U.S. Army Corps of Engineers
Galveston District

Galveston Harbor Channel Extension
Feasibility Study
Houston-Galveston Navigation Channels, Texas

APPENDIX A
ECONOMIC ANALYSIS

U.S. Army Corps of Engineers
Southwestern Division
Galveston District
2016

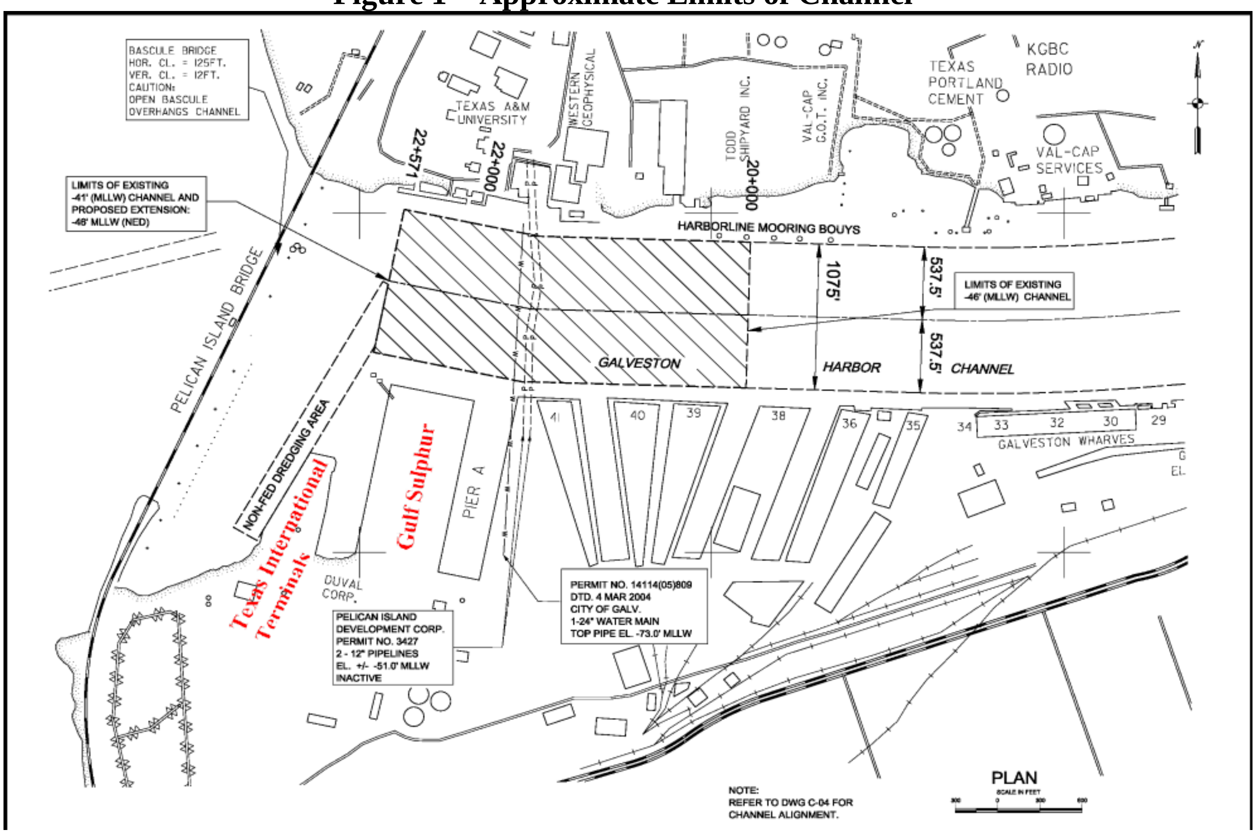
APPENDIX A – ECONOMIC ANALYSIS

Economic Analysis
Galveston Harbor Channel Extension

1.0 Introduction and Purpose

This analysis was conducted to consider the economic feasibility of deepening an additional segment of the Galveston Harbor Channel. A 2007 limited reevaluation confirmed the feasibility of deepening the Galveston Harbor Channel to 46 feet; however, the deepened channel only extends as far as Pier 38. The remainder of the channel has a depth of 41 feet and serves two docks, Gulf Sulphur Services and Texas International Terminals, which handle bulk commodities, such as liquid sulphur, dry sulphur, and barite, among other things, and will benefit from a deeper channel. The un-deepened portion of the channel also serves Port of Galveston Piers 39, 40, and 41, which handle general cargo, but are not routinely subject to draft constraints, and therefore are not considered benefiting by the channel deepening. This analysis focuses on the benefits and costs of deepening the remainder of the channel to a 46-foot depth. Figure 1 shows the approximate limits of the 46-foot channel, the 41-foot channel, and their relation to docks along the channel.

Figure 1 – Approximate Limits of Channel



1.1 Prior Studies

The recent deepening of the Galveston Harbor Channel was initially recommended in the 1987 Galveston Bay Area Navigation Study (GBANS), which evaluated various channel depths on the Houston and Galveston Ship Channels. The environmental complexities of the project required further study and a reevaluation report was completed in 1995. The reevaluation recommended that the Houston and Galveston ship channels be deepened to 46 feet, after determining that the originally recommended 51-foot channel was no longer economically feasible. The Houston Ship Channel was deepened to 46 feet in 2005, but the local sponsor did not have funding available to complete the Galveston channel deepening, so that portion of the project was deferred. The Port of Galveston assumed the role of non-Federal sponsor from the City of Galveston in 2006 and requested that the deepening project be resumed. The 2007 limited reevaluation report (LRR) was conducted to update the economic analysis of the previously recommended and authorized plan. Following the 2007 LRR, the Galveston Harbor Channel was deepened to 46 feet in 2011, with the exception of the last 2,571 feet. A draft Post Authorization Change Report (PACR) was developed in 2010 to evaluate the deepening of the remaining segment up to 46 feet, but was not finalized due to the Houston-Galveston Navigation Channel 902 limit exceedance. The remaining section of the channel is being analyzed in this report under the authorization of Section 216 of the Flood Control Act (FCA) of 1970, P.L. 91-611.

1.2 Basis for the Analysis

Economic benefits can accrue to a navigation project in several ways, because wider and deeper channels reduce the overall cost of transporting goods to markets here and abroad. Wider channels generally reduce delay times that result when vessels are required to pass, and deeper channels allow larger volumes of goods to be transported with each vessel movement, as light-loaded vessels are more fully loaded or smaller vessels are replaced with deeper-drafting vessels.

