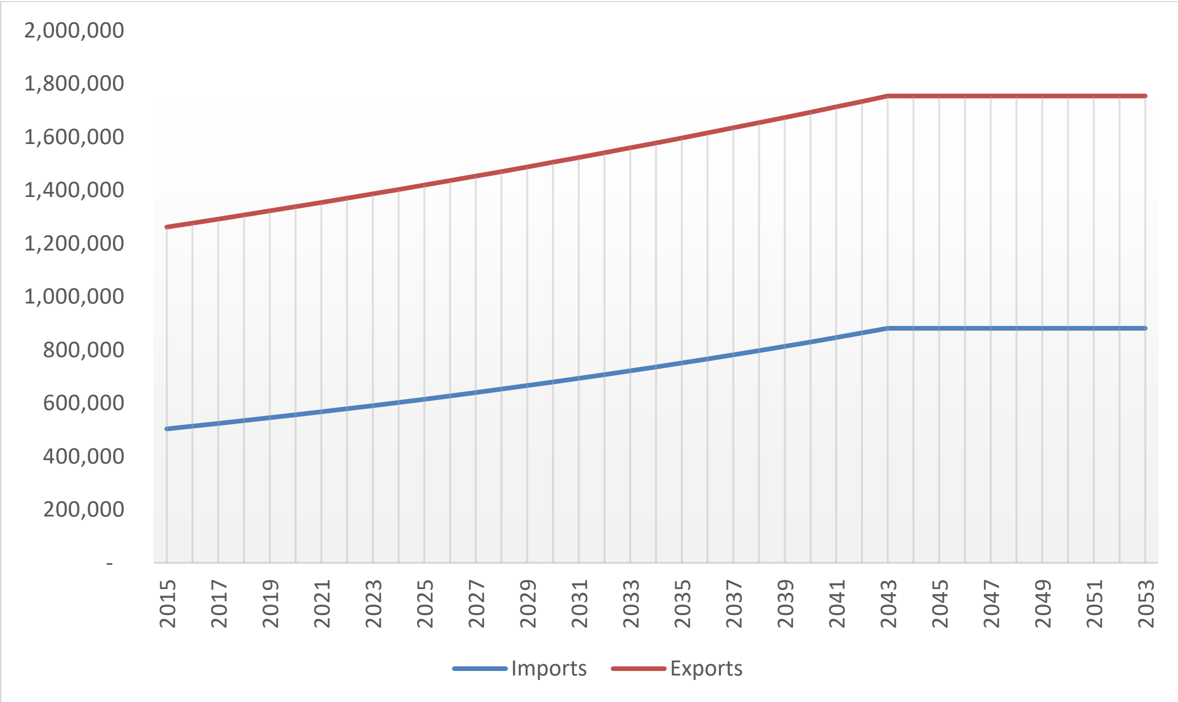
	1996	1997	1998	1999	2000	2001	2002
Imports	107,048	30,844	4,536	50,802	197,766	404,604	478,994
Exports	660,430	524,353	230,425	269,434	1,452,403	1,487,783	1,822,534
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Imports	507,116	560,021	533,359	529,531	580,391	376,256	408,051
Exports	1,385,271	1,320,669	1,510,288	1,182,836	1,397,791	1,026,504	1,374,049
	2010	**2011**	**2012**	**2013**	**2014**		
Imports	565,006	537,579	510,347	498,161	501,118		
Exports	1,277,777	1,340,946	1,372,490	1,280,918	1,131,106		

The compound annual growth rate (CAGR) for both imports and exports were calculated to identify trends in historical chemical tonnage. The CAGR that was calculated using tonnage levels observed in years 1996 through 1999 as the beginning value are unrealistically high due to the low tonnage levels observed in the earliest years for which data is available. To account for this, tonnage levels for years 1999 through 2001 were averaged and labeled as “2001.” For consistency, tonnage levels for years 2012 through 2014 were averaged and labeled “2015.” The calculations of CAGR for “2001” through “2015” resulted in growth rates of 1.18% for exports and 6.17% for imports. Because a large majority of imports to the Port are used as raw materials for the Port’s exports, a growth rate of 6.17% was not considered to be reflective of future conditions, as imports are not expected to outpace exports. As such, the Global Insight forecast prepared for Port of Houston was consulted to assist in projecting the growth of chemical imports.

The Global Insight forecast for chemical growth is broken down in to six sub-categories including inorganic chemicals, organic chemicals, fertilizers, paints, plastics, and other chemicals. Inorganic chemicals, which make up the majority of the Port’s chemical imports, are projected to grow at an annual rate of 2.02% between 2024 and 2073 according to Global Insight. This forecast was accepted as reasonable and was used to project the Port’s future chemical imports.

The chemical tonnage growth rates of 2.02% and 1.18% for imports and exports, respectively were applied annually to the baseline tonnage levels. Growth was capped in 2043, and tonnage levels were held constant from 2043 through 2073. Figure 3-4 displays the chemical tonnage growth forecast in graphical form.

Figure 3-4. Matagorda Ship Channel Chemical Tonnage Forecast (2015-2053)

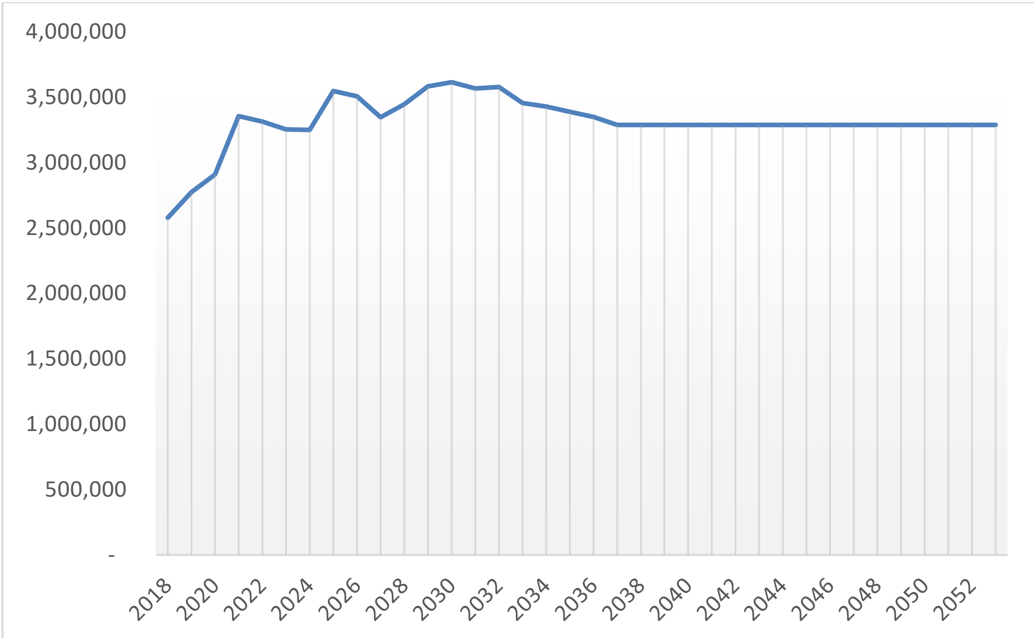


3.2.4 Crude Oil and Condensate Exports

As discussed in Section 2.4.3, the export of petroleum products from the Port of Point Comfort is a new type of commerce. For this reason, historical tonnage levels could not be used as an indicator of future growth. As such, the 2017 American Energy Outlook's (AEO) growth rates for petroleum product exports were applied to the baseline tonnage number, 2.6 million metric tons, to develop the forecast for crude oil and condensate exports.

During the 50-year period beginning in 2024, the AEO's petroleum product export growth rates forecast ranges between -2% and 6% annually. In addition to negative growth forecasted by AEO beginning in in 2028, the baseline tonnage is adjusted downward to account for changes in output due to the Petro Nova project, which is projected to reach its highest level of output in the next ten years (2018-2028). The forecast is held constant after year 2039, the projected end of the Petra Nova project. It is assumed that after the end of the project, the pipeline will be repurposed, but due to the uncertainty, the forecast was capped. Figure 3-5 displays the crude oil and condensate forecast in graphical form.

Figure 3-5. Matagorda Ship Channel Crude Oil Tonnage Forecast (2015-2053)



3.2.5 Benefitting Tonnage Levels

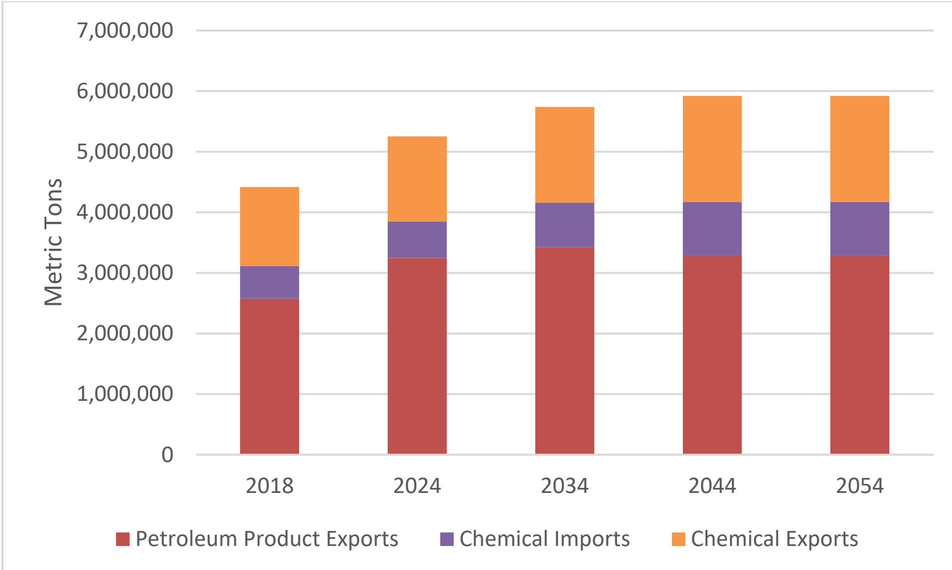
A summary of the annual growth rates for the benefitting commodities is displayed in Table 3-2. Again, growth is capped in year 2043 and tonnage levels are held constant.

Table 3-2. Annual Growth Rates for MSC Benefitting Commodities

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Chemical Imports	-	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Chemical Exports	-	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Crude Oil Exports	-	-	-	-	4%	1%	6%	4%	3%	3%	3%	3%	0%	-2%	3%	3%	-1%	0%	-2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%

As discussed previously, these growth rates were applied to the established baseline tonnage levels to obtain benefitting tonnage levels in three different decades, 2024, 2034, and 2044. Benefitting tonnage levels by decade are displayed in Figure 3-6 below. This commodity forecast is held constant in the future without-project and each of the future with-project scenarios.

Figure 3-6. Matagorda Ship Channel Benefitting Commodity Forecast by Decade



3.3 Route Groups

The route that the vessel takes to import or export commodity is an important factor in the overall transportation costs. Though routes may change based on sources of supply for raw materials for imports and market conditions for exports, it is important that the route be held constant in the with- and without-project conditions so that changes in transportation costs can be correctly attributed to the project.

HarborSym allows users to create multiple route groups and assign vessel calls to each group based on vessel class. It allows for minimum, most likely, and maximum distances to form a triangular distribution to account for uncertainty within each route group. The round trip mileage was used for each route group; however, to account for tonnage for which transportation costs should not be attributed to the Matagorda Ship Channel (i.e., tonnage dropped off/picked up at other ports along the Gulf, backhaul tonnage, etc.) an estimated total trip cargo (ETTC) calculation was applied to each trip. This methodology will be discussed further in Section 4.1.3.7. Route groups and associated round trip mileage are displayed in Table 3-3 below.

Table 3-3. Matagorda Ship Channel Trade Route Summary

Route Group	Countries/Regions	HarborSym Abbreviation	Minimum Distance*	Most Likely Distance*	Maximum Distance*
Caribbean, Gulf of Mexico, E. Coast Central America, E. Coast S. America	Haiti, Jamaica, Trinidad and Tobago, Argentina, Brazil, Columbia, Suriname, Venezuela, Mexico	CAR-ECSA	740	4,600	10,800

Mediterranean, North Europe	Italy, Spain, Turkey, Belgium, Estonia, Germany, Gibraltar, Ireland, Latvia, Netherlands, Netherlands Antilles, Norway, Portugal, United Kingdom, Yugoslavia	NEU-MED	9,400	10,200	13,400
India and South & East Africa, Far East	China, Japan, Russia, Thailand, South Korea, India, Egypt	SUEZ-FE	11,400	19,500	22,000
West Africa	Guinea, West Africa	WA	9,800	12,800	12,800
West Coast Central and South America	El Salvador, Guatemala, Nicaragua, Panama, Chile, Peru	WCSA	2,200	5,500	8,800
*Distances are in nautical miles and are displayed as round trip.					

