Using the selected flow-re-routing plans, the water quality model was rerun to determine whether changes would be required to the preliminary design of the oxygen injection systems. Changes were found to be needed, and those changes were included when the models were rerun to identify the remaining impacts to fishery resources.

This iterative modeling revealed that the proposed mitigation features (flow-altering plans and oxygen injection systems) would substantially reduce project impacts to freshwater wetlands, the dissolved oxygen regime, and fisheries habitat. Chapter 8: Alternative Plan Evaluation: Environmental Impacts identifies and discusses the impacts of the depth alternatives after avoiding and reducing project impacts. Substantial adverse impacts would remain to freshwater wetlands, Shortnose sturgeon habitat, and Striped bass habitat even with the flow rerouting plan and the injection of oxygen. Because of those remaining impacts, additional mitigation is appropriate. Those actions are the third step in the mitigation planning process, which are described in detail in Chapter 9: Alternative Plan Evaluation: Mitigation Planning.

7 Alternative Plan Evaluation: Benefits

The NED Procedures Manual Deep Draft Navigation (IWR Report 10-R-4) presents three general examples of NED navigation project benefits, which are based on the conceptual basis for navigation benefits identified in the Principles and Guidelines (1983). The NED Procedures Manual states as examples of navigation benefits (page 11):

"Reduced cost of transportation through use of vessels (modal shift), through safer or more efficient operation of vessels and/or use of larger more efficient vessels (channel enlargement), and through use of new or alternative vessel routes (new channels or port shift)."

The with-project condition transportation cost savings calculated in this analysis are in concurrence with this example presented in the NED Procedures Manual. With-project condition container ship transportation cost savings are based on safer and more efficient operation of container ships resulting from channel enlargement (widening and deepening). The Principle and Guidelines (1983) require that cargo transportation costs include the full origin to destination costs (sec. 2.7.4 (f) Deep-Draft Navigation Evaluation Procedure). The Principles and Guidelines further explain that factors to be considered in the analysis of transportation costs include "available service and schedules, carrier connections, and institutional conditions".

The benefits evaluation includes benefits from channel deepening alternatives based on transportation cost efficiencies and reduced tide-delays. Benefits are also evaluated for construction of meeting areas, which are based on reduced channel congestion delays. Alternative deepening plans are evaluated for one-foot increments of depth from -44 feet MLLW to -48 feet MLLW. Alternative meeting areas, including Long Island and Oglethorpe, are evaluated at the same one-foot depth increments.

7.1 Transportation Cost Savings Model Benefits

NED benefits were estimated by calculating the reduction in transportation cost for each project depth. Channel deepening reduces transportation cost by allowing a more efficient future fleet mix. As the Savannah Harbor channel is deepened, the reliability of the channel depth increases. The increased reliability is expected to encourage carriers to assign more of their large vessels to Savannah route services.

There are three primary impacts from channel deepening that cause changes in the future fleet at Savannah. The first is increases in a vessel's maximum practicable loading capacity[13]. 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. The second impact of increased channel depth is the increased reliability of water depth, which encourages the deployment of larger vessels to Savannah. The third impact is a consequence of the second. The increase in Post-Panamax vessels displaces the less economically efficient Panamax class vessels.

Forecasted commodities were allocated to the future fleet in the following manner. First, a share of future tonnage was allocated to the sub-Panamax vessel class. As this fleet was not constrained by the existing depth (the maximum design draft was less than 35 feet), additional project depth would not affect the future fleet for this class of vessels and market. The allocation of future traffic to this vessel class was based on its historical share at Savannah and with an expected drop in sub-Panamax vessel class capacity of approximately 33 percent between now and 2015. The allocation varies by route and overall accounts for a small percentage of the forecasted traffic.

The second allocation was to the forecasted Post-Panamax container fleet. The transportation cost saving model does not explicitly account for vessel sailing drafts. Rather, based on historical data, the share of a vessel's capacity that is used to load and off load cargo at Savannah was calculated for the existing Panamax class fleet for each trade route. This historical share of vessel capacity was applied to the maximum practicable vessel capacity of the forecasted Post-Panamax vessels to estimate tonnage carried per call for the Post-Panamax fleet by project depth. These average tonnages per trip were then multiplied by the forecasted number of trips for each Post-Panamax vessel fleet in order to calculate the share of the forecasted tonnages carried by this vessel class. The remaining, unallocated forecasted cargo was then assigned to the Panamax class fleet.