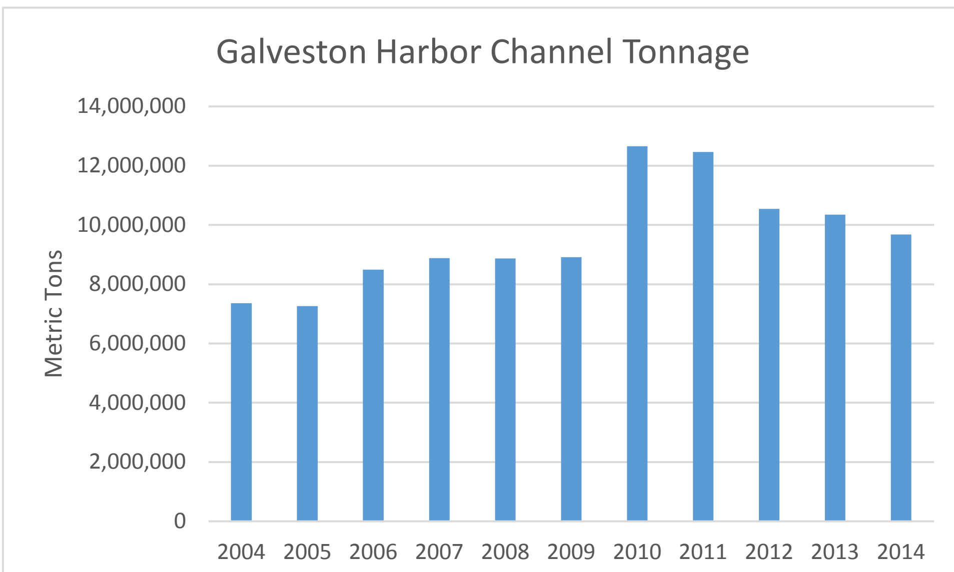
This analysis is focused solely on the economics of deepening the channel. The national economic benefits are a result of lowering the cost of transporting goods to market over the entire period of analysis, which is 50 years in this case (2020-2069). In order to estimate benefits and costs over that time period, a forecast will be made of the commodities to be transported, vessel characteristics and operating costs, and channel dredging and maintenance costs. A Microsoft Excel spreadsheet model was used to calculate benefits in this analysis. The model was first approved for use on 6 June 2012 by Headquarters USACE for the PACR, and on 24 February 2016, the Deep Draft Navigation Planning Center of Expertise (DDN-PCX) endorsed the recommendation to use the model again for this update.

Additional economic impacts may follow from the project in the form of increased employment, tax revenues, and business income, among others. These effects are categorized as regional economic benefits. Regional economic benefits are important in the consideration of local support for a project, but they do not increase the national economic benefits that are used to calculate the benefit-cost ratio (BCR). Because they are not included in the BCR, regional economic benefits have not been calculated at this stage of the analysis.

2.0 Historical and Existing Conditions

Figure 2 graphs total tonnage moving through the entire Galveston Channel between 2004 and 2014. From 2004 to 2009, there were between 8 million and 10 million metric tons moving in all directions (imports and exports) with an upward trend. There was a spike in tonnage in 2010 and 2011 when the amount of imported and exported tonnage was close to 14 million tons each year, largely based on an increase in exports of petroleum and petroleum products. Tonnage amounts leveled out in the following three years when the amount of tons imported and exported has remained between 10 million and 12 million tons.

Figure 2 – Galveston Channel Tonnage (2004-2014)

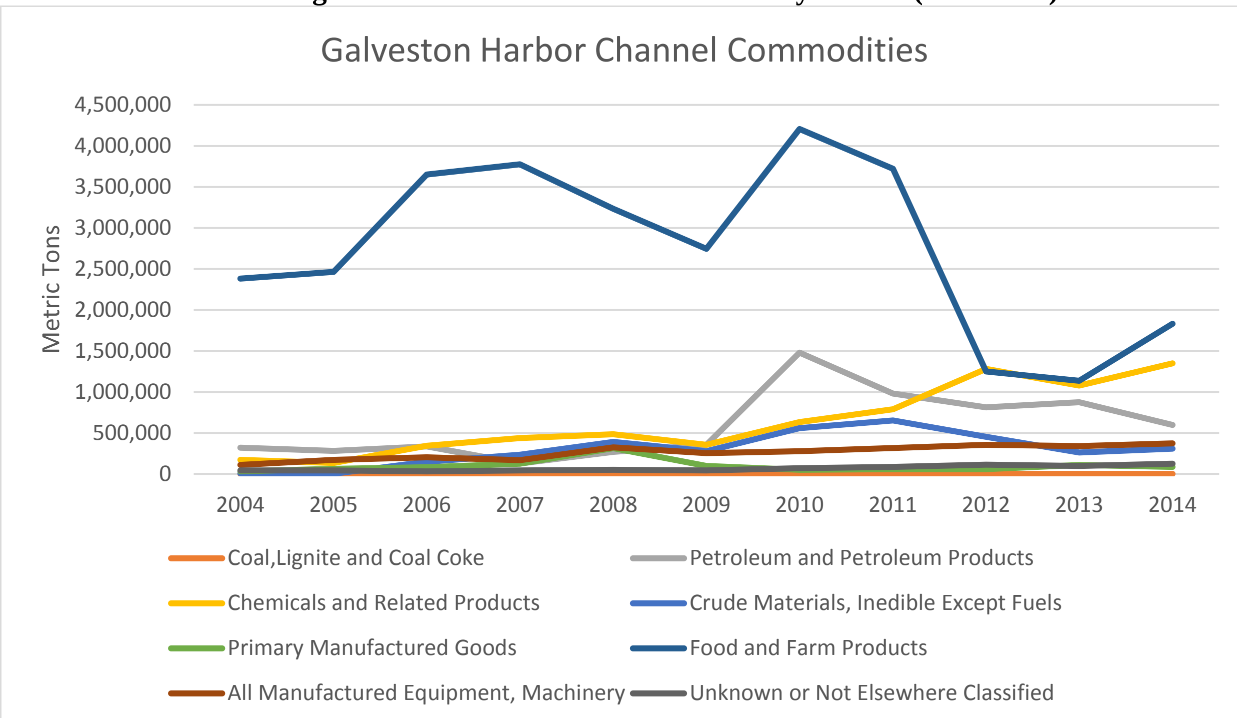


Source: Waterborne Commerce Statistical Center (WCSC)

2.1 Galveston Commodity Trends

Figure 3 displays the trends in foreign imports and exports by commodity group that have moved through Galveston Channel between 2004 and 2014.

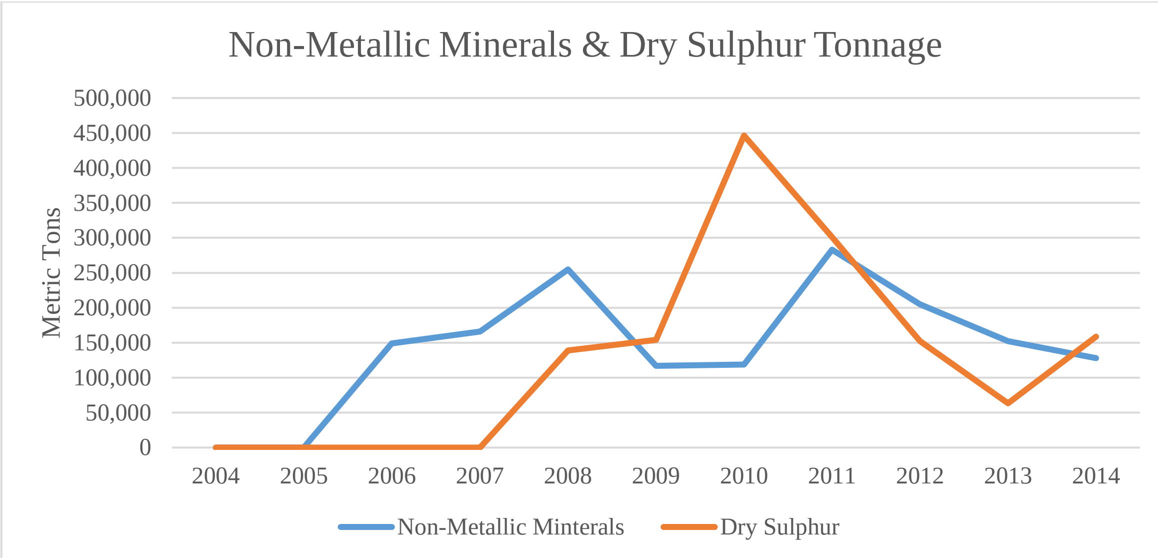
Figure 3 – Galveston Channel Commodity Trends (2004-2014)