The limiting port depths at the various origins and destinations within these route groups were analyzed for chemical products only. Limiting port depths for crude oil were not analyzed. It is assumed that destinations for crude oil exports will be similar to that of other Texas Gulf Coast ports, and therefore will be able to accommodate this study's design vessel, which is used by the other Gulf Coast ports. These limiting port depths, displayed in Table 3-4 were taken into consideration, but were not used in HarborSym, because they are not considered to impact the analysis. Though the Port of Point Lisas is limited by a dock depth of 42' MLLW, a majority (74% in 2015) of tonnage is imported from this port on SPX1 and SPX2 vessels, which have a maximum design depth of 42 feet, so this limiting depth is not expected to impact the benefits analysis.

Table 3-4. Limiting Port Depths of Origin/Destination Ports

Region / *Port*	**Limiting Depth (MLLW)**
Australia, India and South & East Africa, Far East	
Kobe	46'
Onsan	51'
Caribbean, Gulf of Mexico, E. Coast Central America, E. Coast S. America	
Itaqui	45'
Pajaritos	50'
Point Lisas	42'
Mediterranean, North Europe	
Antwerp	49'
West Africa	
Kasim	48'
West Coast Central and South America	

San Vicente	44’

Within each vessel class, a percentage of vessels is assigned to each route group. These route group assignments are used for each year and alternative depth. The chemical tanker route group assignments are based on historical vessel movements at the Port. The petroleum product tanker route groups are based on crude oil export destinations in 2016, the only year of data available after the ban was lifted at the time of this analysis, as reported by the U.S. Energy Information Administration (EIA). Crude oil export destinations by country, excluding Canada, are displayed in Table 3-5 below for the years 2011 through 2016. The effects of the crude oil ban being lifted in the last month of 2015 can be observed in the table.

Table 3-5. Crude Oil Exports by Destination 2011-2016, Excluding Canada (Thousand Barrels)

	2011	2012	2013	2014	2015	2016	% of Total
Total All Countries	334	5	267	7,362	13,704	85,568	100%
Argentina						558	1%
Bahama Islands						1,028	1%
Brazil					641	193	0%
Cameroon							0%
China			267	288	420	7,978	9%
Colombia						3,514	4%
Costa Rica	334						0%
Curacao						10,836	13%
Dominican Republic						298	0%
France					624	3,099	4%
Germany				117			0%
Greece						547	1%
Guatemala						384	0%
Hong Kong							0%
India					309		0%
Israel						770	1%
Italy				1,004	1,558	7,482	9%
Japan						2,885	3%
Korea, South				868	972	3,894	5%
Liberia						452	1%
Marshall Islands						452	1%
Mexico		5				317	0%
Netherlands					1,740	15,745	18%
Netherlands/Antilles							0%
Nicaragua						1,560	2%
Nigeria						603	1%
Panama						1,575	2%
Peru						2,693	3%
Puerto Rico							0%
Russia							0%
Singapore				796		3,870	5%
South Africa						411	0%
Spain				1,058	2,612	3,130	4%

Switzerland				3,231	4,828	5,154	6%
Taiwan							0%
Thailand						728	1%
United Kingdom						5,412	6%
Venezuela							0%
Virgin Islands (U.S.)							0%

Source: U.S. Energy Information Administration

Due to the lack of historical data, the same distribution among route groups was used for each class of petroleum tankers. The established route groups by vessel class are displayed in Table 3-6, below. As shown in the table, the majority of tonnage carried on chemical tankers up to 40,000 DWTs is imported from or exported to the Caribbean and East Coast South America. The majority of tonnage carried by the larger chemical tankers, between 40,000 and 60,000 DWTs, is destined for the Far East. For crude oil, the data from EIA shows that when Canada is excluded, 23% of crude oil will be destined for the Caribbean and East Coast South America, another 24% for the Far East, and 48% for Northern Europe and the Mediterranean, as detailed in Table 3-5 above.

Table 3-6. Route Group Distribution by Vessel Class

	CAR-ECSA	SUEZ-FE	NEU-MED	WCSA	WA
Chemical Tanker Sub-Panamax 1	69%	8%	20%	1%	2%
Chemical Tanker Sub-Panamax 2	61%	27%	7%	5%	0%
Chemical Tanker Panamax 1	30%	64%	3%	3%	0%
Petroleum Tankers (All Classes)	23%	24%	48%	3%	1%

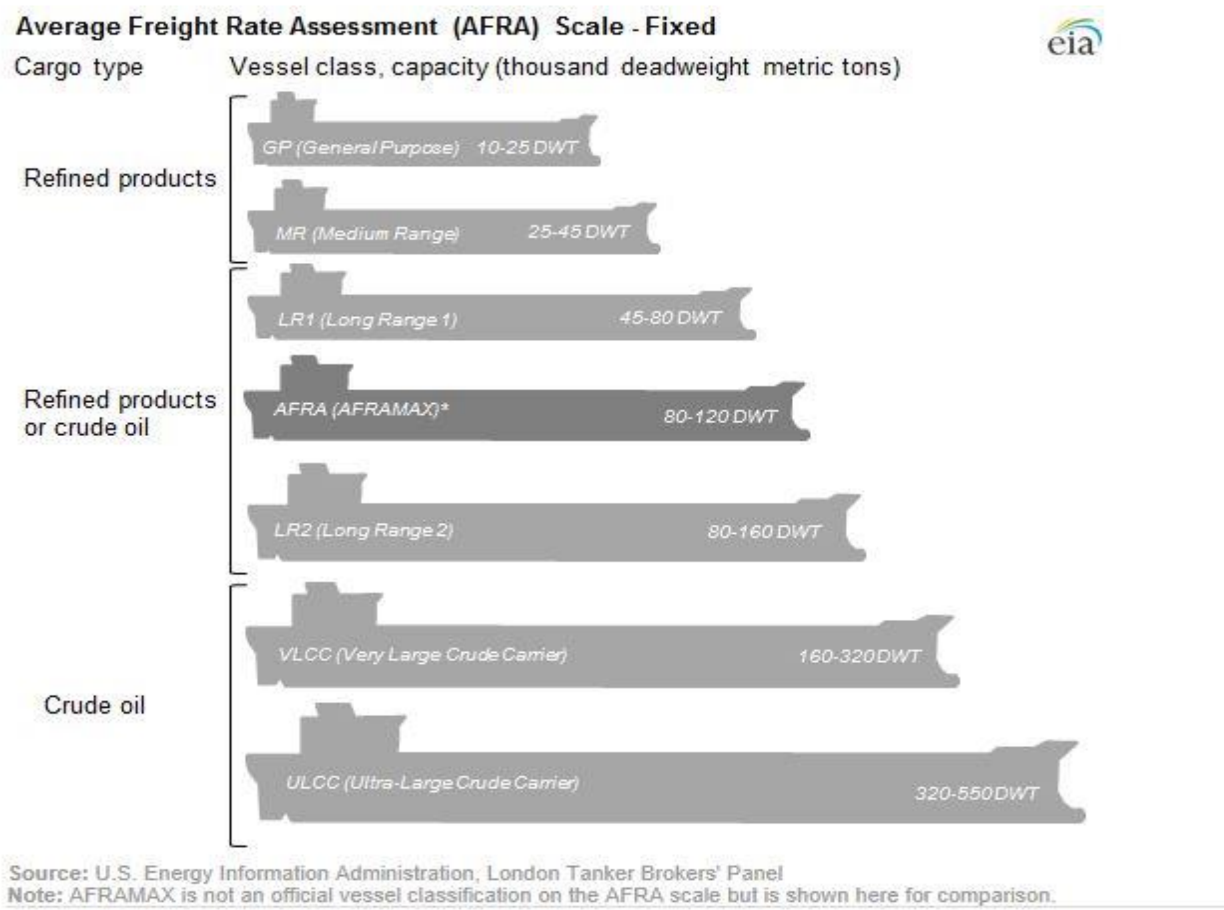
3.4 Design Vessel

The design vessel is the largest vessel that is expected to regularly call in the future with-project conditions. Given the narrow dimensions of the existing channel and, as stated previously, the fact that the widest vessel that can physically fit into the channel is currently being used, the design vessel in this study is expected to be wider (and longer) than vessels currently calling at the Port. The largest vessel in the chemical fleet will remain the same as in the future without-project conditions. The largest vessel in the petroleum tanker fleet in the future without-project condition will remain a PT-PX2 (60,000-80,000 DWT). Though petroleum product exports do not have a long history at the port, this type of vessel has called at the Port in the past. In 2015 two vessels exported condensate that was transloaded by barges from Victoria, Texas on to two PT-PX2 tankers, the Energy Challenger and the Evrotas (pictured in Figure 3-7).

Figure 3-7. Transloading Operation at the Port of Point Comfort

In the future with-project condition, the largest petroleum tanker calling at the Port is expected to transition from a 70,000 DWT petroleum tanker (PT-PX2) to a mid-size Aframax tanker. According to the Energy Information Administration (EIA), the global crude oil and refined product tanker fleet uses a classification system to standardize contract terms, establish shipping costs, and determine the ability of ships to travel into ports or through certain straits and channels. This system, known as the Average Freight Rate Assessment (AFRA) system, is displayed in Figure 3-8. Note that these vessel classes do not correspond to the vessel classes used in the HarborSym analysis, but are displayed for informational purposes.

Figure 3-8. Petroleum Tanker Average Freight Rate Assessment Scale



Long Range (LR) class ships are the most common in the global tanker fleet, as they are used to carry both refined products and crude oil. These ships can access most large ports that ship crude oil and petroleum products. Aframax vessels refer to tankers between 80,000 and 120,000 DWTs. These vessels are used extensively in non-OPEC companies that, in general, do not have the infrastructure to accommodate Very Large Crude Carriers (VLCCs) or Ultra-Large Crude Carriers (ULCCs). Also according to the EIA, this ship size is popular with oil companies for logistical purposes, and therefore, many ships have been built with these specifications. To validate the efficiencies of the Aframax compared to the Panamax vessel, cost per ton calculations were completed using the Institute for Water Resources (IWR) Vessel Operating Costs. The results are displayed in Table 3-7. As the table shows, the Aframax (110,000 DWT) cost per ton is cheaper in each alternative depth when compared to the Panamax (70,000 DWT).

Table 3-7. Aframax and Panamax Cost per Ton

Channel Depth	38'	41'	43'	45'	47'
Tonnage Carried Panamax	51,984	58,165	62,286	66,407	70,527
Cost per Ton Panamax	**$11.41**	**$10.20**	**$9.52**	**$8.93**	**$8.41**
Tonnage Carried Aframax	68,730	77,215	82,872	88,529	94,186
Cost per Ton Aframax	**$10.64**	**$9.47**	**$8.83**	**$8.26**	**$7.77**
Savings per Ton Aframax	**$0.77**	**$0.73**	**$0.70**	**$0.67**	**$0.64**

Investigation in to the Sea-web world fleet database shows that Aframax tankers new builds are increasing when compared to Aframax tankers currently in service. Table 3-8 shows that as of 2017, 7% of the in-service tanker fleet were Panamax vessels. The percentage of new builds that were Panamax vessels increased by only 1%, whereas 15% of the in-service tanker fleet were Aframax vessels in 2017, but 20% of new builds were Aframax vessels. The only vessel classes that showed an increase in new builds as compared to in-service vessels were the Aframax and Suezmax. The percentage of in-service versus new builds in the Panamax, Very Large Crude Carrier (VLCC), and Ultra-Large Crude Carrier (ULCC) tankers was relatively the same, while the percentage of new builds in the Handy, Medium Range (MR) 1, and MR 2 vessel classes all decreased. In addition to the Aframax class becoming a larger percentage of the world fleet and therefore more readily available, because the United States is still a net importer of petroleum products, specifically crude oil, Aframax vessels delivering the crude oil to the Texas Gulf will be able to be chartered for backhaul. Therefore, the design vessel used for this analysis is a, 110,000 DWT petroleum tanker with average dimensions of 800 feet in length overall (LOA), 138 feet in width (beam), and a 48-foot design draft.

Table 3-8. Tankers in the World Fleet (2017)

Vessel Class	Deadweight Tonnage	In Service	In Service %	New Build	New Builds %	Grand Total	InService vs New Build
HANDY	10,000-27,000	1385	23%	122	17%	1507	-5%
MR1	27,000-39,999	607	10%	33	5%	640	-5%
MR2	40,000-54,999	1602	26%	161	23%	1763	-3%
PANAMAX	**55,000-79,999**	**424**	**7%**	**57**	**8%**	**481**	**1%**
AFRAMAX	**80,000-120,000**	**939**	**15%**	**140**	**20%**	**1079**	**4%**
SUEZMAX	125,000-199,999	472	8%	101	14%	573	7%
VLCC	200,000-299,000	689	11%	92	13%	781	2%
ULCC	300,000-550,000	2	0%	0	0%	2	0%

Source: Maritime IHS Sea-Web, 2017

Unlike the smaller, Panamax tankers that are currently calling at the Port, there was no empirical data upon which to base the UKC requirement for the design vessel. As discussed previously, the UKC used in this analysis is 3 feet for vessels that have historically called at the Port. The UKC requirement is a requirement of the vessel owners and is not determined by the pilots or the Port, but according to the Matagorda Pilots is generally in the area of 3 feet or 10% of loaded draft. Empirical data from other ports along the Gulf Coast was analyzed to determine a reasonable UKC for the Aframax vessel when it begins utilizing the MSC. Based on empirical data, a UKC of 4 feet was used for the design vessel in this analysis. Additionally, the 4 foot requirement aligns with the 10% of loaded draft parameter when considering the average loaded draft that will call at the Port.

