United States Department of the Interior

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June 18, 2008

Colonel Edward J. Kertis, Jr.
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Dear Colonel Kertis:

The enclosed Plan Formulation Planning Aid Report for the Savannah Harbor Expansion Study is submitted pursuant to the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) (FWCA). The U. S. Fish and Wildlife Service (Service) prepared this report with funds transferred from the Corps under the National Letter of Agreement between our agencies for funding of FWCA activities. This report is not our final report on the project and we plan to provide a Fish and Wildlife Coordination Act Report later this year when a preferred alternative has been identified.

Savannah NWR and the surrounding estuary support nationally important fish and wildlife resources. However, cumulative impacts of previous harbor modifications, primarily salinity intrusion, have severely impacted the resources that were present when the refuge was established. A freshwater supply system for managed wetlands, installed as mitigation for the tidegate, has failed to function adequately. Tidal freshwater marsh has been reduced from about 12,000 acres to about 3,300 acres. Striped bass reproduction and recruitment were almost eliminated during tide gate operation but have recently begun to recover. Shortnose sturgeon habitat has been greatly impacted both by salinity increase and dissolved oxygen decrease.

Hydrodynamic and water quality models were used to evaluate project impacts and mitigation. The mitigation plans are unlikely to perform precisely as predicted by the models. There is a great deal of risk and uncertainty regarding impacts of the channel and flow mitigation plans. Based on the available information, there is a high degree of uncertainty as to how effective oxygen injection would be. The fish habitat model results are based on predictions from the hydrodynamic and water quality models. If the oxygen injection is not as effective as previously assumed, the model predictions of harbor deepening fish impacts would be underestimated.

TAKE PRIDE IN AMERICA

The 44 and 45 foot plans (with mitigation) avoid or minimize impacts to tidal freshwater marsh and the freshwater supply system. The 45 foot depth minimizes impacts to striped bass habitat and the 44 foot depth minimizes impacts to shortnose sturgeon. Based on the information obtained for the specific purpose of evaluating this project, it is clear that the 44 and 45 foot alternatives would have much lower impacts on fish and wildlife resources. Impacts of the project increase substantially at the 46 and 48 foot depths. For any project implemented, the Service supports a comprehensive monitoring program to document actual impacts.

We appreciate your support of efforts to coordinate this project with the Service. If you have any questions or wish to discuss our recommendations, please contact Ed EuDaly at 843-727-4707 x 227.

Sincerely,

Timothy N. Hall
Field Supervisor

TNH/EME

PLAN FORMULATION PLANNING AID REPORT
ON
SAVANNAH HARBOR EXPANSION

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June 2008

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EXECUTIVE SUMMARY

Savannah NWR and the surrounding estuary support nationally important fish and wildlife resources. However, cumulative impacts of previous harbor modifications, primarily salinity intrusion, have severely impacted the resources that were present when the refuge was established. A freshwater supply system for managed wetlands, installed as mitigation for the tidegate, has failed to function adequately. Tidal freshwater marsh has been reduced from about 12,000 acres to about 3,300 acres. Striped bass reproduction and recruitment were almost eliminated during tide gate operation but have recently begun to recover. Shortnose sturgeon habitat has been greatly impacted both by salinity increase and dissolved oxygen decrease.

The current inner harbor is 42 feet in depth. Impacts of project depths of 44, 45, 46, and 48 feet were evaluated using hydrodynamic and biological models. A number of mitigation measures have been proposed by the Corps. Most of these measures are based on channel and flow modifications in the estuary. In addition, a dissolved oxygen injection system, wetland acquisition, striped bass stocking and a fish bypass channel at New Savannah Bluff have been proposed.

There is a great deal of risk and uncertainty regarding impacts and the channel and flow modification and dissolved oxygen mitigation plans. The mitigation plans are unlikely to perform exactly as predicted. There could be unintended adverse consequences resulting from the channel and flow mitigation measures. All of the proposed mitigation alternatives include flow diversion as a basic and highly important component. The predicted reduction of salinity in the Middle River and Back River is due in large part to the proposed flow diversion from Front River. The EFDC model uncertainty in this geographic area is of concern, particularly because most of the remaining freshwater tidal marsh and the entrance to the diversion canal are located there. Diversion of fresh water into the Back River allows salinity to move further up the Front River and into the Middle River. As a result, in the Front River and lower Middle River mean and maximum salinity would be higher with the mitigation plan than without it. The model may under predict the amount of salinity moving up Front and Middle River.

Based on the available information, there is a high degree of uncertainty as to how effective oxygen injection would be. The fish habitat model results are based on predictions from the EFDC/WASP model. If the oxygen injection system is not as effective as previously assumed, the model predictions of harbor deepening fish impacts would be underestimated. Because dissolved oxygen is a key component of all aquatic habitats, underestimation of harbor deepening impact would be important. In addition, if the number of Speece cones had to be increased the cost of this mitigation feature could increase substantially.

Elevated cadmium levels have been found in several areas of the harbor from about river mile 4 to river mile 11. The project would result in potential exposure of fish and wildlife resources to cadmium levels that would cause adverse impacts. The Service believes available information supports the need to cap all new work sediment containing elevated cadmium concentrations (identified as “high” and “low” in the risk assessment) with clean material.

The 44 and 45 foot plans (with mitigation) avoid or minimize impacts to tidal freshwater marsh and the freshwater supply system. The 45 foot depth minimizes impacts to striped bass habitat and the 44 foot depth minimizes impacts to shortnose sturgeon. Based on the information obtained for the specific purpose of evaluating this project, it is clear that the 44 and 45 foot alternatives would have much lower impacts on fish and wildlife resources. Impacts of the project increase substantially at the 46 and 48 foot depths. For any project implemented, the Service supports a comprehensive monitoring program to document actual impacts.

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SAVANNAH HARBOR EXPANSION

INTRODUCTION

AUTHORITY

A resolution adopted by the Senate Public Works Committee on July 10, 1972, authorized the Tier 1 Savannah Harbor deepening study which the Savannah District Corps of Engineers (Corps) initiated in 1995. After the Corps completed the Reconnaissance Report in 1996, the Georgia Ports Authority (GPA) funded feasibility studies under Section 203 of Water Resources Development Act (WRDA) of 1986. The 1999 WRDA included conditional authorization of the Savannah Harbor Project, which would deepen the harbor by up to six feet. Department of Interior, Department of Commerce and Environmental Protection Agency concurrence is required before project implementation. A Tier 2 study was initiated in 1999 to complete detailed impact evaluation, mitigation plan development and economics evaluation. The Fish and Wildlife Coordination Act (48 Stat. 40l, as amended; 16 U.S.C. 661 et seq.) (FWCA) authorized the U.S. Fish and Wildlife Service's (Service) involvement in this study. The Service participated in planning throughout the study and prepared this report with funds transferred from the Corps under the National Letter of Agreement between our agencies for funding of FWCA activities.

PURPOSE AND SCOPE

The purpose of the Tier 1 Georgia Ports Authority/Corps' study was to determine whether deepening of Savannah Harbor was needed to serve navigation interests. The purpose of the Tier 2 study is to complete detailed impact evaluation, mitigation plan development and economics evaluation. This Planning Aid Report evaluates existing and future fish and wildlife resources within the Savannah Harbor area and provides the Service analysis of project impacts and mitigation plans.

PRIOR STUDIES AND REPORTS

The Corps and other agencies have produced numerous reports dealing with Savannah Harbor. The following discussion focuses on prior Service reports most relevant to the current project and a few of the more relevant Corps studies. The Corps released the Stage I Report for the Savannah Harbor Comprehensive Study (SHCS) in April 1981 and a Preformulation Report in January 1983. In September 1987, the Corps released a Draft Feasibility Report and Draft Environmental Impact Statement on the project. These reports proposed a 2 foot deepening project for the Harbor. Completion of the study was subsequently postponed because of two

general areas of concern. First, the Corps' hydrodynamic model, designed to predict salinity impacts of harbor deepening, was not adequately verified and could not be used with any confidence. Second, impacts of the tide gate on Savannah National Wildlife Refuge (Savannah NWR) were greater than predicted and needed to be addressed prior to further harbor modifications. To address these concerns, the Corps initiated a Savannah Harbor Environmental Study in early 1988.

The Corps released a revised SHCS Draft Feasibility Report and Environmental Impact Statement in April 1991. This report recommended a four foot deepening of Savannah Harbor upstream to the Kings Island Turning Basin.

The Service provided SHCS planning aid letters to the Corps dated March 21, 1981, July 23, 1981, and September 18, 1981, expressing concerns related to dredged material disposal, Savannah National Wildlife Refuge, harbor deepening, and harbor extension. The Service submitted a SHCS Planning Aid Report (PAR) on September 16, 1982, which provided: (1) an analysis of wetland resources in the study area; (2) an evaluation of the impacts of tide gate operation on Savannah NWR and striped bass habitat; and (3) a habitat evaluation procedures study of potential spoil areas. On December 1, 1983, the Service completed a second SHCS PAR which provided: (1) an evaluation of fish and wildlife resources on two new potential dredged material disposal areas; (2) resource categories and general mitigation goals and measures for all potential spoil areas; and (3) further analysis of freshwater supply problems on Savannah NWR.

The Service provided a reconnaissance level PAR on September 27, 1984, which analyzed impacts of harbor extension on fish, wildlife, and wetlands of Savannah NWR and adjacent areas. The PAR also identified information and studies needed to adequately assess impacts of harbor extension.

In November 1986, the Service provided a Draft FWCA Report on the SHCS. This report evaluated existing and future fish and wildlife resources in the study area and identified problems, opportunities, and planning objectives for these resources. In addition, using information available at that time, the report evaluated fish and wildlife impacts of tide gate operation and harbor deepening. The report also questioned the reliability of the Corps' hydrodynamic model and recommended adequate verification before using the model for evaluation of harbor deepening.

In 1986, Service-funded studies were initiated to determine impacts of Savannah Harbor modifications, particularly the tide gate and New Cut, on Savannah NWR, and several reports on these studies were produced. In 1989 a report characterizing the hydrology of the lower Savannah River and impact of the tide gate on salinity levels was released (Pearlstine et al. 1989). In 1990 a report on effects of salinity on striped bass eggs and larvae was released (Winger and Lasier 1990) and a report on fishery resources, primarily striped bass, was published (Van Den Avyle et al. 1990). A report on the impacts of the tide gate on tidal

freshwater marsh and development of a habitat successional model for the marsh was also published in 1990 (Pearlstine et al. 1990).

The Service provided a revised SHCS Draft FWCA Report in November 1990. This report concluded that deepening of Savannah Harbor in conjunction with continued operation of the tide gate project would exacerbate currently unacceptable fish and wildlife impacts. The Service opposed channel deepening until such time as the impacts of the tide gate project were completely offset and strongly recommended that the Corps remove the tide gate and fill New Cut. The Service provided a Fish and Wildlife Coordination Act Report on Savannah Harbor - Closure of New Cut in June 1991. The Service supported the plan to close New Cut and take the tide gate out of operation.

The Service provided a Reconnaissance Planning Aid Report on Port Wentworth Deepening Project in December 1993. The purpose of the Corps' study was to evaluate deepening of Savannah Harbor in the vicinity of Port Wentworth from Station 102 + 000 to Station 112 + 500.

In August 1996 the Service provided a Reconnaissance Planning Aid Report on Savannah Harbor Expansion. The Service recommended that a reliable Savannah Harbor hydrodynamic model be developed to estimate impacts of the alternative plans on river system salinity patterns. The Service expressed concern that the project could increase salinity levels in the lower Savannah River system. An increased salinity level would adversely impact managed wetlands, tidal freshwater wetlands, and striped bass habitat on and near Savannah National Wildlife Refuge. The Service also expressed concern that moderate incremental increases in the salinity level may become cumulatively significant if depth of the harbor is repetitively increased over time.