Source: Waterborne Commerce Statistical Center (WCSC)

The two commodities that were identified as immediately benefiting from the proposed extension, barite and sulphur, are encompassed in the Crude Materials category from Figure 3 above. Within that category, barite is classified as a non-metallic mineral. These commodities will be discussed in more detail in sections 4.1 and 4.2. Figure 4 graphs the tonnage trends of non-metallic minerals and dry sulphur within Galveston Harbor in the last ten years.

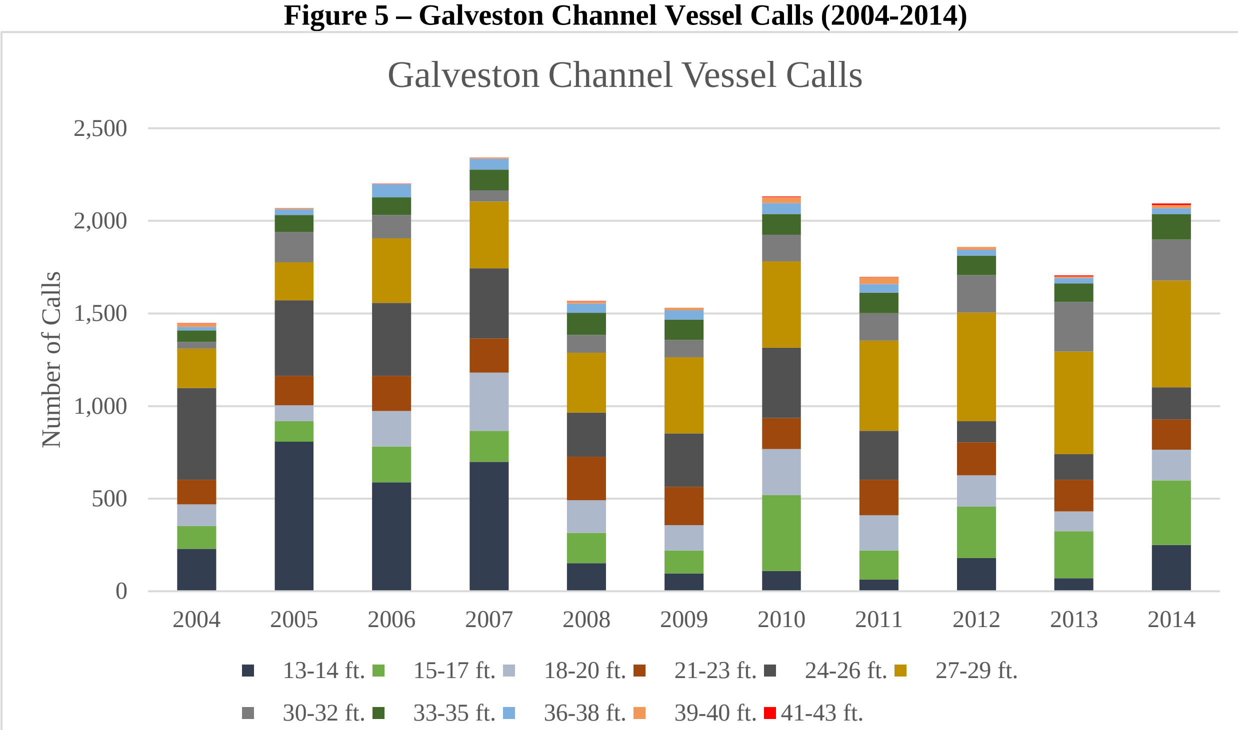
Figure 4 – Galveston Channel Non-Metallic Minerals and Dry Sulphur (2004-2014)



2.2 Galveston Channel Vessel Call Trends

Figure 5 graphs the number of calls by sailing draft to Galveston Harbor for all vessel types between 2004 and 2014, excluding those with drafts of less than 13 feet. Though not a large percentage of total vessel calls in Galveston Harbor, the number of 40 to 43 foot calls have been increasing in Galveston Harbor with the most calls in this category occurring in 2013 and 2014.

Figure 5 – Galveston Channel Vessel Calls (2004-2014)



3.0 Study Reach

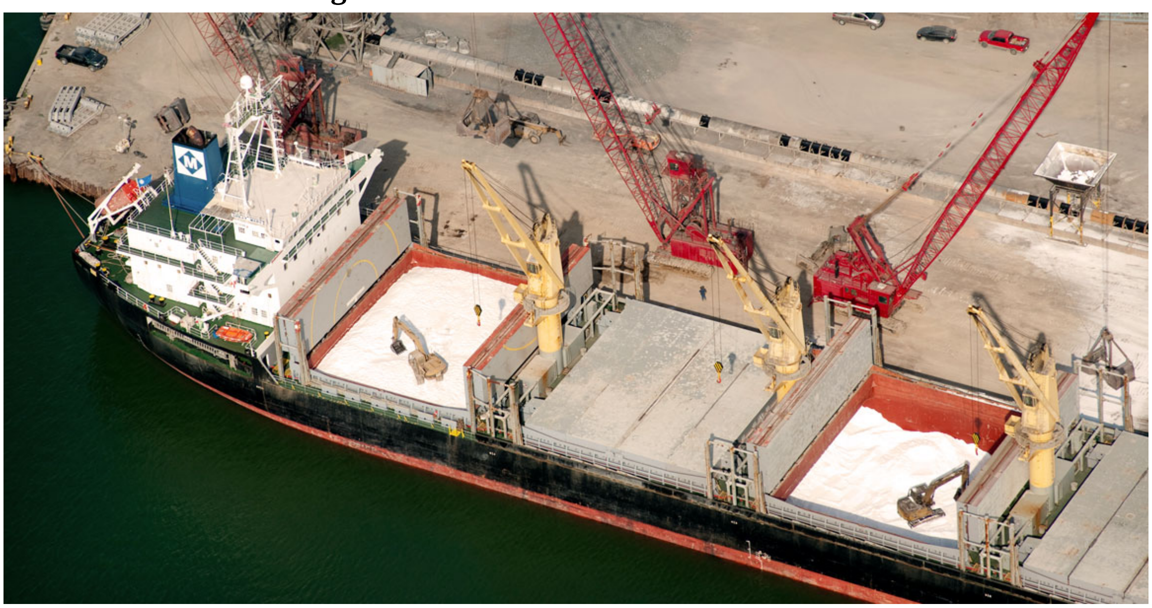
The Galveston Harbor Channel Extension focuses on the most westward end of the Galveston Ship Channel, beginning at Station 20+000 and ending at Station 22+571. There are five docks within the reach that moved 5.6 million metric tons of cargo between 2010 and 2014. Of that tonnage, it was estimated that approximately 152,000 tons could benefit from a deeper channel.