4 Transportation Cost Savings Benefit Analysis

This section describes the economic analysis completed to calculate the national economic development (NED) benefits of each of the deepening (and associated widening) measures that were carried forward for this study. The study measures increase shipping efficiency, leading to a reduction in the total cost of commodity transit, which translates to NED benefits. NED benefits were estimated by calculating the reduction in transportation costs for each project depth using the HarborSym Modeling Suite of Tools (HMST) developed by the Institute for Water Resources (IWR). The HMST reflects USACE guidance on transportation cost savings analysis.

Within this section, the HMST is described in detail, including the inputs required and their application in the study. The resulting benefits are described in Sections 4.2 and 4.3.

4.1 Methodology

Channel improvements result in reduced transportation cost by allowing a more efficient future fleet mix and less wait time when traversing the channel, resulting in at-sea and in-port cost savings. The HMST was designed to allow users to model these benefits.

Channel restrictions limit a vessels capacity by limiting its draft. Deepening the channel reduces this constraint and the vessel's maximum practicable capacity increases towards its design capacity. This increase in vessel capacity results in fewer vessel trips being required to transport the forecasted cargo. HarborSym allows for detailed modeling of vessel movements and transit rules on the waterway.

To begin, HarborSym was setup with the basic required variables. To estimate origin-destination (OD) cost saving benefits (or the reduction in transit costs associated with a drop in the total number of port calls caused by deeper loading or the use of a more efficient fleet mix), the Bulk Loading Tool (BLT), a module within the HMST, was used to generate a vessel call list based on the commodity forecast at the MSC for a given year and available channel depth under the various alternatives. The resulting vessel traffic was simulated using HarborSym, producing average annual vessel OD transportation costs. The Tentatively Selected Plan (TSP) was identified by considering the highest net benefit based on the OD transportation cost saving benefits.

4.1.1 HarborSym Model Overview

IWR developed HarborSym as a planning level, general-purpose model to analyze the transportation costs of various waterway modifications within a harbor. HarborSym is a Monte Carlo simulation model of vessel movements at a port for use in economic analyses. While many harbor simulation models focus on landside operations, such as detailed terminal management, HarborSym instead concentrates on specific vessel movements and transit rules on the waterway, fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with the ocean voyage.

HarborSym represents a port as a tree-structured network of reaches, docks, anchorages, and turning areas. Vessel movements are simulated along the reaches, moving from the bar to one or more docks, and then exiting the port. Features of the model include intra-harbor vessel movements, tidal influence, the ability to model complex shipments, incorporation of turning areas and anchorages, and within-simulation visualization. The driving parameter for the HarborSym model is a vessel call at the port. A HarborSym analysis revolves around the factors that characterize or affect a vessel movement within the harbor.

4.1.2 Model Behavior

HarborSym is an event driven model. Vessel calls are processed individually and the interactions with other vessels are taken into account. For each iteration, the vessel calls for an iteration that falls within the simulation period are accumulated and placed in a queue based on arrival time. When a vessel arrives at the port, the route to all of the docks in the vessel call is determined. This route is comprised of discrete legs (contiguous sets of reaches, from the entry to the dock, from a dock to another dock, and from the final dock to the exit). The vessel attempts to move along the initial leg of the route. Potential conflicts with other vessels that have previously entered the system are evaluated according to the user-defined set of rules for each reach within the current leg, based on information maintained by the simulation as to the current and projected future state of each reach. If a rule activation occurs, such as no passing allowed in a given reach, the arriving vessel must either delay entry or proceed as far as possible to an available anchorage, waiting there until it can attempt to continue the journey. Vessels move from reach to reach, eventually arriving at the dock that is the terminus of the leg.

After the cargo exchange calculations are completed and the time the vessel spends at the dock has been determined, the vessel attempts to exit the dock, starting a new leg of the vessel call; rules for moving to the next destination (another dock or an exit of the harbor) are checked in a similar manner to the rule checking on arrival, before it is determined that the vessel can proceed on the next leg. As with the entry into the system, the vessel may need to delay departure and re-try at a later time to avoid rule violations and, similarly, the waiting time at the dock is recorded.

A vessel encountering rule conflicts that would prevent it from completely traversing a leg may be able to move partially along the leg, to an anchorage or mooring. If so, and if the vessel can use the anchorage (which may be impossible due to size constraints or the fact that the anchorage is filled by other vessels), then HarborSym will direct the vessel to proceed along the leg to the anchorage, where it will stay and attempt to depart periodically, until it can do so without causing rule conflicts in the remainder of the leg. The determination of the total time a vessel spends within the system is the summation of time waiting at entry, time transiting the reaches, time turning, time transferring cargo, and time waiting at docks or anchorages. HarborSym collects and reports statistics on individual vessel movements, including time in system, as well as overall summations for all movements in an iteration.

HarborSym was initially developed as a tool for analyzing channel widening projects, which were oriented toward determining time savings for vessels transiting within a harbor. It did not allow for assessing changes in vessel loading or in shipping patterns. The most recent release of HarborSym was designed to assist analysts in evaluating channel-deepening projects, in addition to the original model capabilities. The deepening features consider fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with ocean voyage.

Each vessel call has a known (calculated) associated cost, based on time spent in the harbor and ocean voyage and cost per hour. Also for each vessel call, the total quantity of commodity transferred to the port (both import and export) is known, in terms of commodity category, quantity, tonnage and value. The basic problem is to allocate the total cost of the call to the various commodity transfers that are made. Each vessel call may have multiple dock visits and multiple commodity transfers at each visit, but each commodity transfer record refers to a single commodity and specifies the import and export tonnage. Also, at the commodity level, the “tons per unit” for the commodity is known, so that each commodity transfer can be associated with an export and import tonnage. As noted above, the process is greatly simplified if all commodity transfers within a call are for categories that are measured in the same unit, but that need not be the case.

When a vessel leaves the system, the total tonnage, export tonnage, and import tonnage transferred by the call are available, as is the total cost of the call. The cost per ton can be calculated at the call level (divide total cost by respective total of tonnage). Once these values are available, it is possible to cycle through all of the commodity transfers for the vessel call. Each commodity transfer for a call is associated with a single vessel class and unit of measure. Multiplying the tons or value in the transfer by the appropriate per ton cost, the cost totals by class and unit for the iteration can be incremented. In this fashion, the total cost of each vessel call is allocated proportionately to the units of measure that are carried by the call, both on a tonnage and a value basis. Note that this approach does not require that each class or call carry only a commensurate unit of measure.

The model calculates import and export tons, import and export value, and import and export allocated cost. This information allows for the calculation of total tons and total cost, allowing for the derivation of the desired metrics at the class and total level. The model can thus deliver a high level of detail on individual vessel, class, and commodity level totals and costs.

Either all or a portion of the at-sea costs are associated with the subject port, depending on whether the vessel call is a partial or full load. The at-sea cost allocation procedure is implemented within the HarborSym Monte-Carlo processing and utilizes the estimate total trip cargo (ETTC) field from the vessel call information along with import tonnage and export tonnage. In all cases the ETTC is the user’s best estimate of total trip cargo. Within the BLT, the ETTC field is estimated as cargo on board the vessel at arrival plus cargo on board the vessel at departure, in tons. ETTC can also be expressed as:

$$\text{ETTC} = 2 * \text{Cargo on Board at Arrival} – \text{Import tons} + \text{Export tons}$$

There is a basic algorithm implemented to determine the fraction of at-sea costs to be allocated to the subject port. First, if ETTC for a vessel call is equal to zero or null, then none of the at-sea costs are associated with the port. The algorithm then checks if import or export tons are zero for a vessel call. If either are zero, then the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

$$\text{At-Sea Cost Allocation Fraction} = (\text{Import tons} + \text{Export tons})/\text{ETTC}$$

Finally, when both import and export tons are greater than zero, the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

$$\text{At-Sea Cost Allocation Fraction} = 0.5 * (\text{Import tons}/\text{Tonnage on board at arrival}) + 0.5 * (\text{Export tons}/\text{Tonnage on board at departure})$$

Where:

$$\text{Tonnage on board at arrival} = (\text{ETTC} + \text{Imports} – \text{Exports})/2$$

$$\text{Tonnage on board at departure} = \text{Tonnage on board at arrival} – \text{Imports} + \text{Exports}$$

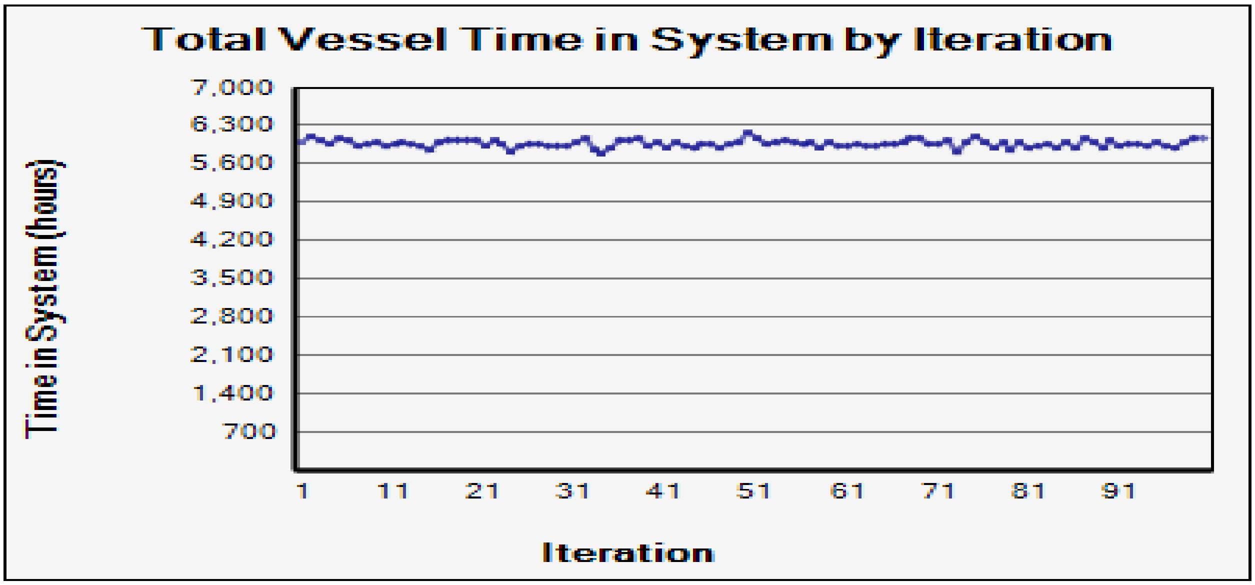
For MSC, ETTC was calculated manually using the formula described above. These results are detailed in Section 4.1.3.7.

4.1.3 Data Requirements

The data required to run HarborSym are separated into six categories, as described below. Key data for the Matagorda Ship Channel feasibility study are provided.