In June 1998 the Service provided a planning aid letter on the proposed expansion project. Because of the lack of needed impact analysis model runs, the lack of an acceptable mitigation plan, and numerous concerns on potential impacts, we could not provide a Fish and Wildlife Coordination Act report at that time. In July 1998 the Department of Interior provided comments on the Tier 1 Draft Environmental Impact Statement for Savannah Harbor Expansion. The comments discussed a number of issues related to inadequate impact analysis, potential significant impacts on Savannah National Wildlife Refuge and the lack of an adequate mitigation plan. In October 1998 the Department of Interior provided comments on the Chief of Engineers proposed report and Final Environmental Impact Statement. These comments reiterated the view that the documents were inadequate regarding impact analysis and proposed mitigation measures.

DESCRIPTION OF THE STUDY AREA

The study area includes the Savannah Harbor and the surrounding land in Chatham County, Georgia, and Jasper County, South Carolina. The study area lies in the Coastal Plain Marine Flatwoods region. The land surface is nearly level with broad depressions associated with drainage ways or wetlands. Elevation ranges from sea level to approximately 40 feet above sea

level. Soils in the study area generally have a sandy surface layer, a high water table, and are underlain by marine sands, loams, and/or clays.

Upland forests in the study area are dominated by longleaf and slash pine. Maritime forests, dominated by live oak with water oak and southern magnolia as associates, are found on less disturbed barrier islands and other uplands near the coast line. Estuarine emergent wetlands (salt marsh), estuarine sub-tidal wetlands, palustrine emergent wetlands (fresh marsh), palustrine forested wetlands (swamp) and riverine wetlands (freshwater rivers and creeks) are significant components of the study area.

Water flow in the Savannah River varies considerably both seasonally and annually. Discharge is typically high in winter and early spring and low in summer and fall, but regulation by upstream reservoirs has reduced natural flow variations. Average discharge (75 years) at the United States Geological Survey Clyo gauge (Effingham County, Georgia) was 11,720 cubic feet per second (cfs) and the average for water year 2005 was 13,300 cfs with a range (daily mean) of 5,490 cfs to 30,300 cfs (Cooney et al 2005). Tidal effects extend upstream to approximately river mile 45.

The existing authorized harbor navigation project provides for a channel 44 feet deep and 600 feet wide across the ocean bar; 42 feet deep and 500 to 600 feet wide to the vicinity of Kings Island Turning Basin; and 30 feet deep and 200 feet wide to a point l,500 feet below the Houlihan Bridge (Highway 17). The terminus of the existing channel for Savannah Harbor is at approximately river mile 21. The project provides turning basins for vessels at various locations in the harbor (Figure 1).

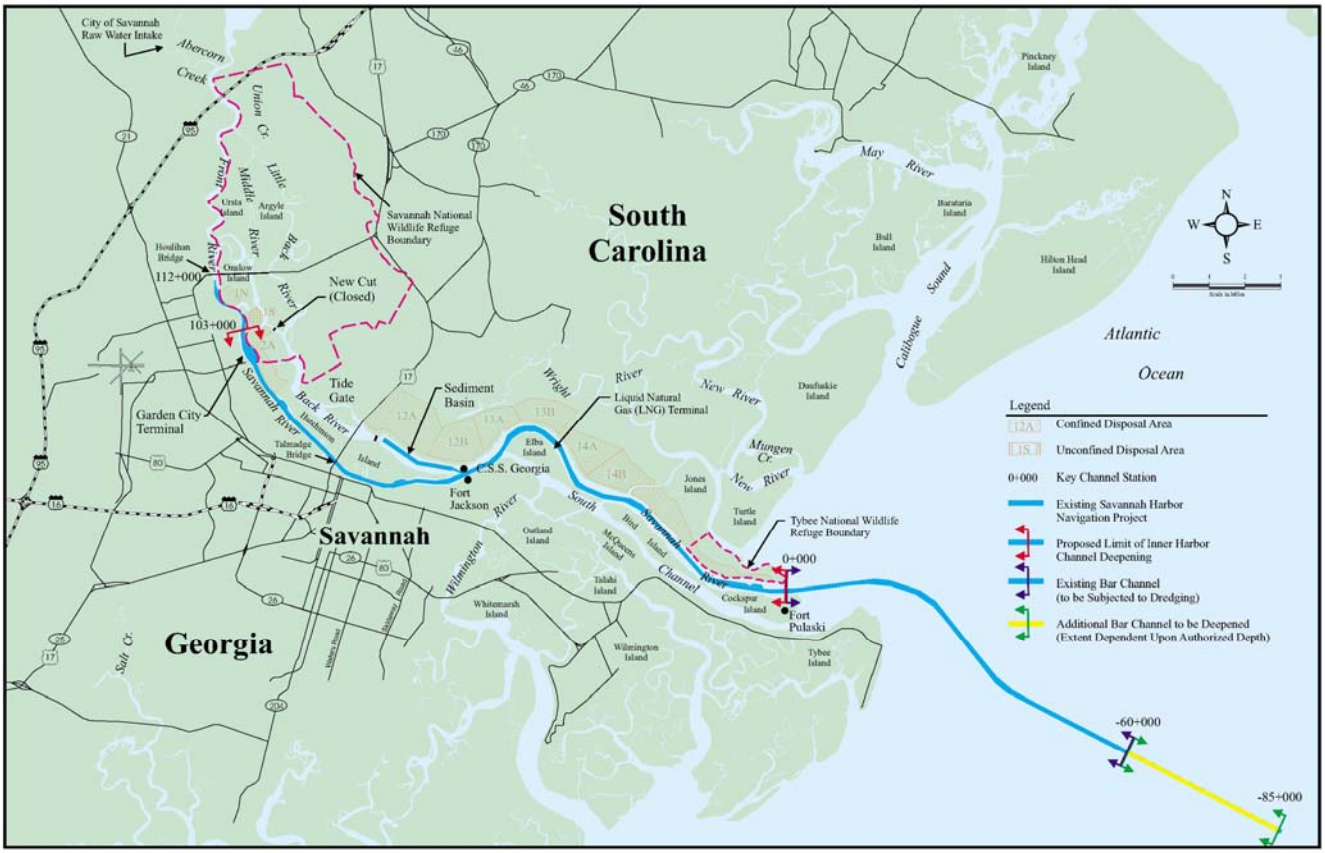

Figure 1. Existing and proposed Savannah Harbor navigation project, Georgia and South Carolina. Boundary of Savannah National Wildlife Refuge extends upstream further than shown on map (source: http://savharbor.com/References/Scoping%20Base%20Map%287-17-00%29.pdf).

From 1977 until 1992, the project also included sediment control works consisting of a tide gate structure across Back River; a sediment basin, 40 feet deep, 600 feet wide, and about 2 miles long, with an entrance channel, 38 to 40 feet deep and 300 feet wide; a drainage canal ("New Cut") across Argyle Island, 15 feet deep and 300 feet wide; control works and a diversion canal on Little Back River. The diversion canal, a mitigation feature to supply fresh water to the Savannah NWR and adjacent private lands, was designed to replace the traditional supply, from various points on Back River that had been used for agriculture and wetland management for hundreds of years. The tide gate, essentially a series of large flap gates, opened during flood (incoming) tides and closed at high water. Therefore, ebb tidal water was forced to flow out through New Cut into Front River, increasing water velocities in the developed harbor and reducing sedimentation in the Front River. In addition, much of the sediment in the harbor was deposited in the sediment basin which is adjacent to dredged material disposal areas.

Because of unacceptable environmental impacts, the tide gate was permanently removed from operation and New Cut was closed with a sand and riprap structure in 1992. The tide gate structure is still in place but the flap gates have been removed to allow water passage at all tides.

The sediment basin is dredged periodically because it continues to trap a large quantity of sediment but less than the amount trapped when the tide gate was in operation.

Maintenance dredging in the harbor averages about 7.04 million cubic yards per year. Most of the material is placed in dredged material disposal areas north and east of the sediment basin in the Barnwell Island area of South Carolina. These disposal areas (12A, 12B, 13A, 13B, 14A, 14B) cover about 4,800 acres. Other disposal areas are located on Onslow Island (130 acres), Argyle/Hutchinson Island (185 acres), and Jones/Oysterbed Island (754 acres). All of these disposal areas were predominantly emergent wetlands (marsh) prior to being diked in the late 1950's. The material dredged to keep the bar channel at project depth is deposited in the Environmental Protection Agency approved interim ocean disposal area, a 4.26 square mile area centered at 31°56'54"N, 80°45'34"W.

On March 12, 2007, Governor Sanford (SC) and Governor Perdue (GA) signed an agreement (Term Sheet) to form a Bi-State Compact and jointly develop a new marine terminal in Jasper County, SC at about Savannah River mile 7. The conceptual plan calls for a new 1,800-acre marine terminal to be located on Barnwell Island (disposal area 14A/B). The island is currently being used by the Corps of Engineers as a disposal site for dredged material which is obtained from maintenance dredging of Savannah Harbor. The site is owned by the Georgia Department of Transportation (GADOT) and is under a Corps disposal easement. Most of the existing container terminals are in Port Wentworth, GA between river miles 16 and 19. The Term Sheet directs GADOT to transfer the land to the Bi-State Authority and requests that the Corps modify or release the disposal easements. The site currently has no infrastructure and a new rail and highway spur to the site would be required for terminal development. The proposed site is adjacent to the existing dredged channel so new dredging could be minimal.

FISH AND WILDLIFE RESOURCES

Savannah National Wildlife Refuge lies adjacent to, and upstream of, the Savannah Harbor project. Savannah NWR consists of 29,175 acres of palustrine forested wetlands, palustrine and estuarine emergent wetlands, palustrine scrub-shrub wetlands, riverine wetlands, diked waterfowl impoundments (managed wetlands) and uplands (Figure 2). About 5,700 acres of the refuge lands are actively managed wetlands which provide excellent habitat for wintering waterfowl, shorebirds, wading birds, and wood ducks. The refuge encompasses much of the high value fish and wildlife habitat that has been or is likely to be impacted by harbor development.

Tybee National Wildlife Refuge is located in Chatham County, Georgia, near the mouth of the Savannah River, adjacent to the navigation channel. The 400 acre migratory bird refuge began as a one acre oyster shoal. The Corps, while engaged in harbor deepening and maintenance, used the shoal as a dredged material disposal site and created Oyster Bed Island (the nucleus of the present refuge).

Wassaw National Wildlife refuge is located in Chatham County, Georgia about 13 miles south on the Savannah Harbor entrance channel. This 10,053 acre island consists of marine wetlands (ocean beach), maritime forest and estuarine wetlands. Loggerhead turtles (threatened) use the ocean beach for nesting and piping plovers (Atlantic Coast population threatened) use the beach habitat for winter foraging and cover. Some of the piping plovers using the Wassaw beach as wintering grounds are from the endangered Great Lakes population (John Robinette, Service, personal communication 2008).

Wassaw Island suffers severe chronic beach erosion which adversely impacts loggerhead turtle and piping plover habitat (John Robinette, Service, personal communication 2008). Dr. Clark Alexander, Skidaway Institute of Oceanography an expert on coastal erosion provided the Service the following statement on impacts of Savannah Harbor construction and maintenance on Wassaw Island.