3.1 Commodities and Benefiting Docks

Waterborne Commerce Statistics Center (WCSC) data were examined to identify the commodities that are moving through this segment of the channel. The 1995 reevaluation report indicated that this segment of the channel was not included in the deepening plan because of the lack of shipping activity from facilities along this segment. While piers 39, 40, and 41 show intermittent usage, mostly for general cargo and other goods moved by barge, there is now a sulphur terminal, Gulf Sulphur Services, and a bulk terminal, Texas International Terminals, that demonstrate the largest need for a deeper channel. Between 2010 and 2014, WCSC records show that Texas International Terminals and Gulf Sulphur Services handled approximately 3.2 million and 389,000 metric tons of cargo, respectively.

Texas International Terminals, a portion of which is displayed in Figure 6, handles both liquid products and dry bulk. The terminal has a deep draft berth capable of accommodating vessels with up to a 760 length overall (LOA), 11,000 feet of onsite rail tracks, 350,000 square feet of covered storage capacity for bulk goods, and 325,000 barrels of storage capacity for liquid products.

Figure 6 – Texas International Terminal



Source: http://titerminals.com/

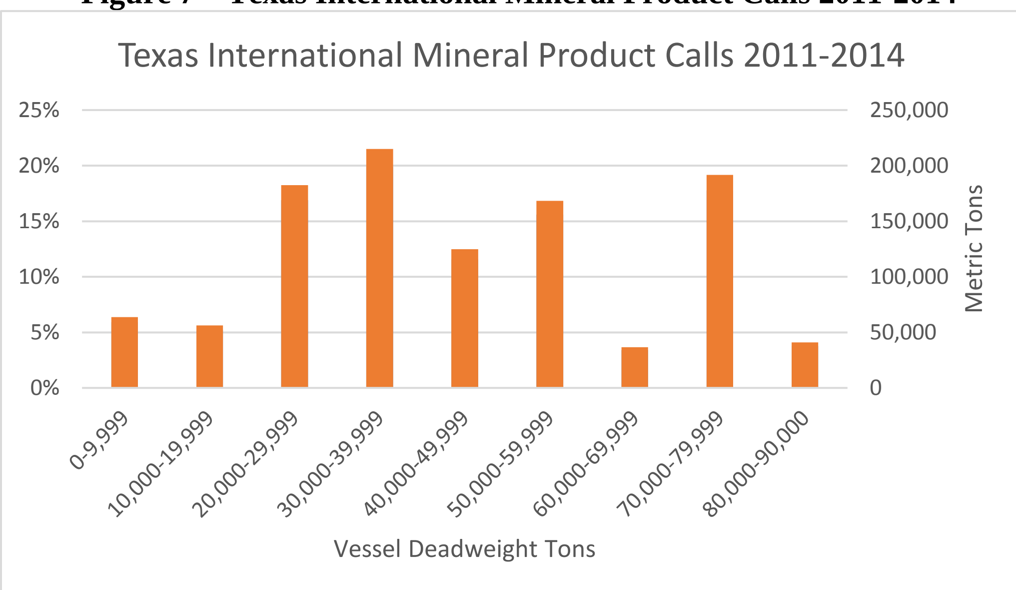
Gulf Sulphur Services is the largest liquid sulphur transportation, storage, and logistics system in the United States. Its terminal in Galveston handles both liquid in dry sulphur and has siqnificant liquid storage and solid facilities with a current capacity of approximately 1.1 million tons per year.

3.2 Vessels

There were 1,063 calls to docks in the extension portion of the channel between the years of 2010 and 2014. These trips were on an assortment of vessel types including bulk carriers, crude/oil products tankers, liquid barges, and general cargo ships with maximum design drafts ranging from 12 to 50.4 feet.

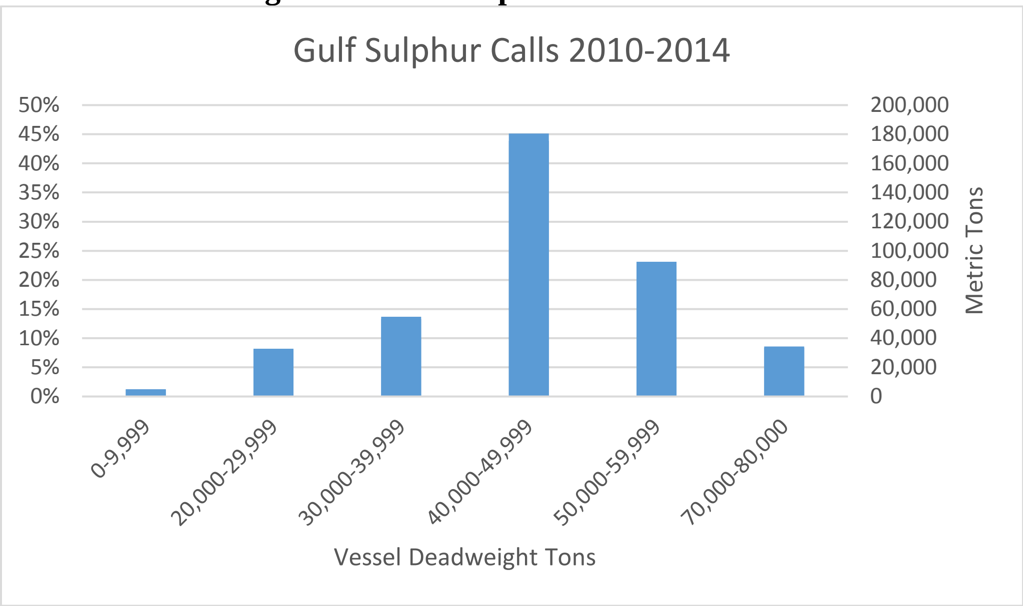
Figures 7 and 8 display the calls to the benefiting terminals carrying the commodity types of interest, barite and sulphur, at Texas International Terminals and Gulf Sulphur Services, respectively. The figures show that there is a vessel fleet mix carrying the commodities of interest. This analysis focuses on the vessels ranging from 40,000-90,000 deadweight tons, as these are the sizes of vessels that could potentially be constrained by the channel depth. Table 7 in section 4.3 describes the characteristics of benefiting vessels in greater detail.

Figure 7 – Texas International Mineral Product Calls 2011-2014



Source: Waterborne Commerce Statistical Center (WCSC)

Figure 8 – Gulf Sulphur Calls 2010-2014



Source: Waterborne Commerce Statistical Center (WCSC)

4.0 Study Reach - Benefitting tonnage summary

In examining the WCSC data from Texas International Terminals between 2011 and 2014 and Gulf Sulphur between 2010 and 2014, it was determined that imports of barite to Texas International Terminals and exports of sulphur from Gulf Sulphur are the two commodities that would currently benefit from the proposed channel deepening. These commodities are routinely shipped on light loaded or fully loaded Panamax vessels.