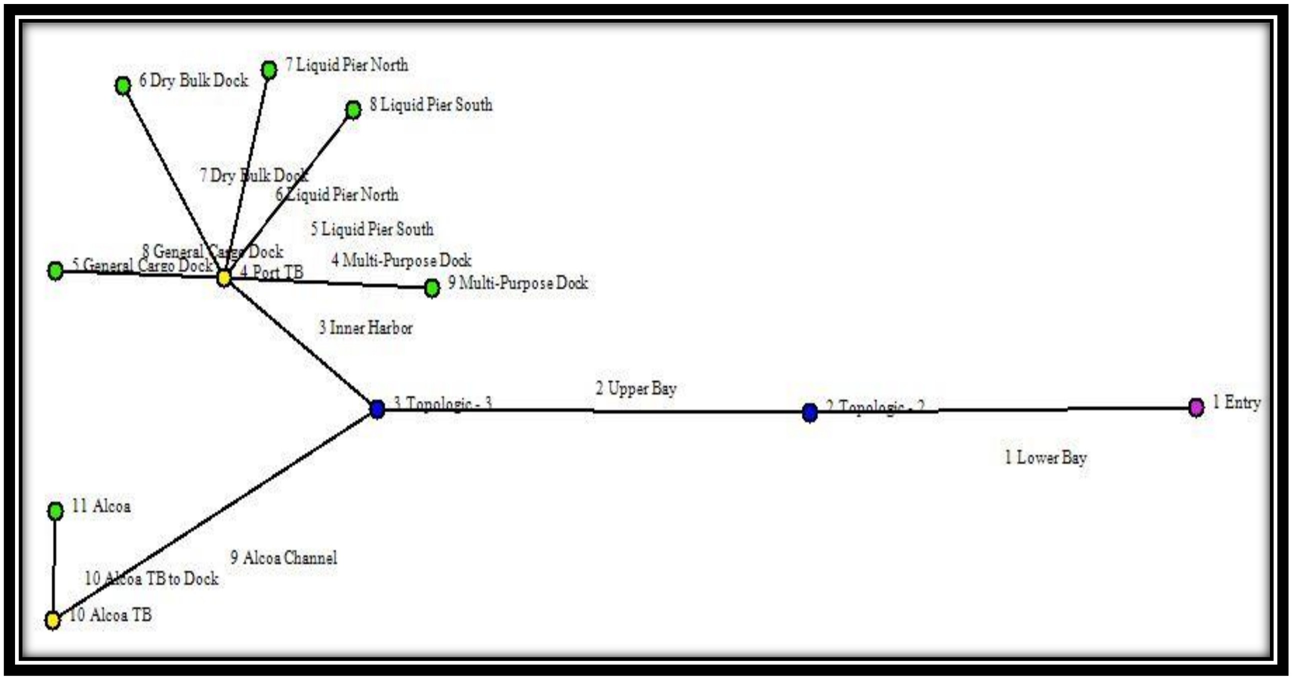
4.1.3.1 Simulation Parameters - Parameters include start date, the duration of the iteration, the number of iterations, the level of detail of the result output, and the wait time before rechecking rule violations when a vessel experiences a delay. A model run was performed for the following years: 2023, 2033, and 2043. After 2043, the forecasted tonnage levels (and therefore associated transportation costs) were held constant. The base year for the model was originally 2023, but the base year for the project was changed to 2024 after additional research on the construction schedule. The model base year was not changed, but the change in base year was taken in to account when calculating project benefits. Each model run consisted of 100 iterations. The number of iterations was determined to be sufficient when comparing the average time of the fleet in the system. Figure 23 illustrates there is very little variation in vessel time in the system for the OD model runs. For the existing condition model run in 2023, the average total vessel time in the system after 10 iterations was 5,968 hours, with a standard deviation of 65 hours.

Figure 4-1. FWOPC (2023) Total Time in System Statistics



4.1.3.2 Physical and Descriptive Harbor Characteristics - These data inputs include the specific network of Matagorda Ship Channel and the Port of Point Comfort, such as the node location and type, reach length, width, and depth, in addition to tide and current stations. This also includes information about the docks in the harbor such as length and the maximum number of vessels the dock can accommodate at any given time. Figure 4-2 displays the node network used for Matagorda Ship Channel and the Port of Point Comfort.

Figure 4-2. Matagorda Ship Channel Node Network



4.1.3.3 General Information - General information used as inputs to the model include: specific vessel and commodity classes, route groups (Table 4-1), commodity transfer rates at each dock (Table 4-2), and specifications of turning area usage at each dock. Route groups were developed by evaluating the origin and destination ports for vessel calls at the Port of Point Comfort in 2015. Countries included in each route group are detailed in Table 3-3. Again, these distances are round trip nautical miles, and transportation costs that are not allocated to the Port of Point Comfort are adjusted for using ETTC. Because vessels do not follow the same routes each time, the distance to prior/next port field was not used in HarborSym; it is assumed these variations in distances will be accounted for in the triangular distribution.

Table 4-1. HarborSym Route Groups

Route Group	Additional Sea Distance Min (nautical miles)	Additional Sea Distance Most Likely (nautical miles)	Additional Sea Distance Max (nautical miles)
CAR-ECSA	740	4,600	10,800
NEU-MED	9,400	10,200	13,400
SUEZ-FE	11,400	19,500	22,000

WA	9,800	12,800	12,800
WCSA	2,200	5,500	8,800

Table 4-2. Commodity Transfer Rates (Metric Tons/Hour)

Commodity	Minimum	Most Likely	Maximum
Liquid Chemicals	700	1,500	3,000
Petroleum Products	700	1,500	3,000

4.1.3.4 Vessel Speeds and Operations - The speed at which vessels operate in the harbor, both loaded and light loaded, were determined by interviews with the Matagorda Pilots. Hourly operating costs while in-port and at-sea were determined for both domestic and foreign flagged vessels. Sailing speeds at-sea were also determined. Both the vessel operating costs (VOCs) and at-sea sailing speeds were entered in a triangular distribution. These values were obtained from Institute for Water Resources (IWR) Vessel Operating Cost spreadsheets and Economic Guidance Memorandum (EGM) 17-04: Deep Draft Vessel Operating Costs FY 2016 Price Levels. Vessel speed inputs are provided in Table 4-3. Vessel operating costs are not displayed, as much of the information is considered proprietary by commercial sources and is protected from open or public disclosure under Section 4 of the Freedom of Information Act.

Table 4-3. Vessel Speed Ranges

Vessel Class	Vessel Type	Speed in Reach, Light (knots)	Speed in Reach, Loaded (knots)	Vessel Speed at Sea, Min (knots)	Vessel Speed at Sea, Most Likely (knots)	Vessel Speed at Sea, Max (knots)
SPX1	Chemical Tanker	11	9	12	13	13
SPX2	Chemical Tanker	11	9	13	13	13
PX1	Chemical Tanker	11	9	12	13	15
PT-SPX1	Petroleum Tanker	11	9	12	13	15

PT-SPX2	Petroleum Tanker	11	9	13	13	14
PT-PX1	Petroleum Tanker	11	9	12	13	15
PT-PX2	Petroleum Tanker	11	9	12	13	15
PT-Afra1	Petroleum Tanker	11	9	12	13	15

4.1.3.5 Reach Transit Rules - Vessel transit rules for each reach reflect restrictions on meeting, loading, and vessel dimensions for each reach of the channel. Underkeel clearance requirements are also to determine if a vessel can enter the system. Traffic rules under existing conditions were discussed in Section 2.6.1. Table 4-4 reiterates those traffic rules in the future without project condition (FWOPC) and describes how the rules are changed in the future with-project condition. Reach 1 is the entrance channel and reaches 1 through 9 encompass all channel reaches with the exception of the Alcoa channel, which is not being modified. It should be noted that the UKC for Aframax vessels was increased from 3 feet (which is the requirement for all other vessel classes in the model) to 4 feet to account for the larger ship size. This increase is based on conversations with the Matagorda Pilots and empirical data from other Gulf Coast ports that are receiving calls by Aframax vessels.

Table 4-4. Reach Transit Rules

Reach	HarborSym Rule FWOPC	Applicable Condition	FWPC Modification to Reach Rule
1-9	No meeting	Always	No movement if combined beam width is greater than 54% of channel
1	No movement if vessel LOA is > 639 feet	Night	No movement if vessel LOA is > 768 feet
1-9	No movement if vessel is drafting within 4' of maximum allowable draft	Night	Rule remains, but maximum allowable draft increases with channel depth
1-9	No movement if vessel is drafting within 3' of maximum allowable draft (UKC requirement)	Always	Rule remains, but maximum allowable draft increases with channel depth

4.1.3.6 Vessel Calls - The vessel call lists are made up of forecasted vessel calls for a given year as generated by the BLT. Each vessel call list contains the following information: arrival date, arrival time, vessel name, entry point, exit point, arrival draft, import/export, dock name, dock order, commodity, units, origin/destination, vessel type, Lloyds Registry, net registered tons, gross registered tons, dead weight tons, capacity, length overall, beam, draft, flag, tons per inch immersion factor, ETTC, and the route group for which it belongs.

4.1.3.7 ETTC - Either all or a portion of the at-sea costs are associated with the subject port, depending on whether the vessel call is a partial or full load. The at-sea cost allocation procedure is implemented within the HarborSym kernel and utilizes the estimate total trip cargo (ETTC) field from the vessel call information along with import tonnage and export tonnage. In all cases the ETTC is the user's best estimate of total trip cargo. The BLT populates the ETTC field in a fashion that assumes for all vessel calls the at-sea cost allocation fraction is 1. If the user knows that bulk vessels are carrying cargo loaded at another port not destined for the subject port, which is the case in Matagorda Ship Channel, the ETTC field should be manually adjusted accordingly. For this study, ETTC was calculated using the formula described in Section 4.1.2 along with 2015 WCSC data from MSC and CCSC. Vessels were assigned an at-sea cost allocation fraction based on the average ETTC for the class, and the ETTC in the vessel call lists were modified accordingly. Table 4-5 displays the at-sea allocation percentage by vessel class that was used in this study. Allocation percentages were held constant in with- and without-project conditions and in each out year.

Table 4-5. At-Sea Allocation Percentage by Vessel Class

Commodity Type	Vessel Class	Allocation Percentage
Petroleum Products	PT-SPX1	56%
	PT-SPX2	61%
	PT-PX1	52%
	PT-PX2	30%
	PT-Afra1	42%
Chemicals	SPX1	29%
	SPX2	27%
	PX1	27%

4.1.4 Bulk Loading Tool

The non-containerized vessel call list for future years was developed using the BLT, a tool within the HarborSym Modeling Suite of Tools. Users must provide data to specify the framework for generating the synthetic vessel call list. The BLT relies on much of the information and data from HarborSym, but has data additional specific requirements. Within the BLT, the input requirements include:

- Commodity forecasts (annual import/export) at each dock;
- Description of the available fleet by vessel class, including:
  - Statistical data describing the cumulative distribution function for deadweight tons of vessels within the class,
  - Regression information for deriving length overall (LOA), beam and design draft from capacity,
  - Regression information for calculating TPI based on beam, design draft, capacity and LOA;
  - The number of potential calls that can be made annually by each vessel class;
- Logical constraints describing:
  - Commodities that can be carried by each vessel class,
  - Vessel classes that can be serviced at each dock,
  - Parameters, defined at the vessel class/commodity level for determination of how individual calls and commodity transfers are generated, such as commodity loading factors, allocation priorities, and commodity flow direction (import or export calls).

Much of the required forecast information was based on an examination of an existing vessel call list created from historical data (obtained from WCSC). Statistical measures, commodity transfer amounts, and logical constraints can all be derived from an examination of a set of historical calls that have been stored in a HarborSym database.

4.1.4.1 BLT Algorithm – With user provided input requirements, the BLT creates and loads a synthetic fleet according to the following steps:

1. Generation of a fleet of specific vessels based upon a known number of vessel calls by class and a statistical description of the characteristics of the vessel class. This process begins by generating one specific vessel for each call in the class. The capacity of the vessel is set by a random draw from the cumulative density function that is stored for the class. Based on the regression coefficients that are stored for the class, each of which is of the form:
   - log (parameter) = a + b* log (Capacity)
   - LOA, Beam and Design Draft are determined for the vessel using a linear regression of the form:

     TPI = a + b*Beam + c*Design Draft + d*Capacity + e*LOA
   - The TPI is calculated based on the previously generated physical characteristics and coefficients stored, at the class level, for this regression model. This process is repeated until a

unique vessel is created for each available call in the forecast. If no TPI is generated, the default TPI specified by the user for the vessel class is assigned.

2. Attempt to assign a portion of the commodity forecast at a dock to a vessel. Each commodity forecast at a dock is processed in turn. If a vessel is available that can serve the commodity at the dock, it is loaded for either export only, import only, or both export and import. Potential vessels that can carry the forecast are assigned in a user-specified (at the class level) allocation order, so that the most economical vessel classes will always be used first. Under the current assumptions, a vessel call handles a single commodity at a single dock, i.e., each call consists of a single dock visit and a single commodity transfer (which may contain both an export quantity and an import quantity). The specification of the actual call assignment and commodity loading is dependent upon the maximum that a vessel can draft and still reach and leave the dock.

    - The amount of the commodity forecast that is actually carried on the vessel is used to decrement the remaining quantity to be allocated for that particular commodity forecast. After a single vessel call is assigned to a particular forecast, the total number of remaining available vessels for the class is decremented and the next commodity forecast in turn is processed. That is, each forecast attempts to have a portion of its demand satisfied by a single vessel call and then the next forecast is processed. This is to prevent all of the most efficient vessels from being assigned to a single commodity forecast.

    - This process proceeds, in a loop, continually attempting to assign commodity to a vessel from the remaining available fleet. Whenever a successful assignment is made, this generates a vessel call, dock visit, and the associated commodity transfer. This effort continues until no more assignments to a vessel call can be made, either because all commodity forecasts have been satisfied or there is no available vessel that can service the remaining quantities (because there is no vessel of the required class that can handle the particular commodity/dock combination of the forecast or because no vessel can be loaded to satisfy the dock controlling depth constraint).

3. At the end of the process, when no more assignments are possible, arrival times are assigned for each vessel. The algorithm used to assign arrival times assumes a uniform inter-arrival time for all calls within a class. After the allocation process is complete, the number of calls made by each class of vessel is known. This is used to calculate the inter-arrival time of vessels for that class. The arrival of the first vessel in the class is set randomly at a time between the start of the year and the calculated inter-arrival time, but all subsequent vessel arrivals for the class will have the identical inter-arrival time.