The basic transportation cost model computes the costs per thousand miles for the forecasted vessel calls for the without and with project condition. The savings in costs between the without and with project condition make up the transportation cost savings benefits per thousand miles. The total trade route distance is then determined based on the weighted average origin-to-destination distances. It should be noted that

[13] The practicable loading capacity is more fully explained in the "Load Factor Analysis" section.

improvements at Savannah Harbor which result in fewer container vessel trips to the port does not necessarily translate into similar reductions in vessel trips for the entire trades routes that service Savannah Harbor. Port rotations are constantly changing. Therefore, to estimate actual transportation cost savings attributable to changes at Savannah Harbor, the amount of total round trip vessel cost savings is multiplied by the share of vessels calling at Savannah. In essence, the voyage cost is "allocated" based on Savannah's share of all vessels calling at Savannah.

To determine how much "weight" or vessel cost "allocation" to attribute to Savannah Harbor improvements, the study team first examined Savannah's historical share of cargo for each trade route, specifically the 2005/2007 cargo plus weight of all laden and empty boxes. The historical data for vessel calls at Savannah provided information as to number of TEUs and cargo weight, expressed in tons, of laden TEUs off loaded (Inbound/Import) and on loaded (Outbound/Export) at Savannah, but it unfortunately did not include total number of TEUs or weight (tons) carried on the vessels when they sailed in and out of Savannah. In addition, the historical data did not include total TEUs or weight of cargo on the entire trade route. Therefore, to estimate Savannah's share of trade route cargo, the study team needed to use proxies derived from the Load Factor Analysis (LFA) and the analysis of sailing draft relative to design draft. The total tonnage is imputed by using the total carriage weight from the LFA for each vessel by sailing draft relative to design draft from the historical calls.

Table 7-1 shows the weighted average estimated Savannah share of trade route cargo carried by Panamax ships on each trade route:

Table 7-1: Savannah Share of Voyage Cost

Service Route	Cargo Share	Route Service Distance	Savannah Proportion
FE (Panama) ECUS	24.48%	22,653	5,572
FE (Suez) ECUS	32.45%	24,196	7,852
FE ECUS EU	20.21%	31,356	6,337
FE ECUS MED	20.38%	34,321	6,994
AU ECUS EU	16.00%	28,526	4,564
ECUS AU PEN	15.99%	21,614	3,456
ECUS EU GULF PEN	9.40%	12,612	1,185
ECUS MED	15.31%	10,568	1,618
ECUS WCSA-ECSA	11.49%	11,701	1,344
RTW	11.86%	25,753	3,054

The total transportation cost savings benefits were estimated for a 50-year period of analysis for the years 2017 through 2066. Transportation cost savings were estimated using the TCSM for the years 2017, 2020, 2025 and 2030. Since Garden City terminal capacity of 6.5 million TEUs is expected to be reached by 2030, the transportation cost savings were held constant beyond 2030. The present value was estimated by interpolating between the aforementioned dates and discounting at the current FY 2011 Federal Discount rate of 4.125 percent. Estimates were determined for each alternative project depth.

Benefits of channel deepening are defined as the reductions in transportation cost by project depth. Table 7-2 shows the average annual equivalent transportation cost savings by project depth by route service. The FE (Panama) ECUS, the FE ECUS EU PEN, and the FE ECUS MED PEN are all services that transit the Panama Canal. Combined with the FE (Suez) ECUS service, which transits the Suez Canal, these four trade route services comprise more than ninety percent of the total transportation cost savings. For the FE (Panama) ECUS world region service, the savings do not increase beyond a 45-foot project as the vessels on this route are generally expected to "cube" out by that depth due to relatively light cargo. On the FE ECUS EU PEN, savings do not increase beyond a 46-foot project depth. The FE (Suez) ECUS service, with its large make-up of heavier imports as well as a large forecasted contingent of Post-Panamax vessels, will continue to reap cost savings as the channel is deepened to 47 feet. For five services, transportation savings continue to accrue with a 47-project depth due to the fact that vessels are expected draft deeper and, at times, attain full design draft.