"Barrier islands, ebb tidal deltas and the intervening inlets are genetically linked components of the coastal barrier systems along the Southeastern United States. The ebb-tidal deltas provide the pathway for sand, being transported from north to south within the longshore transport system, to bypass the deeply entrenched, stable inlets which separate the barriers from each other. This transport of sand is critical for the maintenance of the barrier system, as this is the mechanism by which eroded sand is replaced. When any component of this system is perturbed, the whole system breaks down, causing a degradation of geologic process and habitat quality. In particular, when sand is constrained from naturally renourishing beaches, beach fronts become scarped, dunes are eroded, the intertidal beach narrows or disappears, and sand becomes hard-packed, all of which contribute to a decrease in nesting suitability and success for sea turtles and certain species of shorebirds.

The Savannah River, Tybee Island and Wassaw Island complex is an example of just such a system. Dredging of the Savannah River over the past 130 years has led to a system in which all transported sand that should be bypassing the inlet from Hilton Head to Tybee is intercepted by the shipping channel, and this sand is either deposited in offshore or upland disposal sites, effectively removed from the redistribution system. As sand is denied to Tybee Island, adequate sand resources are also denied to the adjacent, downdrift islands in the longshore system, specifically Little Tybee and Wassaw Islands. The only time these islands receive significant resupply of sand is when artificial renourishment of Tybee Island injects sand into the system, which has been on approximately decadal timescales since the 1970s." He also stated that: "There is no question that the beach and dune habitat of Wassaw Island has been degraded by harbor maintenance activities." (Clark Alexander, Skidaway Institute of Oceanography, written communication 2008).

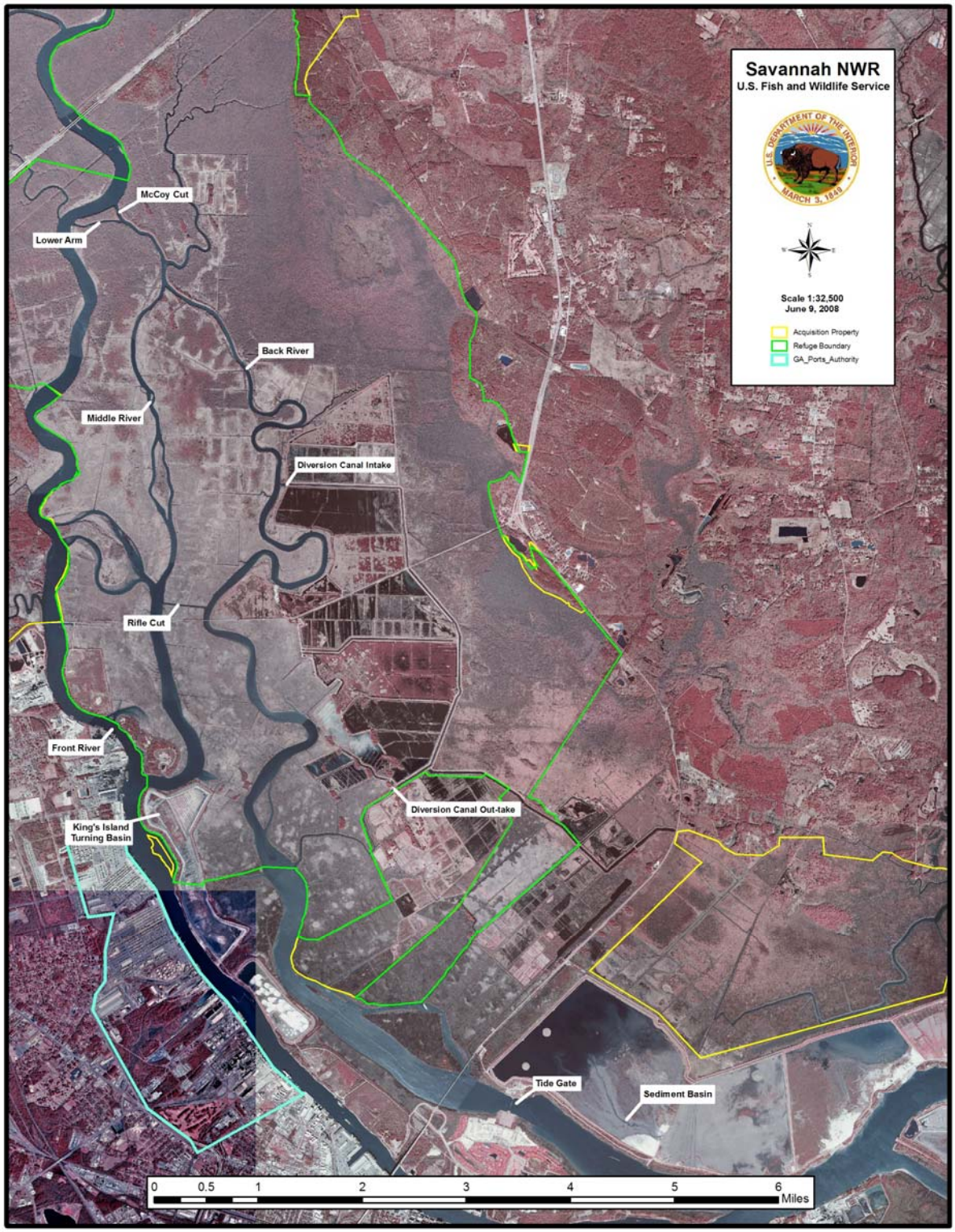

Figure 2. Savannah National Wildlife Refuge and prominent features of Savannah Harbor, May 2008. Refuge extends upstream along the Savannah River to about river mile 41.

Managed Wetlands

The managed wetlands were diked and altered by impoundment, most for purposes of rice culture, during the 18th and l9th centuries. Many of these areas remain impounded and are managed as wintering habitat for waterfowl. Prescribed burning and water level control are two management tools used to promote desirable wetland plants and to suppress vegetation that is of less value to migratory birds. Moist soil management, which is used in most of the management units on Savannah NWR, produces the most productive waterfowl habitat. Fresh water is provided to the managed wetlands at the diversion canal on Little Back River. On Savannah NWR these managed wetlands provide the most heavily used habitat for wintering waterfowl and other migratory birds. From 1990-2002, Savannah NWR supported an average of 23 percent of the South Carolina waterfowl observed during the mid-winter waterfowl counts (Berryman and Webb 2003).

Construction of the freshwater diversion canal, which provides fresh water to the refuge and adjacent plantations, was completed as mitigation for the tidegate in 1977. However, due to salinity levels much greater than predicted, the metal water control structures rusted and failed soon after construction was completed. The Service retrofitted the existing structures with stainless steel channels and solid stop-log structures, stainless bolts and flap-gates. This repair was the most effective and cost efficient for the Service to undertake at the time. The patch allowed the Service to provide for water needs of the refuge and adjacent land owners for the next 27 years, but the system has never functioned as designed. The refuge-funded repair of the structures made the act of filling or draining the canal labor intensive and expensive. Compared to the original design, which required one person and minimal time to fill or drain, it now requires three persons, heavy equipment (for lifting the solid gates) and a full day to adjust the water within the canal. In addition, the structures are systematically failing due to the channels shearing off of the structure walls. There are two structures controlling the water delivery system. Currently the south water control structure cannot be operated, all four of the 48” openings have failed. The north structure has eight openings/pipes and three of these have failed. Many of the interior water control structures which supply water to the individual management units are also failing. Thirteen of these structures are compromised with rust and deterioration.

The Service has installed, operated and maintained this system, at great expense and manpower for over 27 years. Now the system is in disrepair once again and is susceptible to imminent failure. The Service currently has no funding to repair this system and will loose complete control of the freshwater resource if the situation is not addressed promptly.

If the Service looses the ability to control water levels, within the impoundment system, the refuge would be subject to the ebb and flow of the tides. This would result in severe damage to refuge infrastructure, i.e., roads, dikes and internal water control structures. The Service would loose the ability to supply fresh water to the adjacent Fife and Clydesdale plantations, as required by law. This would leave the Service in a position of liability and susceptible to legal action. The Service would not be in a position to fulfill the congressional mandate for the

establishment of the Savannah NWR, to provide for the needs of the nation's migratory bird resources. Migratory birds that utilize the refuge for nesting, feeding, roosting and protection would be forced to attempt to find suitable habitat on other lands. On private lands this resource would be susceptible to disturbance and mortality, from hunting and poaching, and land management practices that are not specifically implemented to provide optimal migratory bird habitat, but for agricultural, developmental or industrial uses. Damage and destruction of refuge infrastructure (i.e. roads, dikes, etc.) would result in the loss of most of the high public use (hiking, birding, wildlife viewing) areas of the refuge.

Freshwater management (salinity less than 0.5 ppt) is necessary to maintain maximum waterfowl use of the Refuge's managed wetlands. According to Tiner (1977), freshwater coastal impoundments in South Carolina produce a greater variety of marsh plants, many of which are desirable duck food, than brackish impoundments. Landers et al. (1976) in a study of South Carolina coastal impoundments found that: "Fifty-five percent of the area impounded in the general study area was freshwater marsh and 62 percent of the ducks were from freshwater impoundments. Ducks, except wigeons, gadwalls and scaups (*Anas americana*, *Aythya marila*, *A. affinis*) took foods that grew mostly in freshwater marsh in greater volume (about 87 percent) than foods from brackish and saline areas." They also found that: "Forty-five percent of the total impounded area was brackish marsh and 38 percent of the ducks were from brackish impoundments. Yet plants characteristically growing in brackish marsh composed only about 13 percent of food volumes." These studies indicate that freshwater management will produce a greater variety and quantity of desirable waterfowl food plants than brackish water management. Therefore, it is essential that the refuge retain freshwater management to provide maximum benefits to the waterfowl resource.

Freshwater managed wetlands on Savannah NWR currently provide high quality feeding habitat for many species of wading birds, including the endangered wood stork. Several areas are managed each year specifically to provide optimum feeding opportunities for wading birds during and after the nesting season. Studies have revealed that wood storks, and many other wading bird species, select freshwater feeding sites (when available) over brackish or salt water sites. Gaines, et al. (1998) found coastal nesting wood storks typically flew significantly longer distances to forage in palustrine habitats than in estuarine habitats and feeding site preference of storks from a colony on St. Simons Island was clearly skewed in favor of palustrine habitat over estuarine habitat despite lower overall availability of palustrine habitat. In addition, some species, such as white ibis (*Eudocimuns albus*), may require a fresh water food source for successful chick rearing (Johnston and Blidstein 1990). When nestling white ibis diets contain fiddler crabs (containing high salt content) nestlings experience depressed growth and increased mortality (De Santo 1992). De Santo et al (1997) found that parental white ibis, in coastal South Carolina, concentrate their foraging efforts in freshwater swamps and impoundments at a considerable distance from the breeding colony site, despite the fact that it was more costly energetically and a greater travel time to these sites as compared to nearby salt marsh feeding sites. Freshwater impoundments are also managed to provide nesting and feeding habitat for shorebirds, and high quality feeding habitat for neotropical migrants such as the swallow-tailed kite.

Tidal freshwater wetlands

Tidal freshwater wetlands (palustrine emergent wetlands) cover much of Savannah NWR in the vicinity of the Harbor and, in contrast to the managed wetlands, are flooded twice daily by tidal action. These marshes were either never diked or the dikes constructed for rice culture have eroded to marsh elevation allowing tidal flooding. Based on vegetation, interstitial (marsh root zone) salinity and soils studies conducted in 1999-2001, the tidal freshwater marshes in the study area are composed of a highly diverse plant community and the community composition is highly dependent on the salinity gradient in the estuary (Dusek and Kitchens 2003). Using cluster analysis these authors identified eight vegetation classes in the study area and the number of species ranged from 11 in the most saline class to 99 in the most diverse freshwater class.