4. The generated vessel calls are written to a HarborSym vessel call database and the user is presented with output information on which commodity forecasts were satisfied, any remaining unsatisfied forecasts and detailed information on each vessel loading and the vessels that were used to satisfy each commodity forecast.

The intended approach is for the user to work iteratively within the BLT, making runs, examining the forecast satisfaction that is achieved and varying the fleet character and composition for subsequent runs, so that the final result is a balanced, reasonable projection of vessel calls to satisfy the input forecast demand. The BLT provides extensive output to assist the user in this regard.

Once a vessel is determined to be available for loading for a particular forecast, the BLT must determine the type of loading, the quantity loaded, and the arrival draft of the vessel. The user can control certain aspects of the process through data specification, in particular the type of call (import, export or both) and the percent of capacity that is loaded for import and export, as described below.

Any given vessel call can attempt to satisfy an import demand (arrive with cargo for the port, leave empty), an export demand (arrive empty, leave with cargo loaded at the port) or simultaneously an import and export demand (that is, arriving with cargo to unload at the port [import], and then departing with cargo bound for another port [export]), based on the user defined directional movement assigned to the vessel class. Four possibilities are defined for this behavior, with specification at the Vessel Class/Commodity Category level:

- Export Only
- Import Only
- Random
- Both Export and Import

Certain combinations of class and commodity categories might be exclusively import only or export only. A “Random” assignment designates that calls from the class/commodity combination can be either import or export at a dock, but not both simultaneously. If a “Random” type is assigned, then the ratio of calls that will be randomly generated as import is specified.

For the Matagorda Ship Channel feasibility study, the “Random” behavior was selected for chemical products, and the “Export Only” behavior was selected for petroleum products. For chemical products, the percentage of imports was specified as 25%, because historically, an average of 75% of the foreign tonnage is exports and 25% is imports.

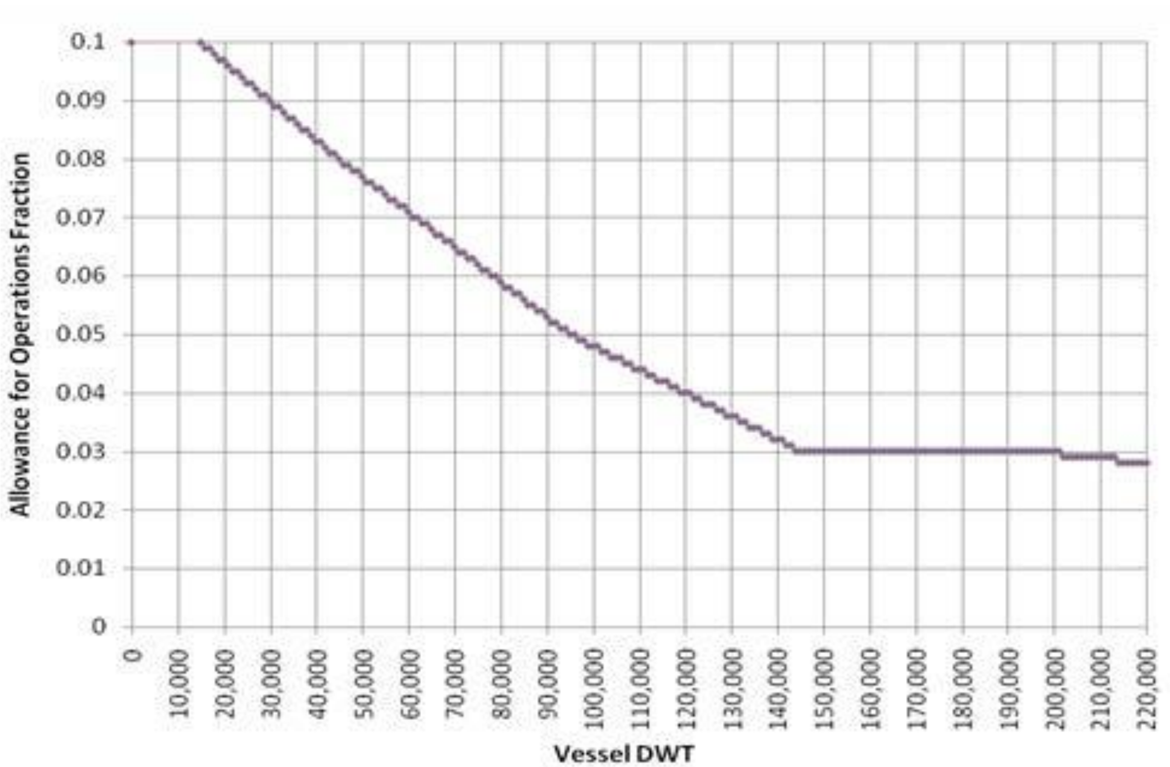
The quantity of a vessel’s capacity that is to be loaded for satisfaction of the import and export demands is described, again at the Vessel Class/Commodity Category level, by a triangular distribution that specifies a loading factor. A minimum, most likely, and maximum, in percent of total available capacity, is defined for both export and import.

When a vessel is available for satisfying a demand, first the type of satisfaction (import only, export only, random or both) is determined, as noted above. If “random” is associated with the current class/commodity, then a random draw is made from a uniform distribution and compared with the user-specified import ratio, to determine if the call is import only or export only. For example, if the user has entered a value of 70 percent for imports, indicating that 30 percent of the calls are exports, then a random draw is made from a uniform (0.1) distribution. If the random number is less than or equal to 0.7, then the call is assigned as an import, otherwise it is assigned as export.

Once the type of call is determined, the BLT must next ascertain how much capacity can be loaded on the vessel while satisfying the draft constraints. The process is similar for both export and import. First, a draw is made from the respective triangular distribution to get a percentage loading factor. This is then applied to the vessel DWT, adjusted to reduce the available tonnage based on allowance for operations, to get a tentative quantity to be loaded. The import/export capacity to be loaded is adjusted only if the available loading capacity is less than the initial calculation.

The tonnage associated with allowance for operations is based on IWR-developed data given fractional allowance for operations as a function of vessel tonnage (DWT) as shown in Figure 4-3.

Figure 4-3. Allowance for Operations by Vessel DWT



The additional draft implied by the tentative quantity to be loaded is calculated based on the vessel TPI. A value of empty vessel draft for each vessel has previously been calculated, based on an assumption that the vessel DWT is associated with the vessel design draft. The empty vessel draft from which loading can start is then calculated as:

Empty Vessel Draft = Design Draft – (DWT/TPI)/12.0

The total draft associated with the tentative loading is then calculated as the sum of four drafts:

Total Draft (tentative loading) = Empty Vessel Draft + Additional Draft Associated with Tentative Loading + Additional Draft associated with Allowance for Operations + Underkeel Clearance

In order to test the ability of the vessel to arrive at or leave the dock, to this total draft associated with tentative loading must be added the required underkeel clearance (a function of the vessel class). This gives the “test draft” that is checked against the limiting depth to the dock. Note that this is not the same as the eventually calculated arrival draft of the vessel at the bar, which is written to the vessel call data base. If this test draft is greater than the limiting depth to the dock (as defined by user input), the quantity loaded must be reduced, so that the calculated draft is less than the limiting depth to the dock. This calculation is executed to determine if the tentative loading can be reduced sufficiently to meet the dock limiting depth. If so, then the vessel is loaded with the amount of commodity to reach the target draft. If it is not possible to assign a commodity quantity that, when loaded on the vessel, does not exceed the dock limiting depth, then the vessel cannot service the allocation.

Once the commodity allocation has been completed, the vessel loading is known and the arrival draft (at the bar) must be determined. A class level "minimum sailing draft" has been specified by the user at the vessel class level. This minimum sailing draft, or empty vessel draft, reflects the ballasted draft at which a light vessel will sail. If a vessel is handling an export only, then it is assumed to arrive light, at the empty vessel sailing draft. If a vessel is handling an import to the port, then it arrives at the draft associated with the import loading (which may have been reduced to the limiting depth at the dock). It is important to note that underkeel clearance is not included in the arrival draft that is stored in the vessel call database because it does not factor into the actual sailing draft, but, as noted above it is used in checking the constraint associated with the limiting depth to the dock. In practice, underkeel clearance is used in the BLT to handle the depth constraint, but is not incorporated in the actual sailing draft. Underkeel clearance is then added back in as an additional constraint that is applied in HarborSym itself based on sailing rules. In this manner, the arrival draft is consistently calculated based on the sum of empty vessel draft, draft associated with loading, and draft associated with allowance for operations.

The BLT module writes all the needed fields to the vessel call database. Of note is how the ETTC field is handled. Within the BLT, unless manually adjusted, ETTC is populated by simply adding together import tons and export tons, which assumes that all at-sea costs for a vessel call generated by the BLT are allocated to the subject port. The ETTC field was manually adjusted for this study. The adjustments to ETTC are described in Section 4.1.3.7.

4.1.5 BLT Vessel Call Lists

Historical vessel call data for the Matagorda Ship Channel that was obtained from WCSC and used to develop the future without and future-with project vessel calls. Using the Bulk Loading Tool and the commodity forecast described in Section 3.2, new vessel call lists were created for the without-project condition and for each alternative depth for the years 2024, 2034, and 2044. New vessel call lists were not created for years after 2044, because the commodity forecast is held constant after this year.

Minimum, most likely, and maximum loading percentages are entered for each vessel class for both imports and exports. For chemical products, the loading percentage figures for the future without-project condition are based on the vessel usage in the 2015 existing condition historical vessel call list. The loading factors for chemical products were modified in each with-project depth based on the more efficient loading practices that are expected to be utilized with a deeper channel. For petroleum products, 2015 vessel usage data from the Corpus Christi Ship Channel (47' MLLW) was used to approximate the loading factors for the Matagorda Ship Channel given a 47' MLLW depth. Export data for petroleum products was isolated to calculate loading factors. Loading percentages for the other with-project depths as well as the without-project condition were extrapolated from the loading factors observed in Corpus Christi at the 47' depth. These loading factor percentages are displayed in Table 4-6 through Table 4-11 below. The loading factors in the sub-Panamax 1 vessel class in both the petroleum tanker and the chemical tanker vessel classes (SPX1 and PT-SPX1) do not increase with a deepened channel. This is because maximum design draft of the SPX1 vessel can be fully accommodated by the existing, 38' MLLW channel. Likewise, the Panamax 1 chemical tanker (PX1) does not benefit (i.e., load deeper) under the 49' alternative. This is because the maximum draft of the PX1 tanker along with its underkeel clearance is accommodated by the 47' channel.

Table 4-6. Without Project Condition Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum
SPX1	Chemicals	9	29	52	16	43	80
SPX2	Chemicals	17	36	53	13	28	42
PX1	Chemicals	23	31	35	10	23	43
PT-SPX1	Petroleum Products	-	-	-	60	76	91
PT-SPX2	Petroleum Products	-	-	-	36	61	63
PT-PX1	Petroleum Products	-	-	-	10	41	75
PT-PX2	Petroleum Products	-	-	-	8	27	69
PT-Afra1	Petroleum Products	-	-	-	-	-	-

Table 4-7. 41' MLLW Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum
SPX1	Chemicals	9	29	52	16	43	80
SPX2	Chemicals	17	40	65	13	33	51
PX1	Chemicals	23	34	46	10	26	49
PT-SPX1	Petroleum Products	-	-	-	60	76	91
PT-SPX2	Petroleum Products	-	-	-	36	65	73

PT-PX1	**Petroleum Products**	-	-	-	10	46	83
PT-PX2	**Petroleum Products**	-	-	-	8	31	77
PT-Afra1	**Petroleum Products**	-	-	-	9	38	68

Table 4-8. 43' MLLW Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum
SPX1	**Chemicals**	9	29	52	16	43	80
SPX2	**Chemicals**	17	43	74	13	36	57
PX1	**Chemicals**	23	37	47	10	28	55
PT-SPX1	**Petroleum Products**	-	-	-	60	76	91
PT-SPX2	**Petroleum Products**	-	-	-	36	68	80
PT-PX1	**Petroleum Products**	-	-	-	10	50	88
PT-PX2	**Petroleum Products**	-	-	-	8	34	82
PT-Afra1	**Petroleum Products**	-	-	-	9	42	73

Table 4-9. 45' MLLW Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum
SPX1	Chemicals	9	29	52	16	43	80
SPX2	Chemicals	17	46	82	13	38	63
PX1	Chemicals	23	39	53	10	30	61

PT-SPX1	Petroleum Products	-	-	-	60	76	91
PT-SPX2	Petroleum Products	-	-	-	36	71	87
PT-PX1	Petroleum Products	-	-	-	10	53	92
PT-PX2	Petroleum Products	-	-	-	8	38	87
PT-Afra1	Petroleum Products	-	-	-	9	45	78

Table 4-10. 47' MLLW Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum
SPX1	Chemicals	9	29	52	16	43	80
SPX2	Chemicals	17	46	82	13	38	63
PX1	Chemicals	23	41	59	10	32	67
PT-SPX1	Petroleum Products	-	-	-	60	76	91
PT-SPX2	Petroleum Products	-	-	-	36	73	92
PT-PX1	Petroleum Products	-	-	-	10	57	92
PT-PX2	Petroleum Products	-	-	-	8	41	92
PT-Afra1	Petroleum Products	-	-	-	9	49	85

Table 4-11. 49' MLLW Vessel Loading Factors

Vessel Class ID	Commodity Category ID	Commodity Loading Factor - Imports			Commodity Loading Factor - Exports		
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum

SPX1	Chemicals	9	29	52	16	43	80
SPX2	Chemicals	17	46	82	13	38	63
PX1	Chemicals	23	41	59	10	32	67
PT-SPX1	Petroleum Products	-	-	-	60	76	91
PT-SPX2	Petroleum Products	-	-	-	36	73	92
PT-PX1	Petroleum Products	-	-	-	10	57	92
PT-PX2	Petroleum Products	-	-	-	8	44	92
PT-Afra1	Petroleum Products	-	-	-	9	52	88

With the increased loading allowed by the deeper channels in each alternative depth, the total number of vessels required to transport the same amount of commodity decreases. The vessel counts by vessel class for each alternative depth and out year are displayed in Table 4-12. As expected, the total number of vessels required to move the same amount of tonnage decreases as the channel is deepened, because each vessel can carry more tonnage in a deeper and wider channel, with the exception of the SPX1 and PT-SPX1 tankers, as mentioned previously.