Table 7-3 shows the incremental average annual equivalent transportation cost savings by project and route service. The savings increase at a decreasing rate for each incremental project depth. There were small additional savings at 47 feet but no incremental savings beyond that depth.

Table 7-2: Average Annual Equivalent Transportation Cost Savings by Project Depth

Service Route	44 feet	45 feet	46 feet	47 feet	48 feet
FE (Panama) ECUS	$ 37,020,000	$46,520,000	$ 46,520,000	$46,520,000	$46,520,000
FE (Suez) ECUS	$ 31,670,000	$ 44,230,000	$53,560,000	$54,500,000	$54,500,000
FE ECUS EU PEN	$ 14,740,000	$19,900,000	$22,330,000	$ 22,330,000	$ 22,330,000
FE ECUS MED PEN	$ 10,720,000	$16,340,000	$ 20,210,000	$ 22,700,000	$ 22,700,000
AU ECUS EU PEN	$0	$0	$0	$0	$0
ECUS AU PEN	$0	$0	$0	$0	$0
ECUS EU GULF PEN	$ 600,000	$ 910,000	$1,150,000	$ 1,330,000	$ 1,330,000
ECUS MED	$ 550,000	$ 830,000	$1,050,000	$ 1,220,000	$ 1,220,000
ECUS WCSA-ECSA	$0	$0	$0	$0	$0
RTW	$ 2,910,000	$4,420,000	$5,560,000	$ 6,450,000	$ 6,450,000
Total AAE* Benefits	$ 98,210,000	$133,150,000	$150,370,000	$155,050,000	$155,050,000

*Average Annual Equivalent

Note: Transportation benefits are updated to 2012 values in Section 14 Selected Plan

Table 7-3: Incremental Transportation Cost Savings by Project Depth

Service Route	44 feet	45 feet	46 feet	47 feet	48 feet
FE (Panama) ECUS	$ 37,020,000	$9,500,000	$0	$0	$0
FE (Suez) ECUS	$31,670,000	$12,560,000	$ 9,330,000	$ 950,000	$0
FE ECUS EU PEN	$14,740,000	$ 5,170,000	$2,430,000	$0	$0
FE ECUS MED PEN	$10,720,000	$5,620,000	$3,870,000	$2,490,000	$0
AU ECUS EU PEN	$0	$0	$0	$0	$0
ECUS AU PEN	$0	$0	$0	$0	$0
ECUS EU GULF PEN	$ 600,000	$310,000	$ 230,000	$180,000	$0
ECUS MED	$ 550,000	$ 290,000	$220,000	$170,000	$0
ECUS WCSA-ECSA	$0	$0	$0	$0	$0
RTW	$ 2,910,000	$1,500,000	$ 1,150,000	$ 890,000	$0
Total AAE Benefits	$ 98,210,000	$34,940,000	$ 17,220,000	$ 4,680,000	$0

Note that incremental values may be affected by rounding
Note: Benefits are updated to 2012 values in Section 14 Selected Plan

7.2 Meeting Area and Tide Delay Benefits

Meeting area and tide delay benefits are based on the reduction in transit time required to navigate Savannah Harbor as a result of channel modifications, which reduce congestion within the harbor. Transportation cost savings were estimated in terms of the reduction in harbor transit times and consequent vessel delays. Transit costs were estimated by analyzing conditions that are most likely to occur in the absence of channel deepening or meeting area (without-project conditions) and compare those results to the transit times/costs that were derived when including the channel deepening and meeting area alternatives. The economic benefits were determined using the HarborSym model.

HarborSym is a Monte Carlo simulation model of vessel movements at a port which is based on transit rules on the waterway. 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, and incorporation of turning areas and anchorages. 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.