From the WCSC data, any calls on Panamax vessels (i.e., vessels with design drafts of 39 and above) were considered potentially benefiting. Of these calls, the ones with a sailing draft of 37 or greater were considered light-loaded for purposes of this analysis. Vessels that were fully loaded with design drafts of 39 were also considered to be benefitting under the assumption that this tonnage will shift to a larger vessel in the future. Table 11 in section 4.3 displays a table of the maximum sailing versus the design draft of all Panamax vessels calling at Texas International Terminals and Gulf Sulphur during the aforementioned timeframe.

4.1 Barite

Barite is a non-metallic mineral that is primarily used in the petroleum industry. The mineral has a high specific-weight, which makes it useful as a weighting agent in the drilling mud used when new wells are drilled during oil and gas exploration. Annual U.S. consumption is largely tied to the number of active drilling rigs in any given year. A comparison of the barite consumption levels to active drill rig counts each year from 1998-2008, shows that 76% of the variance in barite consumption is explained by the drill rig counts. This indicates that barite consumption is fairly well correlated to drill rig activity levels.

Table 1 displays annual imports and annual consumption of barite in the U.S. from 2004 to 2014. Annual consumption has hovered around 3 million metric tons annually since 2005, and 96% of annual U.S. consumption is used in oil and gas exploration. Domestic production is centered largely in the Rocky Mountain region and is consumed within that region or exported to Canada. Imports have risen from 2 million metric tons in 2004 to 2.9 million in 2014. Imports comprise approximately 80% of total U.S. consumption. Sixty eight percent of imports come from China; the remaining 32% is imported from various countries. The U.S. barite historical imports was analyzed for its application to a trend line estimation. A historical trend line produced a 1.05% cumulative average growth rate from the United States Geological Survey (USGS) historical data of U.S. barite import.

Table 1 – U.S. Barite Consumption and Imports

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013[e]	2014[e]
Imports	2,000	2,690	2,550	2,600	2,400	1,430	2,110	2,320	2,920	2,240	2,900
Consumption	2,460	3,080	3,070	3,040	2,960	1,780	2,660	2,930	3,430	2,770	3,400
Net import as % of consumption	0.78	0.84	0.81	0.85	0.79	0.78	0.75	0.76	0.81	0.74	0.79
Import growth rate, year over year		34.50%	-5.20%	2.00%	-7.70%	-40.40%	47.60%	10.00%	25.90%	-22.90%	20.00%
Compound Ann Growth, Imports, 2004		34.50%	12.92%	9.14%	4.66%	-6.49%	0.90%	2.14%	4.84%	1.32%	3.05%

Source: USGS 2014 Mineral Commodity Summary - Barite

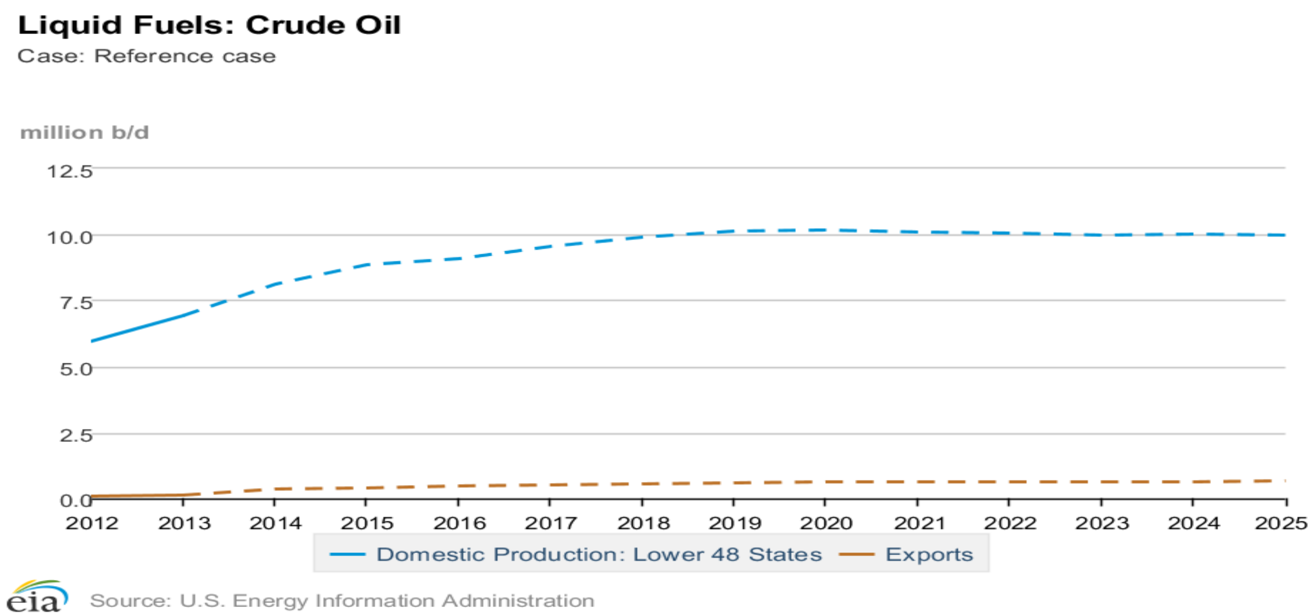
In 2013, the U.S. was the world's leading consumer of barite. Strong demand for barite is driven by domestic production of natural gas and crude petroleum. Oil and gas exploration in the U.S. will require imports of barite from China to the gulf coast of the U.S. Annual volumes will be driven by the active number of drill rigs, which is driven in turn by the market prices of natural gas and crude oil. It is expected that crude oil and natural gas production expectation would be a good proxy for barite imports. The American Energy Outlook 2015 and 2016 was reviewed for their application to the study purposes.

The 2016 Annual Energy Outlook (AEO) expects domestic crude oil and lease condensate production to grow at an annual rate of 0.9% from 2015-2040. The demand for barite in the production function of the crude oil and lease condensates are relatively correlated. The USGS historical patterns of barite produced an annual trend line growth rate of 1.05%, which was used as the median growth rate in this analysis. The 2016 AEO 0.9% growth rate was used as a good practicality check on the growth rate the historical trend provided. The difference between the

2016 AEO 0.9% and USGS historical trend can mostly be attributed to the other drilling operation not considering in the 2016 AEO expectation for crude oil and lease condensates.

Prior to December 2015 there was a ban on U.S. crude oil exports. The ban was lifted last December 2015. The crude oil industry also experienced relatively low crude oil prices late in 2015. The 2015 AEO estimated crude oil production to grow at a rate of 0.1% due to these factors. As shown in Figure 7, the 2015 AEO also expected the effects of removing restrictions on U.S. crude oil exports to produce an annual growth rate of 2.7% and 3.1% on the lower 48 states from (2013-2025). The analysis used the low 0.1% to capture a low price, low expectations on crude oil exports. The analysis then used 1.05% from the USGS historical trend line for the most likely and the 3.1% high growth to capture the scenario of rebounded prices and lifting of the crude oil exports ban.

Figure 9 – Annual Energy Outlook (AEO) Domestic Production Forecast



Galveston bulk terminals has the capacity to continue handling barite, and the access to deep water makes the GSC a rational choice for staging barite and other materials used in Gulf of Mexico oil and gas exploration. Waterborne Commerce (WCSC) records were reviewed back to 1991 and the data show varying volumes of foreign imports and exports of bulk commodities. Beginning in 2006, the operators of the bulk terminal began receiving shipments of barite on light-loaded Panamax vessels. Other materials move through the facility on barges, but it is the light-loaded shipments of barite that are of primary interest in this economic analysis. A review of the detailed WCSC data confirmed that barite increased significantly in 2006, after several years of little or no activity.