Welch and Kitchens (2006) used additional (1999-2005) vegetation, interstitial and soils data and additional ecological models to classify the plant community. Their classification generally resulted in five plant communities under both drought (2002) and non-drought (2005) conditions.
The communities classified under drought and non-drought conditions were similar with minor shifts in the percentages of dominant species (Table 1). The authors developed decision trees that could be used to predict the plant community at a location in the estuary based on salinity, soils and distance to a channel.

Table 1. Marsh succession model (MSM) community names, interstitial salinity (Welch and Kitchens 2006) and mean channel salinity. Channel salinity is the 50% exceedence value for average flow conditions from EFDC model (Bill Bailey, Corps, written communication 2006).

MSM Non-drought Community (2005)	MSM Drought Community (2002)	Non-drought Mean Interstitial Salinity (ppt)	Drought Mean Interstitial Salinity (ppt)	Channel salinity (ppt)
100 % Elemo; Galti; Saglt*	91 % Elemo	<0.83	<1.0	<0.5
80 % Zizmi; Polsp*	100% Zizmi; Polsp	<0.83	<1.0	<0.5
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	45% Elemo 31 % Zizmi_Polsp 23 % Sciva	<0.83	<1.0	<0.5
78 % Sciva	86% Sciva	0.83-3.6	1-4.2	0.5-3
78 % Spasp; Sciro; Astte*	78 % Spasp_Sciro 22% Sciva	>3.6	>4.2	3-9

* Elemo=*Eleocharis montevidensis*, Galti=*Galium tinctorium*, Saglt=*Saggataria lancifolia*, Zizmi=*Zizaniopsis miliaceae*, Polsp=*Polygonum* sp., Sciva=*Scirpus validus*, Spasp=*Spartina* spp.,Sciro=*Scirpus robustus*, Astte=*Aster tenuifolius*

A marsh succession model (MSM) consisting of a geographic information system which displays the plant communities based on the salinity, soils and distance to a channel was developed as a tool to evaluate channel deepening impact (Welch and Kitchens 2006). The first input into the MSM is the channel salinity as predicted by the Environmental Fluid Dynamics Code hydrodynamic model (EFDC). The EFDC is a three-dimensional physics-based turbulence closure model that has been applied in a number of estuarine and riverine systems in the southeastern United States. The channel salinity is translated to interstitial salinity using a model to marsh spreadsheet application developed by data mining techniques that used channel salinity data and interstitial salinity data at several locations in the estuary (Conrads et al. 2006). The decision trees (Welch and Kitchens 2006) were used in conjunction with the environmental data to predict the plant communities in the study area. Table 2 presents the area occupied, determined by the marsh succession model, by the plant communities under current conditions (42 foot channel).

Table 2. Area occupied, determined by the marsh succession model (Welch and Kitchens 2006), by the plant communities under current depth (42 foot channel) for non-drought and drought conditions.

MSM Non-drought Community (2005)	**No action acreage Non-drought**	**MSM Drought Community (2002)**	**No action acreage Drought**
100 % Elemo; Galti; Saglt*	2081	91 % Elemo	868
80 % Zizmi; Polsp*	761	100% Zizmi; Polsp	476
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	427	45% Elemo 31 % Zizmi_Polsp 23 % Sciva	1069
78 % Sciva	2427	86% Sciva	2485
78 % Spasp; Sciro; Astte*	3151	78 % Spasp_Sciro 22% Sciva	3949
Total	8847		8847

Commonly used marsh classifications are usually based on average channel salinity not interstitial salinity (Odum et al 1984). The communities in the table with a channel salinity of <0.5 ppt are considered to be tidal freshwater marsh with differing species composition. *Scirpus validus* (78% Sciva) is considered to be oligohaline marsh. Oligohaline marsh is described by Odum et al. (1984) as having an average annual channel salinity of 0.5 ppt–5.0 ppt. The *Spartina* spp, *Scirpus* spp, *Aster tenuifolius* is considered to be mesohaline marsh. The location of the 50% exceedence 0.5 ppt salinity contour as predicted by the EFDC model is generally located downstream of the tidal freshwater marsh predicted by the MSM in the Front River and Middle River (Figure 3). This difference could be due to prediction errors in the EFDC model, the MSM model or both. The difference amounts to about one river mile on the Front River and on the Middle River. However, the predictions on the Back River from both models are at virtually the same location.

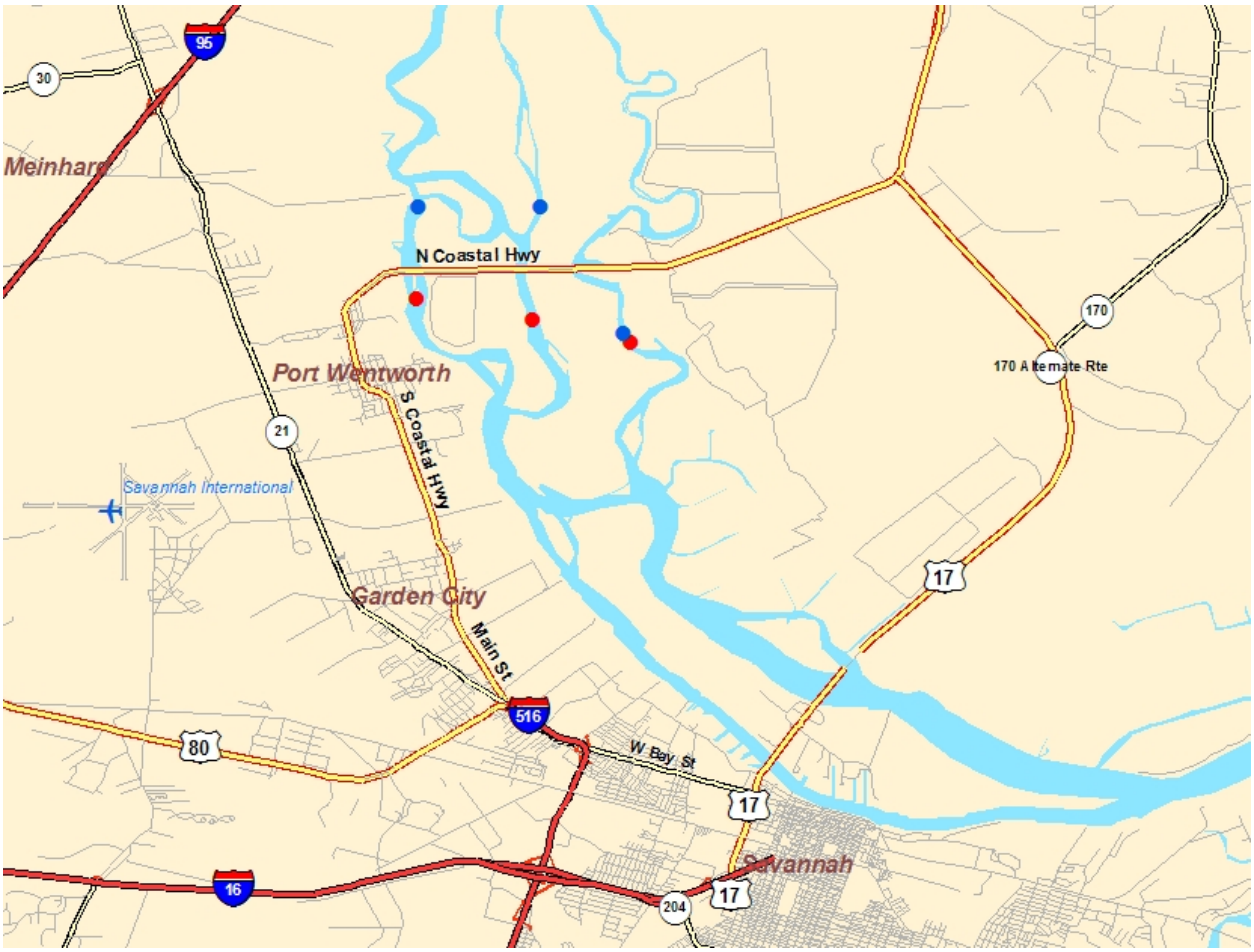

Figure 3. Location of the 50% exceedence 0.5 ppt salinity contour as predicted by the EFDC model (red points) and of the tidal freshwater marsh predicted by the MSM (blue points) in the Front River, Middle River and Back River.

Tidal freshwater marsh primary productivity is high, generally falling in the range of 1,000 to 2,000 gm/m^2/yr (Odum et al. 1984). The quality of primary production of the fresh marsh community is also high. Major primary producers in the salt marsh community are grasses that have little immediate nutritional value to fish and wildlife (Teal 1962). In contrast, the fleshy broad-leaf plants characteristic of fresh marshes generally are high in nitrogen and low in fiber content and there is a high incidence of direct grazing or feeding on these plants (Odum et al. 1984).

Fresh marsh vegetation contributes to the food web base that supports the study area's estuarine fishery. Dominant macroinvertebrates are likely to be amphipods and polychaetes (Odum et al 1984). Malloy 2003 found that members of the families Cyprinodontidae (pupfishes or killifish) and Palaemonidae (grass shrimp) were the most abundant nekton (aquatic organisms with the ability to swim) utilizing the marsh surface in the upper Savannah estuary. Estuarine dependent marine species were more prevalent in the tidal freshwater areas than freshwater species. Much of the prior tidal freshwater research in other areas has indicated that freshwater species are

dominant (Odum et al. 1984). Salinity intrusion due to prior harbor deepening could be a factor facilitating higher use by marine species. Water quality sampling has established the fact that Middle River periodically serves as a conduit for high salinity water far up that river. To a lesser extent Rifle Cut carries brackish water to Back River from Middle River. Such movements of saline water are likely to be favorable for marine species to move further up the estuary than they would under natural conditions.

Palustrine emergent wetlands provide important habitat for many bird species, including neotropical migrants (birds that summer in North America and winter in tropical America). Resident, transient, and migrating birds utilize food and shelter found in this community; some species use freshwater marshes for nesting and breeding. Studies conducted in 2000-2002 reported that more species of neotropical migratory birds were stopping over in tidal freshwater marsh habitat than in tidal saltwater habitat on Savannah NWR (Berryman and Webb 2003). Higher plant diversity and structural diversity in the freshwater marshes compared to brackish marshes may account for the higher use.

Graves (2001) found there were 26 species of birds exclusively associated with tidal freshwater marsh in the lower Savannah River and only four species exclusively associated with salt-dominated wetlands. Lower diversity of plant species combined with less structural diversity among plant communities in brackish marsh is most likely one basis for the differences among avian species richness and composition between freshwater and brackish marshes; brackish marshes might be more advantageous to generalist species, such as red-winged blackbirds (Peterson 1992). King rails are associated with freshwater and intermediate marshes and not found in salt-influenced marsh habitats within the Savannah River estuary (Graves 2001). King rail populations are declining and are listed as a species of concern by the U.S. Fish and Wildlife Service. Graves (2001) concluded that an increase in salinity in tidal wetlands at Savannah NWR would lead to a significant loss of avian diversity and that many bird species could be extirpated from the estuary, resulting in the continued decline of some species of management concern such as the king rail.

Waterfowl feed directly upon fresh marsh vegetation. Wild rice, sedges, spike rush, wild millet, bulrushes, and duckweeds serve as prime waterfowl food, and mollusks, insects, small crustaceans, and fish found in the fresh marsh community also are fed upon by waterfowl and other birds. Various species of ducks feed in the study area fresh marshes, along with wading birds such as the great blue heron, little blue heron, green heron, snowy egret, and great egret and many species of shorebirds.