7.2.1 Meeting Area Benefits

For the future without-project condition at Savannah Harbor, the current channel alignment is considered to be the existing condition for each channel depth being modeled for the deepening study. Given current channel dimensions (500 foot width), two Post-Panamax vessels are not allowed to meet (pass or overtake) while transiting the harbor. As a result, a Post-Panamax vessel exiting the harbor would cause a transit delay for an arriving Post-Panamax vessel. This would also occur for the reverse scenario. All other vessel classes in the system are allowed to pass/overtake while transiting the harbor with the exception of a loaded Liquid Natural Gas (LNG) vessel. When an LNG vessel enters the system, all other vessels are restrained until it has reached its dock. The purpose of this HarborSym analysis is to determine if the inclusion of a meeting area(s) would decrease time delays associated with Post-Panamax vessels transiting the harbor. For this reason, the HarborSym model was run at each potential depth. The without-project transit times/costs were compared to the transit times and costs for meeting area alternatives, which consist of two separate meeting areas and a combination of the two.

The Long Island meeting area alternative consists of an 8,000 foot Meeting Area located from approximately Station 14 to 22 (Corps of Engineers Annual Survey data 1996). This alternative has 1,000 foot transitions and provides for an additional width of 100 feet, making this channel segment 600 feet wide. This alternative is located closest to the entrance of the Savannah River System. The Long Island meeting area would allow two Post-Panamax vessels to pass once inside the harbor channel, thus decreasing the voyage time/cost for this vessel class.

The Oglethorpe meeting area consists of a 4,000 foot Meeting Area located from approximately Station 55 to 59 (Corps of Engineers Annual Survey data). This alternative has 1,000-foot transitions and provides for an additional width of 100 feet. The location is approximately one mile upstream from the Elba Island LNG terminal. The Oglethorpe meeting area would expand the width of the channel to 600 feet and would allow for two Post-Panamax vessels to pass once inside the harbor channel, thus decreasing the voyage time/cost for this vessel class.

The Long Island – Oglethorpe Alternative is the inclusion of both meeting areas within the Savannah River System. Post-Panamax vessels would be allowed to pass in both locations.

The fleet of vessels calling at Savannah Harbor and the number of vessel calls includes the containership fleet, the LNG fleet, and the general cargo fleet. The container ship fleet, number of vessel calls, and operating drafts are identical to that used for the transportation cost savings model. The LNG fleet is based on historical LNG vessel movements within the harbor and planned improvements at the Elba Island LNG Terminal.

During the base year, the LNG terminal is anticipated to initially operate at 60 percent capacity, increasing linearly throughout the project life to 80 percent capacity by 2030. The fleet was held constant from 2030 till the end of the period of analysis. Note, at 100 percent capacity, the possible number of calls could reach approximately 200. These vessels take approximately 4 hours round trip to transit the harbor channel and spend on average 24 to 30 hours at the dock, depending on the size of the vessel. Table 7-4 displays the annual number of calls forecast each year and the size of each vessel class.

Table 7-4: LNG Vessel Fleet (bcm) (2015-2030)

Year	Total Vessels	BU SAMRA 266,000 17.4%	AL HUWAILA 217,000 12.7%	MERSK ARWA 165,500 23.9%	LUSAIL 145,000 23.5%	BRITISH TRADER 135,000 22.5%
2017	126	22	16	30	30	28
2020	136	24	17	32	32	30
2025	151	26	19	36	35	34
2030	167	29	21	40	39	37

The General Cargo vessel class will not benefit from channel modification at Savannah Harbor (i.e., deepening nor the addition of meeting areas); however, determining the annual number of general cargo vessels calling Savannah Harbor was critical for properly assessing harbor congestion. Any vessel not identified as a container or LNG vessel was included in this vessel class.

Using Waterborne Commerce data provided for the years 2001 through 2008, a growth rate was estimated for forecasting the number of General Cargo vessels. The average annual growth for this period was 3.6 percent. Using Georgia Ports Authority data for 2006, an annual vessel fleet was determined for the base year of the project, 2017, and for every five year increment until 2030 (Table 7-5). The forecast was then held constant through the end of the period of analysis. The fleet for each future year was then distributed to the general cargo docks in the same percentages as the 2006 vessel fleet.