Within the Bulk Loading Tool, an allocation priority can be assigned to each vessel class. The allocation priority determines the order in which vessel classes are called upon to satisfy commodity forecasts. For this study, in both the chemical and the petroleum tanker categories, the largest vessels were loaded first (i.e., given an allocation priority of “1”). In both vessel type categories, the mid-sized vessel classes (i.e., PT-PX1 for petroleum tankers and SPX2 for chemical tankers) were given the last allocation priority. Therefore, the number of calls within these classes are reduced as the channel is deepened. This is consistent with the distribution of calls by these respective vessel sizes that is observed in other Gulf Coast ports.

In each out year (2024, 2034, and 2044), the number of Aframax vessels calling at the Port of Point Comfort was increased by 50%. This manual increase in the BLT is to simulate what is expected to take place at the Port as more Aframax vessels are added to the world fleet (as described in Section 3.4).

Table 4-12. Vessel Fleet Forecast (Number of calls by vessel class and alternative depth)

	Vessel Class	FWOP	FWP (41)	FWP (43)	FWP (45)	FWP (47)	FWP (49)
2024	SPX1	110	110	110	110	110	110
	SPX2	58	51	42	29	21	21

	PX1	82	73	73	73	73	73
	PT-SPX1	6	6	6	6	6	6
	PT-SPX2	12	12	12	12	12	12
	PT-PX1	110	96	87	81	78	77
	PT-PX2	30	13	13	13	13	13
	PT-Afra1	0	11	11	11	11	11
	Total	**408**	**372**	**354**	**335**	**324**	**323**
2034	SPX1	127	127	127	127	127	127
	SPX2	69	63	45	33	26	26
	PX1	95	84	84	84	84	84
	PT-SPX1	6	6	6	6	6	6
	PT-SPX2	13	12	12	12	12	12
	PT-PX1	118	94	86	80	76	74
	PT-PX2	32	14	14	14	14	14
	PT-Afra1	0	17	16	17	17	17
	Total	**459**	**416**	**390**	**373**	**362**	**360**
2044	SPX1	146	146	146	146	146	146
	SPX2	71	70	54	35	24	24
	PX1	110	97	97	97	97	97
	PT-SPX1	6	6	6	6	6	6
	PT-SPX2	13	12	12	12	12	12
	PT-PX1	109	76	67	62	53	52
	PT-PX2	31	13	13	13	13	13
	PT-Afra1	0	25	25	25	25	25
	Total	**485**	**445**	**420**	**396**	**376**	**375**

4.2 Transportation Cost Savings Benefits by Depth

Transportation cost benefits were estimated using the HarborSym Economic Reporter, a tool developed by IWR that summarizes and annualizes HarborSym results from multiple simulations. This tool collects the transportation costs from various model run output files and generates the transportation cost reduction for all project years, then produces an Average Annual Equivalent (AAEQ). Results were verified using IWR Planning Suite and spreadsheet models as well.

Transportation costs were estimated for a 50-year period beginning in 2024 and ending in 2073. Transportation costs were estimated using HarborSym for the years 2023, 2033, 2043. Transportation costs were held constant beyond 2043. The present value was estimated by interpolating between the modeled years and discounting at the current FY 2017 Federal Discount rate of 2.75 percent. Estimates were determined for each alternative project depth.

Table 4-13 provides the annual transportation costs in total and for the at-sea and in-port portions. The transportation cost saving benefit is provided in Table 4-14. The AAEQ transportation costs and cost saving benefits are provided in Table 4-15. AAEQ cost statistics are provided in Table 4-16.

Table 4-13. Origin-Destination Annual Transportation Cost (in Thousand $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Thousand $)						
Year	**FWOPC**	**FWPC (41')**	**FWPC (43')**	**FWPC (45')**	**FWPC (47')**	**FWPC (49')**
2024	**$135,130**	**$123,555**	**$117,464**	**$112,844**	**$109,982**	**$109,595**
2025	$136,602	$124,634	$118,479	$113,896	$111,012	$110,574
2026	$138,073	$125,714	$119,493	$114,949	$112,043	$111,553
2027	$139,545	$126,793	$120,507	$116,002	$113,073	$112,532
2028	$141,016	$127,872	$121,522	$117,055	$114,103	$113,511
2029	$142,488	$128,952	$122,536	$118,107	$115,133	$114,490
2030	$143,959	$130,031	$123,551	$119,160	$116,163	$115,469
2031	$145,431	$131,111	$124,565	$120,213	$117,193	$116,449
2032	$146,902	$132,190	$125,580	$121,266	$118,223	$117,428
2033	$148,374	$133,269	$126,594	$122,318	$119,254	$118,407
2034	**$148,689**	**$133,626**	**$126,935**	**$122,598**	**$119,147**	**$118,372**
2035	$149,004	$133,983	$127,276	$122,878	$119,040	$118,338
2036	$149,318	$134,340	$127,616	$123,158	$118,933	$118,304
2037	$149,633	$134,696	$127,957	$123,437	$118,826	$118,269
2038	$149,948	$135,053	$128,298	$123,717	$118,719	$118,235
2039	$150,263	$135,410	$128,639	$123,997	$118,612	$118,201
2040	$150,578	$135,766	$128,979	$124,277	$118,506	$118,166
2041	$150,893	$136,123	$129,320	$124,556	$118,399	$118,132
2042	$151,207	$136,480	$129,661	$124,836	$118,292	$118,098
2043-2073	**$151,522**	**$136,837**	**$130,002**	**$125,116**	**$118,185**	**$118,063**
At-Sea Transportation Cost Allocated to Port (Thousand $)						
Year	**FWOPC**	**FWPC (41')**	**FWPC (43')**	**FWPC (45')**	**FWPC (47')**	**FWPC (49')**

2024	**$130,198**	**$119,043**	**$113,060**	**$108,554**	**$105,759**	**$105,362**
2025	$131,614	$120,069	$114,027	$109,558	$106,740	$106,292
2026	$133,031	$121,094	$114,993	$110,562	$107,721	$107,223
2027	$134,448	$122,120	$115,959	$111,566	$108,702	$108,153
2028	$135,864	$123,146	$116,925	$112,570	$109,684	$109,083
2029	$137,281	$124,171	$117,892	$113,574	$110,665	$110,013
2030	$138,698	$125,197	$118,858	$114,578	$111,646	$110,943
2031	$140,114	$126,222	$119,824	$115,582	$112,627	$111,873
2032	$141,531	$127,248	$120,790	$116,586	$113,608	$112,803
2033	$142,948	$128,274	$121,757	$117,590	$114,590	$113,733
2034	**$143,244**	**$128,600**	**$122,066**	**$117,841**	**$114,459**	**$113,676**
2035	$143,541	$128,926	$122,376	$118,093	$114,329	$113,620
2036	$143,838	$129,252	$122,685	$118,344	$114,199	$113,564
2037	$144,134	$129,577	$122,995	$118,595	$114,069	$113,508
2038	$144,431	$129,903	$123,305	$118,846	$113,939	$113,451
2039	$144,728	$130,229	$123,614	$119,098	$113,809	$113,395
2040	$145,024	$130,555	$123,924	$119,349	$113,679	$113,339
2041	$145,321	$130,881	$124,233	$119,600	$113,549	$113,283
2042	$145,618	$131,207	$124,543	$119,852	$113,418	$113,226
2043-2073	**$145,914**	**$131,533**	**$124,853**	**$120,103**	**$113,288**	**$113,170**
In-Port Transportation Costs (Thousand $)						
Year	**FWOPC**	**FWPC (41')**	**FWPC (43')**	**FWPC (45')**	**FWPC (47')**	**FWPC (49')**
2024	**$4,933**	**$4,512**	**$4,404**	**$4,290**	**$4,223**	**$4,232**
2025	$4,988	$4,566	$4,452	$4,338	$4,272	$4,281
2026	$5,042	$4,619	$4,500	$4,387	$4,321	$4,331
2027	$5,097	$4,673	$4,548	$4,436	$4,370	$4,380
2028	$5,152	$4,727	$4,596	$4,485	$4,419	$4,429
2029	$5,207	$4,781	$4,645	$4,533	$4,468	$4,478
2030	$5,262	$4,834	$4,693	$4,582	$4,517	$4,527
2031	$5,317	$4,888	$4,741	$4,631	$4,566	$4,576
2032	$5,372	$4,942	$4,789	$4,680	$4,615	$4,625
2033	$5,426	$4,996	$4,837	$4,728	$4,664	$4,674
2034	**$5,445**	**$5,026**	**$4,869**	**$4,757**	**$4,687**	**$4,696**
2035	$5,463	$5,057	$4,900	$4,785	$4,711	$4,718
2036	$5,481	$5,088	$4,931	$4,814	$4,734	$4,740
2037	$5,499	$5,119	$4,962	$4,842	$4,757	$4,762
2038	$5,517	$5,150	$4,993	$4,871	$4,780	$4,784
2039	$5,535	$5,180	$5,024	$4,899	$4,804	$4,806
2040	$5,553	$5,211	$5,056	$4,928	$4,827	$4,828

2041	$5,571	$5,242	$5,087	$4,956	$4,850	$4,850
2042	$5,590	$5,273	$5,118	$4,984	$4,873	$4,872
2043-2073	$5,608	$5,303	$5,149	$5,013	$4,897	$4,893

Table 4-14. Annual Transportation Cost Savings by Channel Depth (in Thousands)

At-Sea and In-Port Transportation Cost Saving Benefits (Thousand $)					
Year	**FWP (41)**	**FWP (43)**	**FWP (45)**	**FWP (47)**	**FWP (49)**
2024	**$11,575**	**$17,666**	**$22,286**	**$25,148**	**$25,535**
2025	$11,967	$18,123	$22,705	$25,589	$26,028
2026	$12,360	$18,580	$23,124	$26,031	$26,520
2027	$12,752	$19,037	$23,543	$26,472	$27,013
2028	$13,144	$19,494	$23,962	$26,913	$27,505
2029	$13,536	$19,952	$24,380	$27,355	$27,997
2030	$13,928	$20,409	$24,799	$27,796	$28,490
2031	$14,320	$20,866	$25,218	$28,238	$28,982
2032	$14,712	$21,323	$25,637	$28,679	$29,475
2033	$15,105	$21,780	$26,056	$29,120	$29,967
2034	**$15,063**	**$21,754**	**$26,091**	**$29,542**	**$30,316**
2035	$15,021	$21,728	$26,126	$29,964	$30,666
2036	$14,979	$21,702	$26,161	$30,385	$31,015
2037	$14,937	$21,676	$26,196	$30,807	$31,364
2038	$14,895	$21,650	$26,231	$31,229	$31,713
2039	$14,853	$21,624	$26,266	$31,650	$32,062
2040	$14,811	$21,598	$26,301	$32,072	$32,411
2041	$14,769	$21,572	$26,336	$32,494	$32,760
2042	$14,727	$21,546	$26,371	$32,915	$33,110
2043-2073	**$14,686**	**$21,521**	**$26,406**	**$33,337**	**$33,459**
At-Sea Transportation Cost Saving Benefits (Thousand $)					
Year	**FWP (41)**	**FWP (43)**	**FWP (45)**	**FWP (47)**	**FWP (49)**
2024	**$11,154**	**$17,137**	**$21,643**	**$24,439**	**$24,835**
2025	$11,545	$17,588	$22,056	$24,874	$25,322
2026	$11,937	$18,038	$22,469	$25,310	$25,808
2027	$12,328	$18,488	$22,881	$25,745	$26,295
2028	$12,719	$18,939	$23,294	$26,181	$26,782
2029	$13,110	$19,389	$23,707	$26,616	$27,268
2030	$13,501	$19,840	$24,120	$27,052	$27,755
2031	$13,892	$20,290	$24,532	$27,487	$28,242