Palustrine emergent wetlands also provide excellent habitat for fur-bearing mammals including the mink, beaver, and river otter. Terrestrial species from surrounding forested areas often utilize the fresh marsh edge for shelter, food, and water; these include raccoon, opossum, rabbit, and bobcat. In summary, the tidal fresh marsh on Savannah NWR supports an extremely diverse plant community providing food, cover and nesting habitat for a wide variety of wildlife species.

Cumulative salinity impacts due to previous harbor deepening projects have been significant and have substantially reduced the amount of freshwater marsh in the system. Figure 4 shows the approximate location of the freshwater interface at various times in recent history. Table 3 presents the location of the freshwater limit, channel depth and amount of tidal freshwater marsh at the various times. As the salinity interface has moved upriver, the diverse tidal freshwater marsh has been converted to lower diversity brackish marsh.

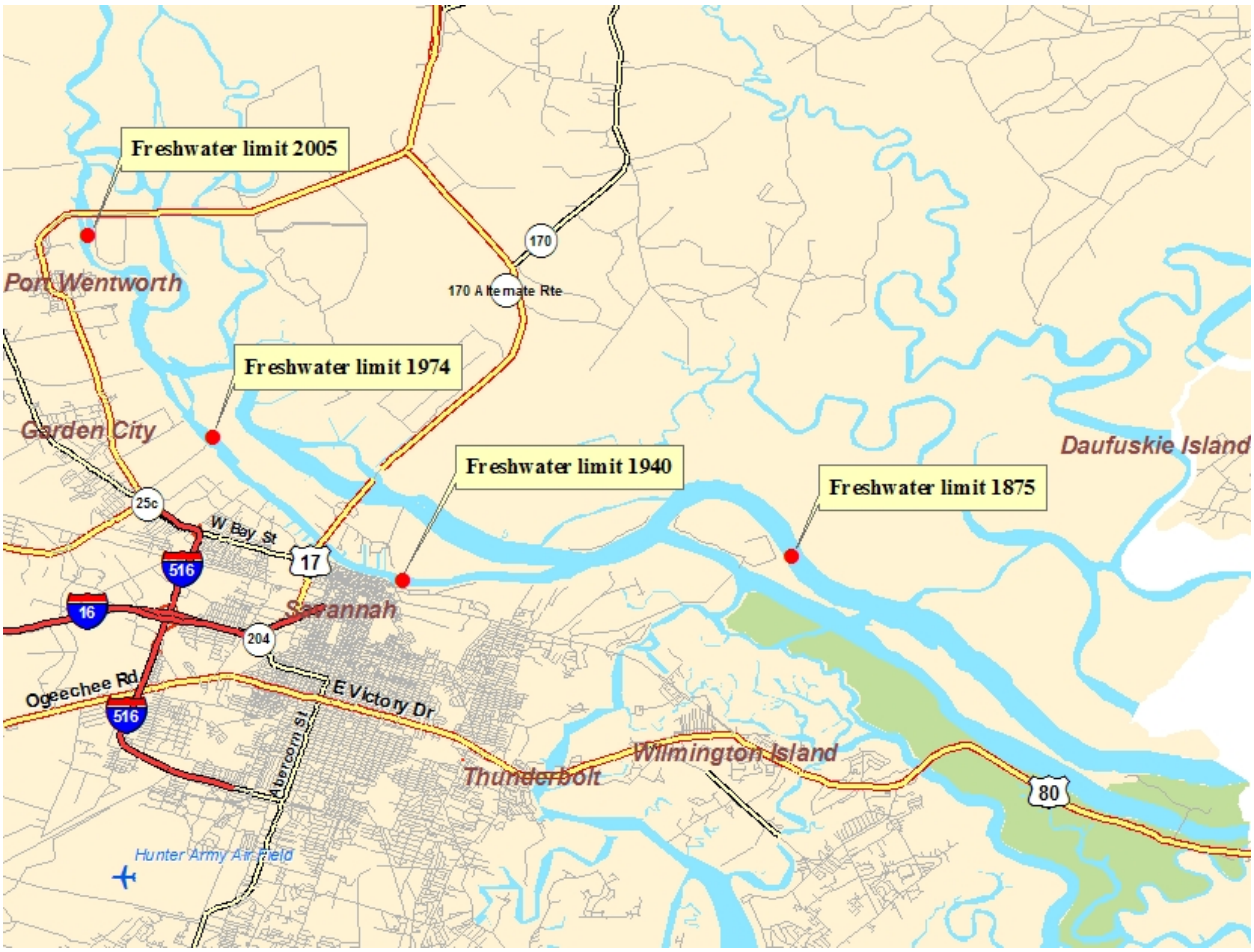

Figure 4. Location of the freshwater interface in the Savannah estuary from 1875-2005.

Table 3. Location of the freshwater limit, channel depth and amount of tidal freshwater marsh in the Savannah estuary from 1875-2005.

Year	Channel depth	Freshwater limit (river mile)	Tidal freshwater marsh (acres)
1875	15	7 (Granger 1968)	12,000 (map estimate)
1940	28	13 (Lamar 1940)	8,000 (map estimate)
1974	34	17 (Corps of Engineers 1975)	6,007 (Tiner 1977)
2005	42	21 (EFDC prediction)	3,269 (Welch and Kitchens 2006)

During the period of tide gate operation (1977-1992), salinity was increased by an additional increment in Back River and Little Back River, moving the freshwater-saltwater interface six miles upriver, and marshes in that area became more brackish and less diverse (Pearlstine et al. 1990). New Cut closure and termination of tide gate operation resulted in reversal of the previous adverse trends that were caused by the gate and some studies have indicated a gradual return to freshwater wetland vegetation characteristic of the Back River before the construction of the tide gate (Latham and Kitchens 1996, Loftin et al 2003). Another study, during 1999-2001, found fluctuations of plant species composition and the trend toward return of freshwater vegetation was not confirmed. However, this study occurred during a period of severe drought that increased salinity throughout the study area (Dusek and Kitchens 2003).

Fish

Jennings and Weyers (2003) conducted fish sampling in the Savannah River estuary during 2000-2002 and reported a diverse and abundant fish community that depended on the availability of specific salinity-defined habitats. A total of 91 fish species were collected with bay anchovy, Atlantic menhaden, Atlantic croaker and spot being the most abundant species. Most species were estuarine habitat generalists that could tolerate a wide range of salinities. A smaller number of species were marine species restricted to areas with higher salinity (>10 ppt) and these species moved further up the estuary as salinity moved inland during periods of low river discharge. Obligate freshwater species that could not tolerate salinity above 5 ppt were the smallest component of the fish community. The authors stated that these freshwater species would probably be at the greatest risk of population declines or range reduction if salinity increased in the estuary.

The shortnose sturgeon (endangered) is the only fish in the project area listed under the Endangered Species Act. This species is almost always located near the river bottom where it feeds on invertebrates. The shortnose sturgeon is also frequently located near the fresh water/salt water interface. A recent study (1999-2000) in the Savannah estuary used acoustic transmitters to track shortnose sturgeon location and determine habitat utilization (Collins et al 2001). Juveniles were found in two different specific locations depending on water temperature. They were found near the intersection of Front River and Middle River (river mile 19.7), moving between both rivers, when water temperature was less that 22º C. When water temperature was greater than 22º C the juveniles moved upstream of the harbor area and concentrated around river mile 29.5, where the salinity was consistently 0.1 ppt. Adult movements were similar but more extensive than the juveniles, with some adult fish moving almost to the mouth of the river during low temperature periods. During the study several fish received transmitters that measured depth and these fish were always located on or near the bottom.

Sampling during 1988-1992 found that juvenile shortnose sturgeon were concentrated in the Kings Island Turning Basin (river mile 18.7) but no juveniles were collected that far downriver in 1999-2000 (Collins et al 2001). Changes in the study area include harbor deepening from 38

to 42 feet, closing New Cut and taking the tide gate out of operation. The low catch rate of juveniles in 1999-2000 indicated that natural recruitment was quite low in the Savannah River. In the southeastern U.S. low recruitment is often thought to be caused by poor water quality in the nursery habitat located at the fresh water/salt water interface (Collins et al 2001).

One of the most important species in the lower Savannah River, both as an important sport fish and as an indicator of environmental quality, is the striped bass. Studies in the 1960's and early 1970's indicated that the primary spawning area for striped bass in the Savannah River system was the tidal fresh water zone approximately 18-25 miles from the river mouth, specifically the Little Back River (McBay 1968; Smith 1970; Rees 1973, 1974). However recent studies using egg surrogates (gellan beads) revealed striped bass egg sampling efficiency biases due to channel morphology and other hydraulic conditions. Sampling efficiency appeared to be higher, by an order of magnitude, in the narrower, shallower Back River than in the Front River (Reinert et al. 2004). Therefore, it is probable that the amount of spawning in the Front River has been underestimated in the past.

Production of striped bass eggs in the Savannah River estuary declined by about 95 percent between 1977, when the tide gate was put into routine operation and 1989 (Van Den Avyle et al. 1990). Tide gate operations increased the salinity on striped bass spawning grounds and altered current velocities and pathways of water movement in the middle and lower estuary (Van Den Avyle et al. 1990, Reinert et al. 2005). Adult spawners continued to use the same spawning grounds reported prior to tide gate installation, but the amount of spawning was reduced. There was no evidence of an upstream shift of spawning as speculated by Dudley and Black (1978). Research results and other supporting data (catch per effort for adult striped bass, Georgia DNR) indicated the reduction in spawning reflects reduced abundance of adults caused by lack of successful recruitment.

Salinities of 10 ppt or greater are toxic to striped bass larvae (Winger and Lasier 1990). Seaward of Hutchinson Island, salinity typically exceeds levels toxic to striped bass eggs and larvae. When the tide gate was operating, most striped bass eggs spawned in the Savannah River estuary were transported beyond Hutchinson Island in 30 to 48 hours. Striped bass eggs hatch within 40 to 60 hours post spawning, and the larvae, which are weak swimmers, are not able to avoid toxic conditions for at least 5 days post hatch.

Recovery of a viable, naturally reproducing, Savannah River striped bass sport fishery following the 1992 tide gate project modification was expected to take many years. Because of the severe decline in brood stock, stocking of striped bass was required for population recovery. The stocking program, which was initiated in 1989 by Georgia Department of Natural Resources (GADNR), was continued through 2002 (Matt Thomas, GADNR, personal communication 2005). Male striped bass require 3 years to reach sexual maturity and females require 5 years (7 to 8 years to become highly fecund). Assuming favorable environmental conditions, striped bass egg production was expected to increase about 6 years following New Cut closure, which occurred in 1992. Another 5 to 6 years was expected to be required for these naturally spawned

fish to be recruited into the adult population and spawn. Studies indicated that striped bass egg production in the Savannah River remained very low from 1994-1996 (Reinert et al 1996).

Recent studies indicate that successful striped bass natural reproduction had increased in the lower Savannah by 2001. Targeted striped bass egg sampling was conducted periodically from 1984 until 2000. There was some indication that egg abundance was increasing, from the very low levels of the mid-1990's, by 1999-2000 (Reinart et al. 2005). Will et al. (2002) assessed the reproductive status of Savannah River striped bass using ultrasonography and histological samples. Oocyte development appeared to be normal and size to fecundity relationships were similar to other striped bass populations. Reproductive status in the Savannah River appeared to be equivalent to status found in healthy striped bass populations (Will et al. 2002). Jennings and Weyers (2003) reported that striped bass larvae were collected in 2001-2002 ichthyoplankton samples from freshwater and low salinity habitats, thus indicating successful reproduction in the estuary. Collins et al (2002) reported collecting a high proportion of juvenile striped bass smaller than those stocked by GADNR in the Savannah estuary, indicating natural reproduction.