Table 7-5: General Cargo Fleet – Annual Vessel Calls (2017-2030)

Year	Vessels
2017	1,867
2020	2,068
2025	2,468
2030	2,946

Container ship operating drafts are based on the drafts developed in the transportation cost savings model. LNG vessel operating drafts were developed through discussion with the Bar Pilots and an assessment of historical data. All LNG vessel calls were modeled at a 40-foot operating draft. Containership operating costs used in the meeting area analysis are the same as the operating costs used in the transportation cost savings model. LNG vessel operating costs were developed specifically for the analysis.

Using the output data for transit costs provided by HarborSym, annual benefits were determined for each meeting area alternative at each project depth. The values provided for the model run years were interpolated to attain benefits for the years between, remaining constant after 2030 when TEU capacity is forecasted to be reached. Average annual meeting area benefits were developed using the Federal

Discount Rate for FY11 of 4.125%, and a 50 year project life. Table 7-6 displays the average annual benefits, rounded to the nearest ten thousand, for each Meeting Area alternative at each project depth.

Table 7-6: Meeting Area Average Annual Benefits

Average Annual Benefits			
	Long Island	**Oglethorpe**	**Long Island/Oglethorpe**
44 Foot Depth	$400,000	$385,000	$717,000
45 Foot Depth	$401,000	$387,000	$722,000
46 Foot Depth	$407,000	$393,000	$731,000
47 Foot Depth	$450,000	$387,000	$730,000
48 Foot Depth	$424,000	$373,000	$723,000

Note: Benefits are updated to 2012 values in Section 14 Selected Plan

7.2.2 Tide Delay Reduction Benefits

Tide benefits were estimated as the reduction in the average tide delay cost of a vessel class and calculated by comparing the existing condition of -42 feet with the alternative project depths (-44, -45, -46, -47, and -48 feet). Currently, due to underkeel requirements and vessel sailing drafts, there is a portion of the annual fleet that cannot transit the Savannah Harbor River System without tidal assistance. With additional channel depth, the transit restrictions are decreased allowing the vessel to call on the harbor with fewer delays.

The tide delay benefit analysis was performed by evaluating the anticipated vessel fleet at each proposed project depth and the projected sailing draft distribution at that depth. Underkeel clearances used in the benefits analysis include:

- Handy Size – 3.5 feet;
- Sub-Panamax – 3.75 feet;
- Panamax – 4.0 feet;
- Post-Panamax Generation 1 – 4.2 feet; and
- Post-Panamax Generation 2 – 4.3 feet.

These underkeel clearances are consistent with current vessel clearances required by the Harbor Pilots.

Benefits were derived by calculating the difference in the average vessel transit costs for each impacted vessel class for the without-project condition (-42 feet MLLW) and each of the alternative deepening alternatives (-44 feet through -48 feet MLLW) A -43-foot project was not evaluated since -43 feet MLLW was not an alternative evaluated for deepening benefits.

The HarborSym model was used to calculate tide delay benefits, which would result from the reduction in tide delay times, for each channel deepening alternative. Meeting areas were not included in the model runs to ensure that the benefits generated were due to additional depth only. The HarborSym model was run for each of the five channel depth alternatives and the -42 foot project depth for the following years: 2017, 2020, 2025, and 2030. The average transit cost for the initial scenario run of each Panamax, Post-Panamax (Generation 1 and 2), and LNG vessel was determined and compared to the average transit cost in the system when an additional one foot of depth was added. Since all other inputs remain the same (Speed in Reach, Docking/Undocking Times, Loading Rates, etc…) benefits are calculated using the reduction in the average transit cost for each of the affected vessel. The vessel operating costs methodology is the same as that used in the Meeting Area analysis. The values provided for the model run years were then interpolated to attain benefits for the years between. Tide delay benefits were held constant from 2030 when port capacity is forecast to be reached (Table 7-7).