For purposes of this evaluation, actual tonnage data at the docks in this segment from 2011 through 2014 were used to establish an estimate of base year tonnage levels, as shown in Table 2. Then, three scenarios were developed for growth over the remainder of the period. The median growth rate scenario was meant to represent the most likely growth rate, and the low and high growth rate scenarios are analyzed to cover uncertainty in the estimates. Between 2011 and 2014, an average of 157, 000 metric tons per year of barite were imported on Panamax vessels. An average of sixty five percent of all shipments traveling to the bulk terminal on Panamax vessels were determined to be subject to draft constraints. These figures are in line with the historical constraints calculated for both 2007 and 2008 (72- and 68-% respectively).

Table 2 – Galveston Channel Extension Barite Tonnage

	2011	**2012**	**2013**	**2014**	**2011-2014**	**2011-2014 Average (Base Tonnage)**
Tonnage	308,339.34	137,843.50	69,752.47	113,031.08	628,966.39	157,241.60
Depth Constrained	208,518.55	132,845.32	6,039.66	64,533.14	411,936.67	102,984.17
% Constrained	68%	96%	9%	57%	65%	65%

Source: Waterborne Commerce Statistical Center (WCSC)

Three rates of growth were used to extrapolate from present levels. At the low end, 0.1% growth rate was used. A median growth rate of 1.05% annually was used as an approximation of the cumulative average growth rate of U.S. barite imports from 2004-2014, shown in table 2 and represents the most likely growth rate based on historical evidence. The high rate is assumed to be correlated with the AEO scenario accounting for the effects of lifting the crude oil export ban, or 3.1%. These rates for the median and high scenarios assume that the bulk terminal would hold onto a constant share of the U.S. import volume. Table 3 displays the forecast volume of bulk imports at the end of each decade during the period of analysis, assuming that 2020 is the first year that a newly deepened channel and associated facilities are in full operation. The forecast displayed in the table applies a constant annual growth rate throughout the period of analysis; however, in calculating benefits, growth was capped at year 25 of the project, or 2044.

Table 3 – Galveston Channel Forecast of Barite Tonnage (metric tons)

Year	Low 0.1%	Median 1.05%	High 3.10%
Base Tonnage	157,242	157,242	157,242
2020	158,188	167,496	189,712
2029	159,617	183,913	248,569
2039	161,220	204,162	337,314
2049	162,840	226,641	457,742
2059	164,475	251,595	621,166
2069	166,128	279,296	842,935

4.2 Sulphur

Elemental sulphur is recovered from petroleum refineries and is used in the production of fertilizer. In 2013, Louisiana and Texas accounted for 54% of domestic production of elemental sulphur, according to USGS.

Figure 10 – Sulphur Operation

Source: http://www.sulphurinstitute.org/

Table 4 below displays U.S. exports of sulphur from 1994-2014. The USGS data shows that despite some volatility year to year, sulphur exports have more than doubled in the past twenty years. As with barite, three growth rates were used to forecast growth from present levels. A zero-percent growth rate was assumed for the low growth scenario. Because the growth rate in the last 10 years has been exceptionally high, the cumulative average growth rate in exports from the last 20 years (1994-2014) as opposed to the past 10 years (2004-2014) was used to calculate a median growth rate. Examination of the USGS data on U.S. exports of Sulphur produced a growth rate of 4.10%. The high growth rate is assumed to be 6.15% to capture the shorter term period trend. The median growth rate is considered the most likely; the low and high growth rates are to account for uncertainty in future volumes.

Table 4 – U.S. Sulphur Exports

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Exports	945,000	962,000	893,000	742,000	940,000	736,000	849,000	780,000	757,000	907,000	1,020,000
Export growth rate, year over year		1.80%	-7.17%	-16.91%	26.68%	-21.70%	15.35%	-8.13%	-2.95%	19.82%	12.46%
Export growth rate, compound			-2.79%	-7.74%	-0.13%	-4.88%	-1.77%	-2.70%	-2.73%	-0.45%	0.77%
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Exports		794,000	716,000	1,030,000	1,040,000	1,510,000	1,520,000	1,420,000	1,910,000	1,830,000	2,050,000
Export growth rate, year over year		-22.16%	-9.82%	43.85%	0.97%	45.19%	0.66%	-6.58%	34.51%	-4.19%	12.02%
Export growth rate, compound		-1.57%	-2.29%	0.66%	0.69%	3.17%	3.02%	2.42%	3.99%	3.54%	3.95%

Source: USGS 2014 Mineral Commodity Summary – Sulphur

There is a terminal within the proposed extension, Gulf Sulphur Services, which is an exporter of both liquid and dry sulphur. Though liquid sulphur shipments have the longest recent record of continuous deep-draft activity on this segment of the Galveston Harbor Channel, these are currently short, domestic trips on 25,000 DWT vessels. The WCSC data displayed in Figure 3 below shows that in 2008, dry sulphur began moving through Galveston Harbor. A portion of this tonnage is international exports from Gulf Sulphur on draft constrained vessels. It is anticipated that exports from Gulf Sulphur are expected to continue and grow in future years. The movement of sulphur is vital to the refining industry as a key product of petrochemical refining in the great Houston-Galveston area.

According to the AEO 2016 petroleum product U.S. imports and exports are expected to grow at 3.0% and 2.1%, respectively. Sulphur is used in fertilizers, normally in the form of ammonium sulphate, where there is a deficiency of sulphur in the soil. Sulphur is also used to make sulphuric acid from sulphur dioxide. Sulphur dioxide is used to make dyes and as a bleaching agent.

There are two key sources of processing sulphur. The first is the Frasch process, where sulphur is extracted from underground without mining it. In the Frasch process, underground deposits of sulphur are forced to the surface using superheated water and steam (to melt the sulphur) and compressed air. This gives molten sulphur, which is allowed to cool in large basins. Purity can reach 99.5%. The process is energy intense. Another source of sulphur is as a by-product of processing crude oil and natural gas, which contain hydrogen sulphide. As the production of crude oil from off the coast, lease condensates from west Texas and natural gas from Oklahoma continue to be refined in the Houston/Galveston region, we should expect that a major by-product, sulphur, will be exported to meet international fertilizer demand.

Specific dock tonnage from WCSC was examined to establish an estimate of base year tonnage levels. Based on detailed WCSC data from 2010-2014, it is estimated that approximately 60,000 metric tons per year of sulphur were exported on Panamax vessels from the Sulphur dock in this reach with an average of 82% of those tons being draft constrained. Table 5 displays actual tonnage, both constrained and unconstrained, being exported from Gulf Sulphur on Panamax vessels between 2010 and 2014.