2032	$14,283	$20,740	$24,945	$27,923	$28,728
2033	$14,674	$21,191	$25,358	$28,358	$29,215
2034	**$14,645**	**$21,178**	**$25,403**	**$28,785**	**$29,568**
2035	$14,615	$21,165	$25,448	$29,212	$29,921
2036	$14,586	$21,152	$25,494	$29,639	$30,274
2037	$14,557	$21,139	$25,539	$30,065	$30,627
2038	$14,528	$21,126	$25,585	$30,492	$30,980
2039	$14,498	$21,114	$25,630	$30,919	$31,333
2040	$14,469	$21,101	$25,675	$31,346	$31,686
2041	$14,440	$21,088	$25,721	$31,773	$32,039
2042	$14,411	$21,075	$25,766	$32,199	$32,391
2043-2073	**$14,381**	**$21,062**	**$25,812**	**$32,626**	**$32,744**
In-Port Transportation Cost Saving Benefits (Thousand $)					
Year	**FWP (41)**	**FWP (43)**	**FWP (45)**	**FWP (47)**	**FWP (49)**
2024	**$421**	**$529**	**$643**	**$709**	**$700**
2025	$422	$536	$649	$715	$706
2026	$423	$542	$655	$721	$712
2027	$424	$549	$661	$727	$718
2028	$425	$556	$668	$733	$723
2029	$426	$562	$674	$739	$729
2030	$427	$569	$680	$745	$735
2031	$428	$576	$686	$751	$741
2032	$430	$582	$692	$756	$746
2033	$431	$589	$698	$762	$752
2034	**$418**	**$576**	**$688**	**$757**	**$748**
2035	$405	$563	$677	$752	$745
2036	$393	$550	$667	$747	$741
2037	$380	$537	$657	$742	$737
2038	$368	$524	$646	$737	$733
2039	$355	$511	$636	$732	$729
2040	$342	$498	$626	$726	$726
2041	$330	$485	$615	$721	$722
2042	$317	$472	$605	$716	$718
2043-2073	**$304**	**$459**	**$595**	**$711**	**$714**

Table 4-15. AAEQ Transportation Cost Reduction Benefit by Alternative

Alt A	AAEQ Transportation Cost	AAEQ Transportation Cost Reduction Benefit
FWOPC	$147,380,000	-
41’	$133,220,000	$14,160,000
43’	$126,577,000	$20,802,000
45’	$121,902,000	$25,478,000
47’	$116,789,000	$30,590,000
49’	$116,428,000	$30,952,000

Table 4-16. AAEQ Transportation Cost Statistics

Statistic	FWOPC	Alt A - 41’	Alt A - 43’	Alt A - 45’	Alt A - 47’	Alt A - 49’
Mean	$147,379,534	$133,219,659	$126,577,055	$121,901,524	$116,789,272	$116,427,830
SD	$904,501	$885,420	$936,192	$973,225	$814,459	$734,929
Median	$147,278,508	$133,204,696	$126,612,544	$121,883,310	$116,886,168	$116,390,115
Min	$145,061,544	$130,455,327	$123,843,890	$119,269,186	$114,884,263	$114,828,599
Max	$149,565,417	$135,067,679	$129,334,056	$124,137,110	$118,923,027	$118,745,549
Range	$4,503,873	$4,612,352	$5,490,165	$4,867,924	$4,038,763	$3,916,950
Confidence of Mean +/-	$177,282	$173,542	$183,494	$190,752	$159,634	$144,046
Note: Confidence calculation assumes a normal distribution and 95% confidence level.						

4.3 Transportation Cost Savings Benefit Analysis

A summary of project first cost by alternative is provided in Table 4-17 below. Only the costs for the 41’, 47’, and 51’ MLLW were calculated by cost engineering. Costs (and durations) between the three depths displayed in the table were interpolated assuming a linear relationship. Navigation costs include the associated costs, which will be paid by the non-Federal sponsor, that are necessary to realize project benefits. Between the depths of 41’ and 47’, berth deepening will be required and is considered an associated cost. After 47’ MLLW, dock modifications are required in order to deepen berths. The costs to modify docks and deepen berths are included in the navigation costs for the 51’ alternative.

Table 4-17. Project Cost Estimate by Depth

Construction Item	Cost at 41’	Cost at 47’	Cost at 51’
01 - Lands and Damages	$162,500	$162,500	$162,500
02 - Relocations	$57,694,675	$57,694,675	$57,694,675
06 - Fish and Wildlife	$26,055,650	$26,055,650	$26,055,650
12 - Navigation	$227,651,900	$323,605,475	$417,135,875
Subtotal	$311,564,725	$407,518,300	$501,048,700
Construction Management (E&D, S&A)	$43,596,300	$57,029,800	$70,124,075
TOTAL PROJECT FIRST COST	**$355,161,000**	**$464,548,100**	**$571,172,775**
E&D – Engineering and Design, S&A - Supervision and Administration			

The economic cost summary, including project first cost, Interest During Construction (IDC), total investment costs, Operations, Maintenance, Repair and Replacement (OMRR&R) costs, and annualized total costs are presented in Table 4-18. The OMRR&R costs presented are an estimate of the difference in existing OMRR&R costs and the with-project OMRR&R costs and are held constant for all alternative depths. Note that the 51’ alternative depth was not modeled because incremental net benefits became negative at the 49’ depth (as shown in Table 4-19).

Table 4-18. AAEQ Cost Summary (in thousands, Oct 2017 prices, 2.75% discount rate)

Alt A	Project Costs	IDC	Total Investment	AAEQ Total Investment	AAEQ OMRR&R	Total AAEQ	Incremental AAEQ Costs
41’	$355,161	$14,853	$370,014	$13,706	$6,000	$19,706	-
43’	$391,623	$17,492	$409,115	$15,154	$6,000	$21,154	$1,448
45’	$428,086	$20,131	$448,216	$16,602	$6,000	$22,602	$1,448
47’	$464,548	$22,770	$487,318	$18,051	$6,000	$24,051	$1,449
49’	$517,860	$29,549	$547,409	$20,277	$6,000	$26,277	$2,226

The results of transportation cost savings benefit analysis are annualized and displayed in Table 4-19. These annualized benefits are compared with the annualized costs to calculate net benefits and select the NED plan. As displayed in the table, net benefits are negative in the 41' and 43' alternative. Net benefits become positive at 45' and maximize at 47' before again becoming negative at 49', resulting in an NED plan of deepening the channel to 47' MLLW.

Table 4-19. Summary of Economic Analysis (in thousands, Oct 2017 prices, 2.75% discount rate)

Alt A	Alternative Depth	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	Benefit/Cost Ratio
41'	**FWPC (41')**	$19,706	$14,160	($5,546)	-	0.7
43'	**FWPC (43')**	$21,154	$20,802	($352)	$5,194	1.0
45'	**FWPC (45')**	$22,602	$25,478	$2,876	$3,228	1.1
47'	**FWPC (47')**	$24,051	$30,590	$6,539	$3,663	1.3
49'	**FWPC (49')**	$26,277	$30,952	$4,675	($1,864)	1.2

5 Sensitivity Analysis

The principle & Guidelines and subsequent ER1105-2-100 recognize the inherent variability to water resources planning. Navigation projects are subject to various uncertainties about future conditions. Therefore, a sensitivity analysis in which key quantitative assumptions and computations are changed is required to assess their effect on the final outcome. Sensitivity analysis will be completed for this study following the TSP milestone. Sensitivity analysis will be completed, at a minimum, to evaluate the effects of the commodity forecast on the selected plan. Results will be presented in this section.

6 Multiport Analysis

Multiport impacts, or the potential effects the deepening of the Matagorda Ship Channel could have on other ports, were assessed qualitatively for this study. Multiport analysis is necessary to consider, because with-project alternatives could induce regional transfer of cargo among competing ports. Therefore, it must be determined to what extent competition exists and how it impacts the with- and without-project conditions.

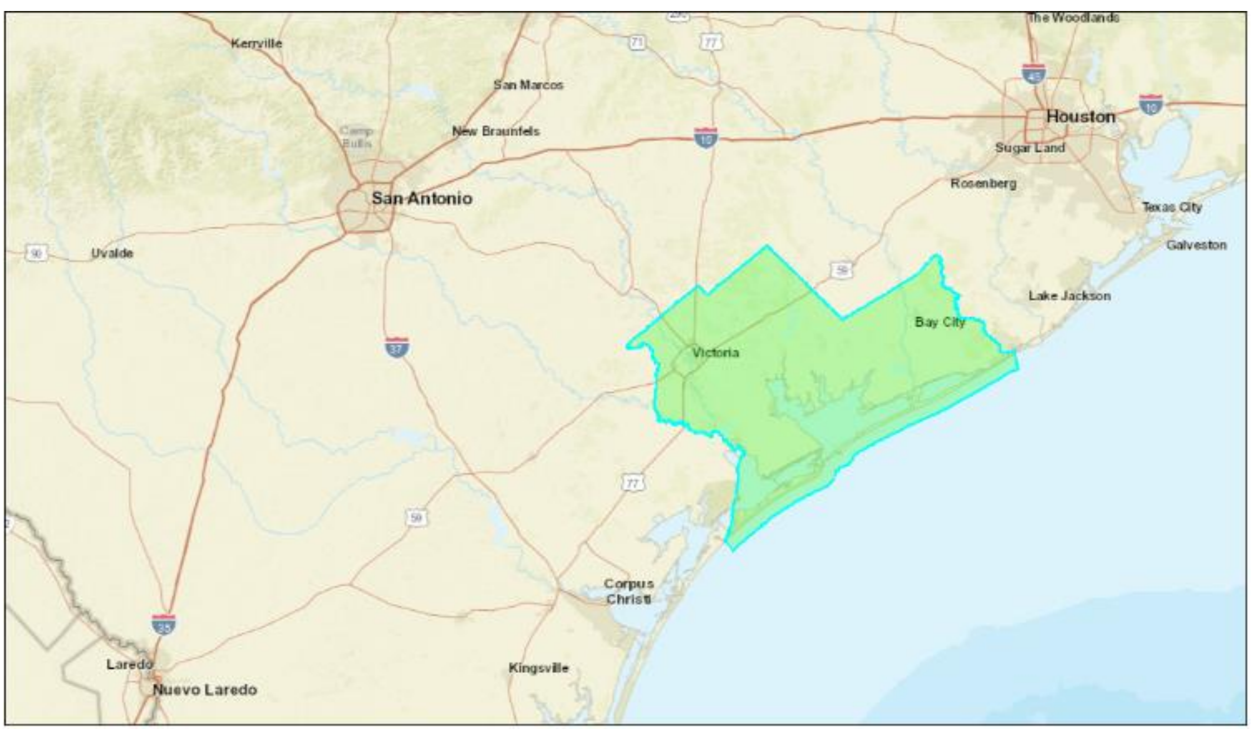
In multiport analysis, port hinterlands must be defined as either captive or competitive. Competitive cargo hinterlands are those in which there is a choice between ports for the origin or destination of cargo. Captive cargo hinterlands will use the study port exclusively for either origin or destination. The historical users of the Matagorda Ship Channel, such as Formosa, Invista, and INEOS, have a long history at the port and have facilities and infrastructure in close proximity to the Port. Though there are several ports along the Texas Gulf Coast that handle similar types of cargo to the Port of Point comfort, the Port has historically had a captive cargo hinterland, with its onsite/nearby channel users exclusively utilizing the Matagorda Ship Channel to receive and ship chemical products to and from their facilities.

The new users of the channel who are beginning to export crude oil via the MSC create more of a competitive cargo hinterland at the Port, because there are multiple ports along the Texas Gulf Coast that are equipped to export crude oil. However, these new channel users have recently made considerable investments in their facilities at Point Comfort. The recommended plan is intended to allow these users to more efficiently move cargo, either by loading vessels deeper or using larger vessels. There are many factors may influence the growth of a particular harbor: landside development and infrastructure, location of distribution centers for imports, source locations for exports, population and income growth and location, port logistics and fees, business climate and taxes, carrier preferences, labor stability and volatility, and business relationships. Though the deepening and widening may make the Port of Point Comfort a more desirable location for shippers in the future, it is not expected that the recommended plan will cause a shift in traffic from nearby ports.

7 Socioeconomic Analysis

The socioeconomics of the community surrounding the Matagorda Ship Channel and the Port of Point Comfort are summarized in this section. This section will describe the socioeconomics and demographics of the four counties that surround the Port, which are Calhoun, Jackson, Victoria, and Matagorda Counties in Texas. These four counties will be referred to as the "Matagorda Ship Channel (MSC) region" in this section of the appendix. The MSC region is pictured in Figure 7-1. The parameters used to describe the demographics and socioeconomics environment include population trends, private sector employment, and wage earnings. Other social characteristics such as race composition, age distribution, and poverty will be examined in order to recognize any potential environmental justice issues that the improvement project may induce.