GADNR conducts regular striped bass sampling using electrofishing in the estuary and has collected striped bass spawned in 2003 and 2004. In addition, the number of striped bass age two years or more caught per hour of electrofishing has increased from two or less in the mid-1990's to more than 12 in the mid-2000's. The number of large striped bass (> 9 kilogram) caught per hour of electrofishing has increased from less than 0.1 in the early-1990's to more than 1.5 in the 2003 (Reinert et al. 2005). Although no formal creel studies have been conducted, anecdotal evidence indicates that sport fishing catch has greatly increased (Matt Thomas, GADNR, personal communication 2005). Therefore it appears that striped bass habitat restoration, by closing New Cut and taking the tide gate out of operation has been successful and that striped bass numbers, size and reproduction are increasing in the Savannah estuary.

Endangered Species

The Savannah Harbor study area supports a number of endangered and threatened species. Maintenance and enhancement of habitat for endangered and threatened species is an important Service goal. The species listed below should be taken into consideration in any future federal projects. The shortnose sturgeon is known to use the harbor area (see discussion under fish above) and impacts on this species must be carefully evaluated. The National Oceanic and Atmospheric Administration Fisheries Service (NOAA) is responsible for conducting Section 7 consultation with the Corps for this species, sea turtles (except when nesting) and whales.

Federal endangered (E), threatened (T) that could occur in the Savannah Harbor Expansion Study Area include the following species (whales are not listed here, consult NOAA).

West Indian manatee (*Trichechus manatus*) – E
Red-cockaded woodpecker (*Picoides borealis*) – E
Wood stork (*Mycteria americana*) – E
Piping plover (*Charadrius melodus*) – T (Atlantic coast population), E (Great Lakes population)

Kirtland's warbler (*Dendroica kirtlandii*) – E
Bachman's warbler (*Vermivora bachmanii*) - E
Eastern indigo snake (*Drymarchon corais couperi*) – T
Kemp's ridley sea turtle (*Lepidochelys kempi*) – E
Leatherback sea turtle (*Dermochelys coriacea*) – E
Loggerhead sea turtle (*Caretta caretta*) – T
Green sea turtle (*Chelonia mydas*) – T
Hawksbill turtle (*Eretmochelys imbricata*) - E
Flatwoods salamander (*Ambystoma cingulatum*) – T
Shortnose sturgeon (*Acipenser brevirostrum*) – E
Pondberry (*Lindera melissifolia*) – E
Canby's dropwort (*Oxypolis canbyi*) – E
Chaff-seed (*Schwalbea americana*) – E

PROBLEMS, OPPORTUNITIES, AND PLANNING OBJECTIVES

Based on the fish and wildlife resources in the project area the following fish and wildlife planning objectives have been formulated.

1. Restoration and maintenance of tidal freshwater marsh in the lower Savannah River.

Tidal freshwater marsh is one of the most diverse wetland types and provides excellent fish and wildlife habitat. Cumulative impacts of previous deepening projects have converted most of the tidal freshwater marsh to less diverse brackish marsh. Maintenance of normal tidal and salinity patterns is a major objective of coastal refuges and management areas to allow these areas to meet their wildlife objectives (Weller 1994). Therefore, the deepening project must avoid loss of tidal freshwater marsh due to salinity increase.

2. Restoration and maintenance of spawning and nursery habitat to support a self-sustaining striped bass population.

The striped bass is a nationally important fishery resource. Prior to tide gate installation, the Savannah River supported an important population of this species. Restoration of the habitat has been initiated by closing New Cut and removing the tide gate from operation. Savannah Harbor Expansion needs to avoid habitat impacts that would hinder recovery of this population.

3. Maintenance of the freshwater supply for management of approximately 5,700 acres of managed wetlands on Savannah NWR and for meeting legal agreements to supply freshwater to adjacent land owners.

Managed wetlands on Savannah NWR are managed for wintering waterfowl, wading and shore birds, and endangered species. Dabbling ducks are especially dependent on this habitat.

Conversion of freshwater impounded wetland habitats on the refuge to brackish wetland would severely impact management efforts, would be in direct opposition to the purpose for which the refuge was established, and must be avoided. The freshwater delivery system, which was installed as mitigation for the tide gate, failed soon after construction due to an inadequate design. The Service has repaired the system at great expense and management of the freshwater system has required significant staff time. This system must be repaired and functional prior to any additional harbor modifications.

4. Protection of riverine, palustrine, and estuarine wetlands in the lower Savannah River basin.

Palustrine, estuarine, and riverine wetlands provide the highest quality fish and wildlife habitat in the SHCS study area. These wetlands also provide habitat for wildlife of high public significance, such as waterfowl and most of the endangered species in the study area. Harbor development and maintenance have resulted in loss of approximately 6,000 acres of wetlands due to filling and dredged material disposal. Future harbor activities should avoid or minimize the use of these highly valuable habitats.

5. Maintenance and enhancement of endangered and threatened species and their habitat.

Endangered and threatened species are Service trust resources and our goal is to avoid or minimize any potential impacts.

6. Protection of beach habitat on Wassaw National Wildlife Refuge.

Beach on Wassaw NWR provides habitat for threatened loggerhead turtle and piping plover. This habitat is being lost due to erosion caused by cumulative impacts of harbor modifications.

ALTERNATIVES

The study evaluated deepening existing channels and selected turning basins by up to 6 feet. Total actual depths consist of nominal authorized project depths, plus advance maintenance and allowable overdepth, where applicable. Authorized project depth is the nominal channel depth provided for navigation. Advance maintenance (AM) is additional depth in the channel to provide storage for shoal material and currently adds four feet of depth in most of Savannah Harbor. Allowable overdepth is a dredging tolerance due to the inaccuracies of the dredging process and adds another two feet of depth. Therefore, immediately after dredging, depth of the channel may be six feet deeper than the nominal depth. As sedimentation occurs the actual depth approaches the nominal depth until the next dredging cycle. Table 4 presents the alternatives evaluated by the expansion project by nominal and maximum actual inner channel depth. The entrance channel is two feet deeper than the inner channel.

Table 4. Authorized depths, maximum actual depths (feet below MLLW) and new dredged material quantity with the no action alternative and various depth alternatives.

Alternative	Authorized depth (AD)	Maintenance depth (AD+AM)	Dredged material (cubic yards)
No action (current conditions)	42	46-48	0
Alternative 1	44	48-52	7,539,271
Alternative 2	45	49-53	13,882,441
Alternative 3	46	50-54	18,272,994
Alternative 4	48	52-56	26,532,811

The Corps did not conduct a detailed environmental analysis of the Jasper County terminal proposal because in their view the plans and schedule are uncertain. A sensitivity analysis was conducted to determine how terminal development would affect the economic viability of harbor deepening.

PROJECT IMPACTS

Project impacts and mitigation alternatives were primarily assessed using a hydrodynamic and water quality model. The three-dimensional hydrodynamic model selected for this project is based on the Environmental Fluid Dynamics Code (EFDC), a physics-based turbulence closure model that has been applied in a number of estuarine and riverine systems in the southeastern United States. Water-quality impacts (DO, nutrients, temperature) are simulated using the water-quality model WASP (Ambrose et al 1993). The WASP model uses the hydrodynamic input from the EFDC model.The Savannah Harbor expansion version of the EFDC is based on the model originally developed by Tetra Tech for the Environmental Protection Agency to determine the total maximum daily load for dissolved oxygen in the lower Savannah River. This model and the associated water quality model have been improved with an enhanced grid and other modifications. Extensive model development, coordination and peer review processes were conducted to ensure that the model was acceptable to evaluate project impacts. The EFDC model output provides salinity and dissolved oxygen predictions in the river channels of the harbor and lower Savannah River.

A marsh succession model (MSM) consisting of a geographic information system which displays the plant communities based on the salinity, soils and distance to a channel was developed as a tool to evaluate channel deepening impact (Welch and Kitchens 2006). The first input into the MSM is the channel salinity as predicted by the Environmental Fluid Dynamics Code hydrodynamic model (EFDC). The channel salinity is translated to interstitial salinity using a model to marsh spreadsheet application (M2M) developed by data mining techniques that used channel salinity data and interstitial salinity data at several locations in the estuary (Conrads et al

2006). The decision trees (Welch and Kitchens 2006) were used in conjunction with the environmental data to predict the plant communities in the study area.

Salinity and dissolved oxygen predictions from the EFDC and WASP models were also applied to simple fish habitat models developed by an interagency group that included scientists from the Corps, Service, NOAA, South Carolina Department of Natural Resources and Georgia Department of Natural Resources. Habitat models were developed for striped bass, shortnose sturgeon, southern flounder and American shad.

The most significant predicted impact of the deepening project is that salinity, in portions of the lower Savannah River, will be increased. Deepening of the Front River channel will increase tidal volume and increase salinity. Moderate incremental increases in the salinity level have become cumulatively significant as depth of the harbor has been repetitively increased over time. The potential impacts of the proposed deepening project must be considered in the context of these cumulative salinity impacts. Figure 4 presented the approximate location of the freshwater interface at various channel depths and times in recent history. As the salinity interface has moved upriver, tidal freshwater marsh has been converted to lower diversity brackish marsh. Habitat for striped bass and shortnose sturgeon has been modified and most of the original habitat for these fish has been rendered unsuitable.

Another highly significant impact is the predicted decrease in dissolved oxygen concentration due to increased salinity stratification. The numerous aquatic species that utilize wetlands in the Savannah estuary are dependent on suitable water quality to complete their life cycle. Dissolved oxygen is a key water quality component and adequate dissolved oxygen concentrations are essential to support fish and other aquatic life.

Managed Wetlands

With regard to managed wetlands, potential impacts of increased salinity levels in the lower Savannah River system include the following. During times of low flow, fresh water may not be available for the managed wetland system of Savannah NWR. The presence of brackish water would increase operation and maintenance costs due to increased personnel requirements to monitor salinity levels and adjust operations to prevent frequent introduction of brackish water. Water control structures and other equipment would also require more frequent repair and/or replacement due to salinity levels. The freshwater delivery system is inadequate and water is leaking around the failing structures. The refuge will not be able to prevent brackish water from entering the system unless it is repaired.

Evaporation tends to increase salinity levels in impoundment waters, and salt uptake by plants tends to increase soil salinity. Odum et al. (1977) state: “The floor of the freshwater marsh is composed of matted organic matter (mainly dead, non-decomposed roots and rhizomes) through which water flows. This mat will readily absorb sodium chloride and effectively increase the marsh salinity more than water level indicates.” Soils frequently flooded with brackish water

cannot have water removed for long periods of time because soil acidity increases beyond acceptable limits. These factors would change the plant community to less desirable plants for wildlife and preclude the ability to manage for freshwater plants. Freshwater management (salinity less than 0.5 ppt) is necessary to maintain maximum waterfowl use of the Refuge's managed wetlands.

Table 5 presents the predicted 10 % exceedence salinity at the diversion canal for average flow conditions. Although the 10 % exceedence includes the upper 10 % of the predicted salinity these predictions are for average flow. The need for water in the managed wetlands is generally in the fall to flood the areas shortly before wintering waterfowl arrive from the north. Savannah River flows are usually the lowest in the fall of the year. Water flow into the diversion canal is dependent on tidal action through flap gates and can only occur near high tide. Because of both of these factors the mean flow predictions will underestimate the impacts. Comparison of the salinity level at mean flow and low flow in Table 5 provides some measure of the under prediction. However even the low flow used in the EFDC is higher than typical fall flow.