Table 5 – Galveston Channel Extension Sulphur Tonnage

	2010	2011	2012	2013	2014	2010-2014	2010-2014 Average (Base Tonnage)
Tonnage	81,414.18	81,994.64	76,639.35	-	58,719.12	298,767.29	59,753.46
Depth Constrained	81,414.18	28,081.64	76,639.35	-	58,719.12	244,854.29	48,970.86
% Constrained	100%	34%	100%	-	100%	82%	82%

Source: Waterborne Commerce Statistical Center (WCSC)

Based on the growth rates described above, Table 6 displays the forecast volume of sulphur exports at the end of each decade during the period of analysis, assuming that 2020 is the first year that a newly deepened channel and associated facilities are in full operation. Again, the forecast in the table applies a constant annual growth rate throughout the period of analysis, but growth was capped at year 25 of the project, or 2044, in calculating benefits.

Table 6 – Galveston Channel Forecast of Sulphur Tonnage (metric tons)

Year	Low 0.00%	Median 4.10%	High 6.15%
Base Tonnage	59,753	59,753	59,753
2020	59,753	76,662	87,105
2029	59,753	109,175	146,273
2039	59,753	163,167	265,683
2049	59,753	243,859	482,573
2059	59,753	364,457	876,522
2069	59,753	544,695	1,592,073

4.3 Benefiting Fleet Characteristics

As summarized in Table 7, the vessels involved in the commodity activity of interest mentioned above are generally 50,000 – 85,000 DWT vessels with design drafts of 40-48 feet, measuring 620-752-feet long by 95-106-feet wide.

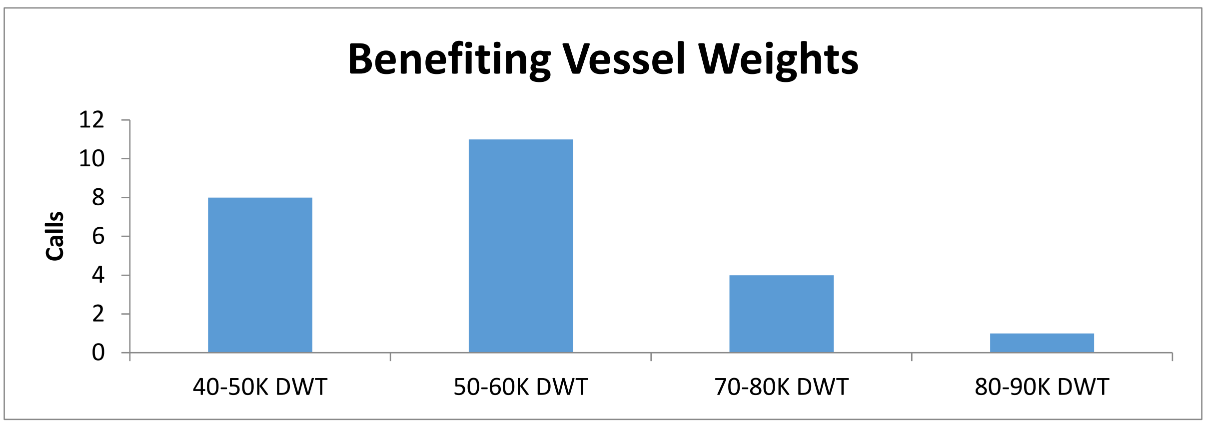
Table 7 – Galveston Channel Extension Benefiting Vessel Characteristics

Vessel DWTs	40,000-49,999	50,000-59,999	70,000-79,999	80,000-89,999
LOA	611.7-653.6	600.4-700.2	738.1-738.2	751.3
Beam	98.4-101.7	101.7-105.8	105.6-105.8	105.8
Design Draft	38.7-39.5	39.4-42.1	44.2-46.5	47.7
Number of Calls	8	11	4	1

Source: Waterborne Commerce Statistical Center (WCSC)

Figure 11 shows that while the largest majority of benefiting calls are from vessels in the 50,000 to 60,000 DWT range followed by the 40,000 to 50,000 DWT range, there are also vessels with 70,000 to 90,000 DWT capacity that are currently using the channel and could benefit immediately from its deepening.

Figure 11 – Galveston Channel Extension Benefiting Vessel Weights



Source: Waterborne Commerce Statistical Center (WCSC)

The existing conditions distribution of these calls tend to center around the 65,000 DWT vessels. In the without project condition it is unlikely that the facilities will utilize the larger DWT vessels with any regularity due to the approximately eight feet of light loading they currently experience. With a deepened channel, it is assumed that the 80,000 DWT vessel is a representative vessel of the total vessel size distribution. It is calling with some frequency in the without project condition, and it will be an average of the more cost efficient vessels calling with significant frequency in the future with project condition.

The routes of existing benefiting vessels were examined to calculate a weighted mileage to be used in calculating the savings per ton under each alternative scenario. Table 8 below displays the regions to and from which the benefiting tonnage is being imported/exported as well as the estimated round-trip mileage from Galveston Harbor, and the weights applied to each.

Table 8 – Galveston Channel Extension Benefiting Mileage

Country/Region	Miles Round Trip	Percent of Benefiting Tonnage
Gulf Coast	1,200	9%
Canada	13,800	15%
South America	13,500	38%
Far East Asia	29,500	23%
Middle East	22,000	15%
Weighted Average	17,390	100%

Source: Waterborne Commerce Statistical Center (WCSC)

Table 9 displays the characteristics of the current representative vessel and the with-project representative vessel. The table presents results for each incremental foot of dredging, showing the cost savings available for channels from 42 to 46 feet in depth. The results were calculated using the aforementioned Microsoft Excel spreadsheet model that was approved on 6 June 2012. Because the with-project vessel is assumed to be the same in each increment, the total voyage costs is the same, but the maximum load is constrained by the depth of the channel, resulting in lower costs per ton as the channel is dredged deeper. As shown in the bottom line, the savings per ton increase from $2.91 for a 42-foot channel to $6.47 for a 46-foot channel.

Table 9 – Transportation Cost Savings Per Ton

Channel Depth	41 foot	42-foot	43-foot	44-foot	45-foot	46-foot
Vessel Deadweight Tons	60,000	80,000	80,000	80,000	80,000	80,000
Design Draft (ft)	41.6	45.6	45.6	45.6	45.6	45.6
Cargo Capacity (%)	95%	95%	95%	95%	95%	95%
Cargo Capacity (metric tons)	57,000	76,000	76,000	76,000	76,000	76,000
Immersion Factor (tons per inch)	150.5	180.2	180.2	180.2	180.2	180.2
Underkeel Clearance (ft)	1	1	1	1	1	1
Weighted Mileage	17,390	17,390	17,390	17,390	17,390	17,390
Speed (Knots)	12.9	12.8	12.8	12.8	12.8	12.8
Total Voyage Cost (mileage/speed)*(hourly vessel cost)	$1,666,765	$1,855,082	$1,855,082	$1,855,082	$1,855,082	$1,855,082
Maximum Load	52,304	63,891	66,053	68,215	70,378	72,540
Total Loading and Unloading Cost	$51,168	$59,890	$61,020	$62,150	$63,280	$64,410
Total Cost Per Ton	$33.82	$30.91	$29.93	$29.02	$28.16	$27.35
Savings Per Ton		$2.91	$3.89	$4.81	$5.67	$6.47

The present value of bulk commodity transportation savings that could be realized during each year of the period of analysis was calculated by multiplying the unit cost savings at each depth by the annual benefiting tonnage forecast under each of the low, median and high scenarios discussed previously.