Figure 7-1. Socioeconomic Area of Interest



7.1 Overview

The economies of Calhoun, Victoria, Jackson, and Matagorda counties are based primarily on the petrochemical industry, commercial fishing, agriculture and livestock, construction, and mineral extraction. Tourism and recreation, including hunting, fishing, and boating also play a significant economic role. Calhoun County is also home to large industrial facilities, including the Carbon/Graphite Group, Union Carbide, and INEOS Nitriles, as well as assorted smaller industry supportive firms.

7.1.1 Population

The state of Texas is ranked as the second largest state in terms of resident population as of the 2010 census, with 25.1 million residents. Population estimates for the state of Texas and the MSC region are displayed in Table 7-1 below. As of 2010, the population estimate for the MSC region was just under 159,000. Between 2000 and 2016, Texas' population experienced a 29% growth, while the MSC region experienced a 5% growth. The state is expected to grow by 50% between 2016 and 2050 while the MSC region grows by 24%.

Table 7-1. Population Estimates and Projections (2000, 2016, 2050)

Geographical Area	2000 Population Estimate	2010 Population Estimate	2016 Population Estimate	2050 Population Projection
Texas	20,851,820	25,145,561	26,956,435	40,502,749
Calhoun County	20,647	21,381	21,805	31,666
Jackson County	14,391	14,075	14,678	15,649
Matagorda County	37,957	36,702	36,719	44,774
Victoria County	84,088	86,793	90,989	110,868
MSC Region Total	**157,083**	**158,951**	**164,191**	**202,957**
Source: U.S. Census Bureau, Population Division (2000, 2010 Estimates); U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates (2016 Estimate); Texas State Data Center, The University of Texas at San Antonio (2050 Projections)				

7.1.2 Employment by Industry

The labor force by industry is characterized in Table 7-2. The largest majority of the MSC region is employed in the Educational services, and health care and social assistance sector at 22%, followed by the Manufacturing sector (14%), the Retail trade sector (12%), and the Construction sector (9%). The Arts, entertainment, and recreation, and accommodation and food services sector, the Professional, scientific, and management, and administrative, and waste management services sector, and the Agriculture, forestry, fishing and hunting, and mining sector each employ between 7 and 8% of the population. The remaining sectors each employ 5% or less of the MSC region population.

Table 7-2. Employment by Sector

Industry	Texas	Calhoun County	Jackson County	Matagorda County	Victoria County	MSC Region
Agriculture, forestry, fishing and hunting, and mining	3.3%	6.1%	11.5%	6.3%	7.3%	7.3%
Construction	8.0%	12.0%	10.0%	10.4%	8.1%	9.3%
Manufacturing	8.9%	25.1%	19.2%	12.0%	11.3%	13.9%
Wholesale trade	3.0%	3.1%	0.6%	2.4%	2.9%	2.6%
Retail trade	11.5%	8.7%	9.0%	11.2%	13.7%	12.1%
Transportation and Warehousing, and utilities	5.5%	2.6%	7.1%	10.1%	4.3%	5.6%
Information	1.8%	0.5%	0.6%	0.6%	0.6%	0.6%
Finance and insurance, and real estate and rental and leasing:	6.6%	4.3%	4.5%	2.5%	4.7%	4.1%
Professional, scientific, and management, and administrative, and waste management services	11.2%	9.4%	5.5%	9.0%	7.5%	7.9%
Educational services, and health care and social assistance	21.6%	18.9%	18.6%	21.1%	22.8%	21.6%
Arts, entertainment, and recreation, and accommodation and food services	9.0%	4.7%	7.0%	7.3%	8.0%	7.4%
Other services, except public administration	5.3%	2.5%	3.3%	5.3%	5.2%	4.7%
Public administration	4.2%	2.0%	3.2%	1.8%	3.5%	2.9%
Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates (2016 Estimate)						

7.1.3 Income and Poverty

Median household and per capita incomes for selected counties in 2016 are displayed in Table 7-3. The median household incomes within the MSC region were comparable to the state of Texas in 2016. The only county within the MSC region whose median household income was substantially below the state's median of $54,727 was Matagorda County, which had a median household income of $41,253. In terms of per capita income, the MSC region's incomes were slightly below that of the state, which had a median income of $27,828. Per capita incomes in the MSC region ranged from $22,939 in Matagorda County to $27,509 in Victoria County.

Also displayed in the table is the percentage of individuals and families whose incomes were below the poverty level within the last twelve months. Two of the four counties in the MSC region, Calhoun and Matagorda, had a greater percentage of both families and people with incomes below the poverty level when compared to the state of Texas.

Table 7-3. Median, Per Capita Income and Poverty Data (2016)

Geographical Area	Median Household Income	% of Families with Incomes Below Poverty Level (Last 12 months)	Per Capita Income	% of People with Incomes Below Poverty Level (Last 12 months)
Texas	$54,727	13.0%	$27,828	16.7%
Calhoun County	$54,167	14.4%	$25,181	18.1%
Jackson County	$56,601	8.8%	$25,594	13.0%
Matagorda County	$41,253	18.3%	$22,939	21.7%
Victoria County	$54,697	11.1%	$27,509	14.7%
Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates (2016 Estimate)				

7.1.4 Labor Force and Employment

Details on the labor force and unemployment rates are displayed in Table 7-4 below. The 2016 annual average unemployment rate in Texas was 4.6%. The unemployment rates in the counties surrounding the project area were slightly higher. The annual average unemployment rate was 5.6% in Calhoun County, 4.8% in Jackson County, 7.4% in Matagorda County, and 5.4% in Victoria County.

Table 7-4. Labor Force, Employment and Unemployment Rates (2016 Annual Averages)

Geographic Area	Civilian Labor Force	Number Employed	Number Unemployed	Unemployment Rate
Texas	13,294,000	12,688,000	606,000	4.6%
Calhoun County	10,815	10,213	602	5.6%
Jackson County	7,246	6,900	346	4.8%
Matagorda County	16,833	15,587	1,246	7.4%
Victoria County	43,919	41,558	2,361	5.4%

Source: Bureau of Labor Statistics, Current Population Survey (State estimate, 2016), LAUS (County estimates, 2016)

7.1.5 Race and Ethnicity

Table 7-5 displays race and ethnicity for the comparative geographies. Within the MSC region, 47% of the population is White, 6% is Black, 43% is Hispanic or Latino, 2% is Asian, and 1% is two or more races. By comparison, within the state of Texas, 43% of the population is White, 12% is Black, 39% is Hispanic or Latino, 4% is Asian, and 2% is two or more races. In general, the MSC region has a slightly smaller minority population than that of Texas.

Table 7-5. Racial Composition by Geographical Area (2016)

Geographical Area	White	Black	American Indian and Alaska Native alone	Asian alone	Native Hawaiian and Other Pacific Islander alone	Some other race alone	Two or more races	Hispanic or Latino
Texas	11,705,684	3,134,962	63,336	1,161,742	18,990	35,509	423,062	10,413,150
Calhoun County	9,518	594	9	1,006	40	0	206	10,432
Jackson County	8,803	1030	0	29	10	6	160	4,640
Matagorda County	16,681	3,776	99	778	86	0	372	14,927
Victoria County	41,882	5,166	95	1183	0	113	1178	41,372
MSC Region Total	**76,884**	**10,566**	**203**	**2,996**	**136**	**119**	**1,916**	**71,371**
Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates (2016 Estimate)								

7.1.6 Age

The distribution of population by age group is displayed in Table 7-6 for both the MSC region and the state of Texas. The age distribution among the two regions is similar. The MSC region has a slightly larger population ages 65 and over when compared to the state of Texas. 15% of the MSC region's population is was 65 or over in 2016 compared to 11% of the state's population.

Table 7-6. Population by Age Group (2016)

Geographical Area	Age Group												
	<5	5 - 9	10 - 14	15 - 19	20 - 24	25 - 34	35 - 44	45 - 54	55 - 59	60 - 64	65 - 74	75 - 84	85 and over

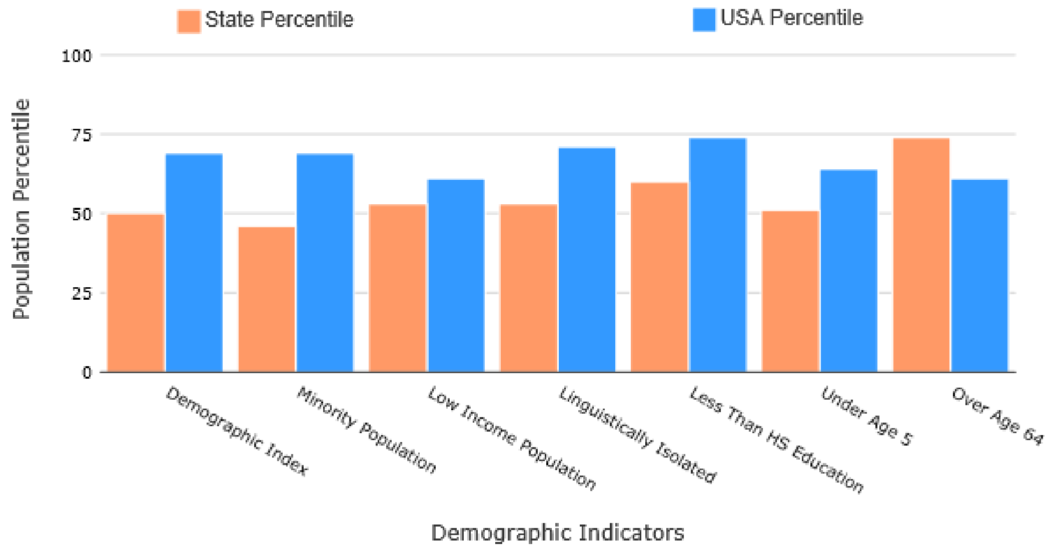
Texas	7%	7%	7%	7%	7%	15%	14%	13%	6%	5%	7%	3%	1%
Calhoun County	7%	8%	7%	7%	5%	13%	11%	13%	7%	6%	9%	5%	2%
Jackson County	7%	7%	7%	7%	5%	12%	12%	12%	8%	6%	9%	5%	2%
Matagorda County	7%	8%	7%	7%	6%	12%	11%	13%	6%	8%	8%	5%	2%
Victoria County	7%	7%	7%	7%	7%	14%	12%	12%	6%	6%	8%	4%	2%
MSC Region	**7%**	**7%**	**7%**	**7%**	**6%**	**13%**	**12%**	**13%**	**7%**	**6%**	**8%**	**5%**	**2%**
Source: U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates (2016 Estimate)													

7.1.7 Demographic Indicators for Environmental Justice

EJSCREEN is an environmental justice mapping and screening tool that is used by the Environmental Protection Agency (EPA) to obtain and display demographic and environmental information for a given area. The geographic area of interest for the Matagorda Ship Channel project was input in to the EJSCREEN tool, and Figure 7-2 displays the results in terms of six demographic indicators and a demographic index. The demographic indicators shown on the graph are: Percent Low-Income (the percent of an area's population in households where the household income is less than or equal to twice the federal poverty level), Percent Minority (the percent of individuals in an area who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino), Less than high school education (Percent of people age 25 or older in an area whose education is short of a high school diploma), Linguistic isolation (percent of people in households in which all members age 14 years and over speak a non-English language and also speak English less than "very well"), Individuals under age 5, and Individuals over age 64:

As shown in the figure, the MSC region's minority population is at the 46th percentile in the state, meaning that the region's percentage of minority population is equal than 46% of the state. When compared with the U.S., the region is at the 69th percentile. The MSC region is in the 53rd percentile in the state in terms of low income population (61st in the national percentile); it is also in the 53rd percentile in the state in terms of linguistically isolated population (71st in the national percentile); it is in the 60th percentile in terms of population with less than a high school education (74th in the national percentile); 51st in population under the age of five (64th in the national percentile); and 74th in population over age 64 (61st in the national percentile). The demographic index, which is based on the average of two demographic indicators: percent low-income and percent minority, shows that the MSC region is in the 50th percentile when compared to the state and 69th percentile in the nation.

Figure 7-2. Environmental Justice Demographic Indicators for MSC Region



8 Regional Economic Development Analysis

The regional economic development (RED) account measures changes in the distribution of regional economic activity that would result from each alternative plan. Evaluations of regional effects are measured using nationally consistent projection of income, employment, output, and population.

The USACE Online Regional Economic System (RECONS) is a system designed to provide estimates of regional, state, and national contributions of federal spending associated with civil works and American Recovery and Reinvestment Act (ARRA) projects. It provides a means for estimating the forward linked benefits (stemming from effects) associated with non-federal expenditures sustained, enabled, or generated by USACE recreation, navigation, and Formally Utilized Site Remedial Action Program (FUSRAP). Contributions are measured in terms of economic output, jobs, earning, and/or value added.

Once final costs are received for this project, RECONS will be used to perform the regional analysis for the Matagorda Ship Channel deepening and widening, and results will be displayed in this section.

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