Table 5. Predicted salinity at Savannah NWR diversion canal intake at alternative channel depths with no mitigation.

Channel depth	**Salinity at Existing sea level Mean flow 10% exceedence**	**Salinity at Existing sea level Low flow 10% exceedence**	**Salinity at Sea level +25cm Mean flow 10% exceedence**	**Salinity at Sea level +50cm Mean flow 10% exceedence**
42	0.1-0.2 ppt	0.5-0.6 ppt	0.2-0.3 ppt	0.4-0.5 ppt
44	0.1-0.3 ppt	0.7-0.9 ppt	0.3-0.5 ppt	0.8-1.0 ppt
45	0.1-0.3 ppt	0.7-0.9 ppt	0.3-0.5 ppt	0.8-1.0 ppt
46	0.1-0.3 ppt	0.7-0.9 ppt	0.4-0.6 ppt	0.9-1.1 ppt
48	0.2-0.4 ppt	0.9-1.1 ppt	0.4-0.6 ppt	1.0-1.2 ppt

Of the information available, the low flow 10% exceedence provides the best comparison of the plans because mean flows are too high to be realistic for fall conditions when water is needed in the managed wetlands. Without mitigation, all of the deepening alternatives would increase salinity at the diversion canal and are likely to impair or preclude freshwater management. The predicted increase of 0.2-0.3 ppt would be the same for the 44-46 foot depths but the increase would be 0.4-0.5 ppt, almost doubling the existing salinity level, for the 48 foot alternative.

Tidal freshwater wetlands

Increased salinity is predicted to cause conversion of tidal freshwater marsh to brackish marsh. Based on previous studies, as the marshes become more saline plant species composition

becomes less diverse (Pearlstine et al. 1990, Dusek and Kitchens 2003, Welch and Kitchens 2006). The magnitudes of marsh change predicted by the MSM for the 44 foot channel depth and the 48 foot channel depth under non-drought (2005) conditions are presented in Tables 6 and 7. The magnitudes of marsh change predicted by the MSM for the 44 foot channel depth and the 48 foot channel depth under drought (2002) conditions are presented in Tables 8 and 9.

Table 6. The magnitudes of marsh change predicted by the MSM for the 44 foot channel depth under non-drought (2005) conditions.

MSM Non-drought community (2005)	No action acreage	44 foot channel	Acreage change
100 % Elemo; Galti; Saglt*	2081	1999	- 82
80 % Zizmi; Polsp*	761	724	- 38
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	427	458	+ 31
78 % Sciva	2427	2339	-88
78 % Spasp; Sciro; Astte*	3151	3327	+ 177
Total	8847	8847	8847

Table 7. The magnitudes of marsh change predicted by the MSM for the 48 foot channel depth under non-drought (2005) conditions.

MSM Non-drought community (2005)	No action acreage	48 foot channel	Acreage change
100 % Elemo; Galti; Saglt*	2081	1607	- 474
80 % Zizmi; Polsp*	761	657	- 104
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	427	703	+ 275
78 % Sciva	2427	2262	-165
78 % Spasp; Sciro; Astte*	3151	3618	+ 468
Total	8847	8847	8847

Table 8. The magnitudes of marsh change predicted by the MSM for the 44 foot channel depth under drought (2002) conditions.

MSM drought community (2002)	No action acreage	44 foot channel	Acreage change
100 % Elemo; Galti; Saglt*	868	740	- 129
80 % Zizmi; Polsp*	476	305	- 171
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	1069	925	- 144
78 % Sciva	2485	2806	+ 321
78 % Spasp; Sciro; Astte*	3949	4071	+ 123
Total	8847	8847	8847

Table 9. The magnitudes of marsh change predicted by the MSM for the 48 foot channel depth under drought (2002) conditions.

MSM drought community (2002)	No action acreage	48 foot channel	Acreage change
100 % Elemo; Galti; Saglt*	868	517	- 351
80 % Zizmi; Polsp*	476	65	- 411
45 % Zizmi; Polsp; 29 % Elemo; Galti; Saglt; 26 % Sciva*	1069	651	- 418
78 % Sciva	2485	3362	+ 877
78 % Spasp; Sciro; Astte*	3949	4252	+ 303
Total	8847	8847	8847

Fish

The Savannah estuary supports a diverse fish community that utilizes the complex mosaic of tidal wetland habitat. However, only a few species of fish were selected to evaluate harbor deepening impacts. Species selected were based on their status as protected or trust resources, knowledge of habitat requirements and sensitivity to expected impacts. The shortnose sturgeon, striped bass, southern flounder, and American shad were the species chosen for evaluation.

The shortnose sturgeon is particularly vulnerable to water quality impacts, which will be most severe in deep water and will impact the fish directly as well as impacts to its invertebrate food

source. In the past, shortnose sturgeon used the Kings Island Turning Basin and other locations in the Savannah estuary as nursery and foraging habitat. As the salinity increased in the estuary, due primarily to harbor deepening, these locations could no longer support shortnose sturgeon.

Current dissolved oxygen levels in much of project area are frequently marginal to support shortnose sturgeon. Shortnose sturgeon juveniles are extremely sensitive to dissolved oxygen concentrations. In a 6-hour test using 64 day old fish and a dissolved oxygen concentration of 2.5 mg/l, a mortality rate of 86 % was observed. While older juveniles appear to be more tolerant of this concentration, it has been shown that a concentration of 3.0 mg/l can alter sturgeon behavior possibly reducing the likelihood of survival in the environment (Jenkins et al. 1993). Shortnose sturgeon are also impacted by high water temperature. Ziegeweid et al. (2008a) reported that thermal preference upper limit safe temperature varied for different acclimation temperatures. Thermal growth optima were 26°C (low acclimation temperature) and 28°C (high acclimation temperature) and estimated "safe temperature" ranged from 28.7°C to 31.1°C (Ziegeweid et al. 2008b). Thermal stress is likely exacerbated by low dissolved oxygen conditions observed during summer critical months. During these months sturgeon seek out deeper cooler water and may suffer an "oxygen squeeze" due to the low dissolved oxygen observed at these depths of the river (Secor and Niklitschek 2001). Ziegeweid et al. (2008b) found that probability of survival of young-of-year shortnose sturgeon was dependent on interaction of salinity, temperature and fish weight.

The predicted impacts to shortnose sturgeon habitat due to salinity increase and dissolved oxygen decrease are presented in Table 10. Impact to shortnose sturgeon adult summer habitat is predicted to decrease by 26-42 percent depending on the depth alternative while impact to adult winter habitat is predicted to be negligible. Loss of juvenile winter habitat would range from 5 - 22 percent. Cumulative impact was determined by multiplication of life stage impacts because these habitat predictions are considered independent events (Sokal and Rohlf 1969). Specifically, predicted remaining habitat for each category (juvenile winter, adult winter, adult summer) was determined by subtraction, the results were multiplied to determine cumulative remaining habitat, and the remaining habitat was subtracted from 1 to determine cumulative loss. For example, at 48 feet cumulative loss would be (from Table 10, last row): $1 - [(1-0.22) * (1-0.01) * (1-0.42)] = 0.55$. Cumulative impact ranged from -30 percent at 44 feet, to -55 percent at 48 feet.

Table 10. Model predicted impact to shortnose sturgeon juvenile winter (January) habitat, adult winter (January) habitat, and adult summer (August) habitat for depth alternatives. Cumulative impact is calculated as described in text.

Channel depth	Juvenile winter percent change	Adult winter percent change	Adult summer percent change	Cumulative percent impact
42 feet (baseline)	0	0	0	0
44 feet	-5	-1	-26	-30
45 feet	-10	-1	-34	-41
46 feet	-16	-1	-39	-49
48 feet	-22	-1	-42	-55

In the Savannah River, the striped bass is dependent on habitat in the estuary for successful reproduction and recruitment into the adult population because almost no spawning has been documented upstream of the estuary. After spawning the egg and early larval stages are transported by tidal currents both upstream and downstream but the net movement is toward the ocean. Therefore this important sport fish is very sensitive to salinity increases caused by harbor deepening.

The habitat suitability model for striped bass indicates that a maximum salinity of 1.5 ppt or less is optimal for spawning (Bain and Bain 1982). Studies on the Savannah River indicate that striped bass almost exclusively spawn in areas where maximum salinity near the surface is less than one ppt (Van Den Avyle et al 1990, Will et al 2000).

Winger and Lasier (1990) concluded that exposure to salinity greater than 15 ppt was toxic to Savannah River striped bass eggs. However, normally eggs will develop into larvae within about two days of spawning. Winger and Lasier (1990) concluded, using laboratory studies at a constant salinity, that Savannah River striped bass larvae survived well at three (3.0) to nine (9.0) ppt salinity but survival decreased at higher salinity. Five day old larvae were able to tolerate higher salinity than two day old larvae.

The effects of low dissolved oxygen on egg, larval and juvenile striped bass can be dramatic. For example, dissolved oxygen concentrations between 2.0 and 3.5 mg/l were determined responsible for the absence of striped bass eggs and larvae in the Delaware River (Bain and Bain 1982). Other studies have indicated that even moderate reductions from 5.0 to 4.0 mg/l decreased the survival of eggs and larvae and that striped bass larvae need a minimum of 3.0 mg/l dissolved oxygen to survive. (Bain and Bain 1982). Juvenile striped bass exhibit no survival at a dissolved oxygen level of 1.0 mg/l, intermediate survival at 3.0 mg/l and high survival at 5.0 mg/l. Adult striped bass appear to have similar water temperature and dissolved oxygen requirements as juveniles and have been observed avoiding areas with low dissolved oxygen where the percent of saturation reaches 44% or less (Bain and Bain 1982).

Increased salinity levels and reduced dissolved oxygen levels would degrade spawning and nursery habitat for striped bass and reduce the area of available habitat. Estimated impacts to striped bass habitat for the various alternatives are shown in Tables 11-13. At the 50th percentile flow, impact to spawning habitat ranges from -8% at the 44 foot depth to -20% at the 48 foot depth. At the 50th percentile flow, impact to egg habitat ranges from -10% at the 44 foot depth to -25% at the 48 foot depth. At the 50th percentile flow, impact to larval habitat ranges from -14% at the 44 foot depth to -21% at the 46 foot depth.

Table 11. Predicted percent change in striped bass spawning habitat for depth alternatives at 20th , 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted average
42 feet (baseline)	0	0	0	0
44 feet	-8	-8	-6	-8
45 feet	-11	-12	-7	-11
46 feet	-13	-13	-13	-13
48 feet	-17	-20	-17	-19

Table 12. Predicted percent change in striped bass egg habitat for depth alternatives at 20th , 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted average
42 feet (baseline)	0	0	0	0
44 feet	-10	-10	-2	-8
45 feet	-12	-11	-5	-10
46 feet	-14	-16	-5	-13
48 feet	-19	-25	-7	-19

Table 13. Predicted percent change in striped bass larval habitat for depth alternatives at 20th , 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted average
42 feet (baseline)	0	0	0	0
44 feet	38	-14	-1	+2
45 feet	56	-19	-7	+3
46 feet	100	-21	-5	+13
48 feet	105	-16	-6	+17

To assess cumulative impact to striped bass we first determined a weighted average impact, assigning twice as much value to the 50th percentile flow than the other two flows. Cumulative impact was determined by multiplication of life stage as described earlier in this report. Positive impacts in larval habitat were not included because the loss of spawning and egg habitat would reduce the earlier life stages that would utilize that habitat. Table 14 summarizes the striped impacts for depth alternatives. The 44 foot depth with plan 6b is predicted to have the least overall impact (-15 percent). The 48 foot alternative has a higher impact, a 34 percent loss of habitat.