The amount of benefiting tonnage was determined by examining individual calls from Texas International Terminals and Gulf Sulphur Services. First, tonnage from calls on Panamax vessels (i.e., vessels with design drafts of 39 or greater) carrying the commodities of interest was aggregated. From the aggregated number, tonnage carried by vessels with a sailing draft of 37 or greater was considered to be benefiting. The number of tons carried by vessels with design drafts of 37 or greater was divided by the aggregate tonnage to obtain a percentage of depth constrained tons. From these numbers, an annual average benefiting tonnage was calculated. This amount of benefiting tonnage is the base tonnage to which the growth rates and savings per ton were applied. The amount of benefiting tonnage for each dock as well as the total amount of benefiting tonnage is summarized in Table 10.

Table 10 – Benefiting Tonnage Summary

	Texas International	Gulf Sulphur	Total
Panamax Tonnage	157,242	59,753	216,995
Benefiting Tonnage	102,984	48,971	**151,955**

Source: Waterborne Commerce Statistical Center (WCSC)

Table 11 displays the sailing and design drafts of the Panamax vessels that called at either Gulf Sulphur Services dock between 2010 and 2014 or Texas International Terminals between 2011 and 2014.

Table 11 - Drafts of Panamax Calls in Galveston Channel Extension (2010-2014)

		Sailing Draft (Feet)												
		31	32	33	34	35	36	37	38	39	40	41	42	Total
Design Draft (Feet)	39		1							3				4
	40							1		1	7	1		10
	41		1			1			1					3
	42	1					2		2		2		2	9
	43													-
	44			1									1	2
	45												1	1
	46				1		1			1				3
	47										1			1
	48									1				1
Total		1	2	1	1	1	3	1	3	6	10	1	4	54*

*Total includes calls where sailing draft was less than 30 feet (excluded in table)

Source: Waterborne Commerce Statistical Center (WCSC)

The growth rates discussed in sections 4.1 and 4.2 were then applied to estimate benefiting tonnage in each of the years in the period of analysis. The equivalent annual value for each scenario was then calculated from the total present values by amortizing the total over a 50-year period using the FY 2017 discount rate of 2.875%. These numbers were carried forward to Table 11 to calculate total benefits and the benefit-cost ratios.

The benefiting tonnage forecast was loaded onto vessels for all the period of analysis. Table 12 depicts the fleet forecast given that total trip tons and non-benefiting tonnage remains constant.

Table 12 - Fleet Forecast

	Without Project Vessels	With Project Vessels
2015	13.10	-
2019	14.08	13.18
2029	14.86	13.74
2039	15.96	14.54
2044*	16.74	15.09

Benefits capped at year 25 of project (2044)

5.0 Comparison of Alternatives

Table 13 displays a summary of the economic analysis for the most likely, or median growth rate, scenario rounded to the nearest thousand. The benefits were calculated for a 50-year period of analysis using FY 2017 Federal Discount rate of 2.875 percent and the deep-draft vessel operating costs Economic Guidance Memorandum (EGM 15-04). Though the forecasts were made throughout the 50-year period of analysis, growth rates applied to the benefits were capped at year 25 of the project, or 2044. The deepening calculations were estimated using a Microsoft Excel spreadsheet model, certified for one time use on 6 June 2012. Columns are presented for 43-, 44-, 45-, and 46-foot channels. The benefits from sulphur and barite are estimated from tonnage reported by the Waterborne Commerce Statistics Center between 2010 and 2014. The annual savings per ton for each commodity are combined and presented as Average Annual Benefits. Average annual benefits range from a low of $960,000 for the 43-foot channel to $1,597,000 for the 46-foot channel (FY 2017 price level).

The table goes on to present average annual costs for each increment of channel depth, increasing from $303,000 for a 43-foot channel to $585,000 for a 46-foot channel (FY 2017 price level). The costs include the amortized value of project first and estimated associated costs plus interest during construction, but exclude any incremental operations and maintenance costs above the costs to maintain the present 41-foot channel.

Benefit-cost ratios (BCR) were determined for each alternative by comparing average annual benefits to the corresponding average annual costs. The 46-foot channel has the highest net benefit results and an expected BCR value of 2.7 for the median growth scenario.

Table 13 – Summary of Economic Analysis @ 2.875% Interest Rate

Galveston Harbor Channel Extension Summary of Economic Analysis				
Item	**43-foot**	**44-foot**	**45-foot**	**46-foot**
Project Cost	$6,828,000	$9,002,000	$11,202,000	$13,395,000
Associated Costs	$1,108,000	$1,385,000	$1,661,000	$1,938,000
Months to Construct	5	5	5	5
Interest During Construction	$38,000	$50,000	$62,000	$74,000
NED Investment Cost	$7,974,000	$10,437,000	$12,925,000	$15,407,000
Average Annual Cost	$303,000	$396,000	$491,000	$585,000
Average Annual Benefits	$960,000	$1,186,000	$1,398,000	$1,597,000
Net Excess Benefits	$657,000	$790,000	$908,000	$1,012,000
Benefit-Cost Ratio @ 2.875%	3.2	3.0	2.9	2.7

Table 14 presents low, median and high scenarios that consider the growth rate of tonnage volumes moving through the terminals in Galveston for sensitivity purposes. In all scenarios, the 46-foot channel has the highest net benefits. These numbers while not absolute, they are reasonable approximations of how benefits can vary. The amount of risk in the decision is based on expectation of volumes and vessel size that a dock can facilitate in the future versus the needs of the customers. The low and high scenarios show that the BCR is likely to fall between 1.7 and 4.4 for the 46-foot channel. The critical factors in achieving a result in the upper end of this range is the volume and transport distance of foreign imports arriving at the bulk terminals.

Table 14 – Sensitivity Analysis for Alternatives

	43-foot			44-foot			45-foot			46-foot		
Item	**Low**	**Median**	**High**	**Low**	**Median**	**High**	**Low**	**Median**	**High**	**Low**	**Median**	**High**
Average Annual Benefits	$601,000	$960,000	$1,556,000	$742,000	$1,186,000	$1,922,000	$875,000	$1,398,000	$2,266,000	$999,000	$1,597,000	$2,590,000
Average Annual Cost		$303,000			$396,000			$491,000			$585,000	
Net Excess Benefits	$298,000	$657,000	$1,253,000	$346,000	$790,000	$1,526,000	$385,000	$908,000	$1,776,000	$414,000	$1,012,000	$2,005,000
Benefit-Cost Ratio	2.0	3.2	5.1	1.9	3.0	4.9	1.8	2.9	4.6	1.7	2.7	4.4

6.0 Summary

The results of the economic analysis show that there is an economically rational justification to deepen the Galveston Harbor Channel to 46-feet through the reaches that are presently authorized to 41 feet. Volume continues to increase at the bulk terminal for minerals used in oil & gas exploration and a significant share of this volume is constrained by the current channel depth. An even more significant share of sulphur tonnage is estimated to be constrained by the channel. Sulphur volumes have been stable over the last decade or more, and it is believed these trends will continue, as they are tied to petroleum refinery operations. In addition, these bulk docks are located at the end of the deep-draft channel, and bulk commodities stand to gain the most economic efficiencies by their very nature as bulk items that make best use of deeper drafting vessels.

(This page left blank intentionally)