Table 7-7: Tide Delay Benefits

Year	42 to 44 Foot	44 to 45 Foot	45 to 46 Foot	46 to 47 Foot	47 to 48 Feet
2017	$ 1,036,564	$ 554,120	$ 450,832	$ 304,875	$ 186,724
2018	$ 1,080,214	$ 586,951	$ 510,291	$ 342,354	$ 233,941
2019	$ 1,123,863	$ 619,781	$ 569,750	$ 379,832	$ 281,158
2020	$ 1,167,512	$ 652,611	$ 629,208	$ 417,311	$ 328,375
2021	$ 1,221,220	$ 711,386	$ 668,777	$ 431,174	$ 358,815
2022	$ 1,274,929	$ 770,161	$ 708,346	$ 445,036	$ 389,256
2023	$ 1,328,637	$ 828,936	$ 747,915	$ 458,898	$ 419,696
2024	$ 1,382,346	$ 887,711	$ 787,484	$ 472,761	$ 450,137
2025	$ 1,436,054	$ 946,486	$ 827,053	$ 486,623	$ 480,577
2026	$ 1,452,883	$ 978,093	$ 833,076	$ 519,738	$ 499,960
2027	$ 1,469,713	$ 1,009,699	$ 839,099	$ 552,853	$ 519,343
2028	$ 1,486,542	$ 1,041,306	$ 845,122	$ 585,969	$ 538,725
2029	$ 1,503,371	$ 1,072,912	$ 851,145	$ 619,084	$ 558,108
2030	$ 1,520,200	$ 1,104,519	$ 857,168	$ 652,199	$ 577,490

Average annual tide delay reduction benefits were developed using the Federal Discount Rate for FY11 of 4.125% and a 50-year project life (Table 7-8).

Table 7-8: Average Annual Benefits - Tide Delay Reduction

Project Depth	Cumulative Benefits
42 to 44	$1,408,000
44 to 45	$2,366,000
45 to 46	$3,146,000
46 to 47	$3,702,000
47 to 48	$4,190,000

Note: Benefits are updated to 2012 values in Section 14 Selected Plan

7.2.3 Cumulative Benefits – Meeting Area and Tide Delay Reduction

Table 7-9 displays the benefits of both the Meeting Area and tide delay benefits. The numbers have been rounded.

Table 7-9: Cumulative Benefits – Meeting Areas and Tide Delay Reduction

Project Depth	Tide Benefits	Long Island	Total Benefits
42 to 44	$ 1,408,000	$ 400,000	$ 1,808,000
44 to 45	$ 2,366,000	$ 401,000	$ 2,767,000
45 to 46	$ 3,146,000	$ 407,000	$ 3,553,000
46 to 47	$ 3,702,000	$ 450,000	$ 4,152,000
47 to 48	$ 4,190,000	$ 424,000	$ 4,614,000
Project Depth	**Tide Benefits**	**Oglethorpe**	**Total Benefits**
42 to 44	$ 1,408,000	$ 385,000	$ 1,793,000
44 to 45	$ 2,366,000	$ 387,000	$ 2,753,000
45 to 46	$ 3,146,000	$ 393,000	$ 3,539,000
46 to 47	$ 3,702,000	$ 387,000	$ 4,089,000
47 to 48	$ 4,190,000	$ 373,000	$ 4,563,000
Project Depth	**Tide Benefits**	**Long Island/Oglethorpe**	**Total Benefits**
42 to 44	$ 1,408,000	$ 717,000	$ 2,125,000
44 to 45	$ 2,366,000	$ 722,000	$ 3,088,000
45 to 46	$ 3,146,000	$ 731,000	$ 3,877,000
46 to 47	$ 3,702,000	$ 730,000	$ 4,432,000
47 to 48	$ 4,190,000	$ 723,000	$ 4,913,000

7.3 Total Average Annual Equivalent Project Benefits

Table 7-10 presents the total average equivalent project benefits, including transportation cost savings, meeting areas, and tide delay reduction benefits.

Table 7-10: Total Average Annual Equivalent Incremental Deepening Benefits

Project Depth	Transportation Cost Savings	Tide Delay Benefits	Meeting Area Benefits	Total Project Benefits	Incremental Benefits
-44	$98,210,000	$1,408,000	$717,000	$100,335,000	
-45	$133,150,000	$2,366,000	$722,000	$136,238,000	$35,903,000
-46	$150,370,000	$3,146,000	$731,000	$154,247,000	$18,009,000
-47	$155,040,000	$3,702,000	$730,000	$159,472,000	$5,225,000
-48	$155,040,000	$4,190,000	$723,000	$159,953,000	$481,000

Note: Values discounted 50 years at 4.125%
Note: Benefits are updated to 2012 values in Section 14 Selected Plan