Table 14. Striped bass spawning habitat, egg habitat, larval habitat and cumulative impact predicted for Savannah Harbor deepening.

Channel depth	Spawning habitat impact	Egg habitat impact	Larval habitat impact	Cumulative impact (%)
42 feet (baseline)	0	0	0	0
44 feet/6b	-8	-8	+2	-15
45 feet/6a	-11	-10	+3	-20
46 feet/6a	-13	-13	+13	-24
48 feet/6a	-19	-19	+17	-34

Reinert and Peterson 2008 constructed a quantitative Bayesian belief network model for striped bass egg and early larval survival in the Savannah estuary. The Bayesian model was based on a stochastic model of river discharge, tidal phase, salinity, striped bass egg and larval survival and hypothetical salinity shifts. Using this model and EFDC predicted salinity shifts in the Front River results in a prediction of about five percent loss of egg/larval habitat for the 44 foot and 45 foot alternatives and about nine percent loss for the 46 foot and 48 foot alternatives. It should be noted that the Bayesian model predictions were based on a simple salinity shift in the Front River but the EFDC model provide more detailed salinity impact predictions throughout the estuary (Front River, Middle River and Back River).

Southern flounder is an important recreational fish that uses the river bottom as its primary habitat. Therefore, it is particularly susceptible to channel deepening induced dissolved oxygen reduction, which is most pronounced in deep water. The model predicted impacts to southern flounder are presented in Table 15.

Table 15. Predicted percent change in Southern flounder habitat for depth alternatives.

Channel depth	Percent change
42 feet (baseline)	
44 feet	-13
45 feet	-15
46 feet	-18
48 feet	-21

The American shad model was selected for evaluation because it is an important migratory commercial and sport fish that has been impacted throughout its range by dam construction and decreases in water quality. The predicted impacts to American shad were less than two percent for all deepening alternatives. This species model was not very sensitive to deepening impacts because the dissolved oxygen requirement was relatively low and was located in the upper half of the water column where the dissolved oxygen is generally higher than dissolved oxygen near the bottom.

Endangered Species

Consultation under the endangered species act is being conducted to determine the effect of the project on listed species. The endangered species most susceptible to impact from this project is the shortnose sturgeon because it is a bottom dweller and the juveniles utilize the freshwater/saltwater interface. NOAA is responsible for endangered species consultation for shortnose sturgeon. Impacts to this species predicted by the model were presented earlier in this report.

Cadmium

Elevated cadmium levels have been found in several areas of the harbor from about river mile 4 to river mile 11. These elevated cadmium levels are in Miocene clays in the river bottom that would be dredged during construction of the expansion project (EA Engineering, Science and Technology 2008). The dredging would remove these clays and place them in a confined disposal area. Therefore, the project would result in potential exposure of aquatic organisms in the river bottom and in the disposal area and in waters receiving effluent from the disposal area. In addition terrestrial organisms would be subject to exposure to cadmium in the disposal area.

Cadmium is toxic to freshwater and marine organisms at various concentrations depending on the species. Sublethal effects include decreased growth, inhibited reproduction, respiratory disruption and altered enzyme levels (Eisler 1985). Birds and mammals are more resistant than aquatic organisms to the biocidal properties of cadmium requiring higher doses to cause death. Sublethal effects in birds include growth inhibition, anemia and testicular damage (Eisler 1985).

The risk assessment prepared for the Corps concludes that cadmium concentrations in new work sediments have no potential to impact the ecology of the Savannah River and are unlikely to cause adverse impacts in placement site wetlands (EA Engineering, Science and Technology 2008). Based on our detailed review of the risk assessment, the Service believes that short-term and long-term adverse impacts are possible on the Savannah River ecology as a result of dredging activities and exposure of sediments containing elevated cadmium concentrations and that adverse impacts on plants and wildlife in placement site wetlands/drainage areas and effluent-receiving waters may occur. Our detailed comments on the risk assessment are being provided to the Corps under separate cover.

Beach Erosion

The proposed project may not increase erosion on Wassaw Island because essentially all of the sand in the longshore transport system is being trapped by the current Savannah Harbor channel (Clark Alexander, Skidaway Institute of Oceanography, written communication 2008). The cumulative beach erosion impacts of Savannah Harbor deepening and maintenance have not been addressed in previous projects. While the proposed project may not cause additional incremental impacts, the on-going impacts on Wassaw Island are severe. The loss of loggerhead turtle and piping plover habitat on Wassaw National Wildlife Refuge is substantial. The Corps needs to coordinate further with the Service to implement mitigation for this impact.

MITIGATION OPTIONS

Channel and flow modifications

To address salinity impacts a number of options to modify flows and channel depths in the different branches of the river were proposed for evaluation using the various models (Figure 5). The Corps proposed most of these options and the Service proposed option g (close Drakies Cut).

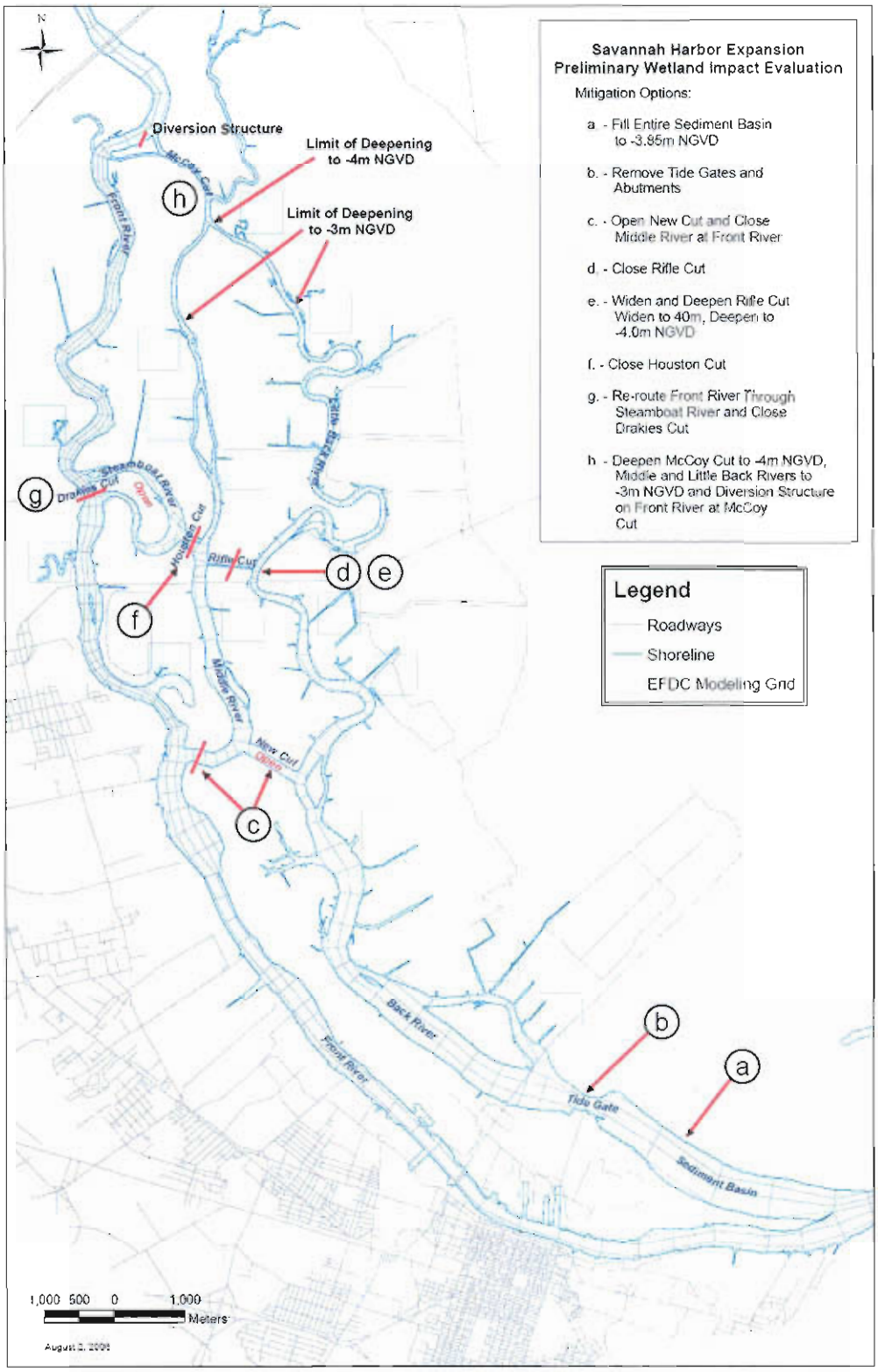

Figure 5. Flow and channel modifications evaluated as mitigation for the Savannah Harbor deepening project.

Based on preliminary modeling, the options were either evaluated individually or combined to develop a number of mitigation plans. Plan 1 includes a rock diversion structure in the Savannah River at McCoys Cut and dredging of small channels in the upstream portions of Little Back River and Middle River (h, Figure 5). These features were designed to divert water from Front River into Middle and Back River and thus reduce salinity in tidal freshwater wetlands. Plan 2 would add filling of the sediment basin (to elevation -3.85 NGVD), or allowing it to fill through sedimentation (h and a, Figure 5) Filling of the sediment basin would reduce salinity intrusion up Back River into important wetland areas. Plan 3 would add closing of Rifle Cut to the features of the first two plans (h, a and d, Figure 5). Closing Rifle Cut would reduce salinity intrusion into Back River because saline water flows up Middle River and through Rifle Cut.

Plan 4 includes the diversion features at McCoys Cut, closing Middle River at its downstream end and at Houston Cut and opening New Cut between Back River and Middle River (h and c, Figure 5). This plan is designed to isolate the Middle River and Back River from salinity intrusion up the Front River. The opening of New Cut is meant to provide tidal exchange in Middle and Back River because tidal exchange from Front River would be eliminated. Plan 5 would include the diversion features at McCoys Cut, closing Middle River at its downstream end and at Houston Cut and opening New Cut between Back River and Middle River and filling of the sediment basin (h, c and a, Figure 5).

After using the EFDC model to evaluate the potential mitigation plans, two major additional features were considered. One additional feature was the removal of the tide gate structure and Abutments (b, Figure 5). The tide gate has been out of operation since 1992; but, the gate structure and abutments have remained in place. These structures restrict tidal flow in the Back River and may have resulted in sedimentation upstream of the gate. The second feature consists of restoring the Front River to its former channel at Drakies Cut (g, Figure 5). The Cut would be closed and the river would be routed through the Steamboat River, the former Front River channel. A weir would be used to control the amount of flow into Middle River at Houston Cut. These features would add about two miles of channel length to the Front River and have the potential to reduce salinity intrusion up Front River and Middle River.

Two additional modifications of the most effective plans were evaluated. The first modification would include only the diversion structure at McCoys Cut and eliminate the dredging in Middle River and Back River. The second modification was to close the downstream arm at McCoys Cut. Qualitative on-site observations indicate that much of the river flow entering the upstream arm of McCoys Cut enters the downstream arm and returns to the Front River. It is likely that flow through the downstream arm would reduce the effectiveness of the potential McCoys Cut diversion structure.

The mitigation alternatives were screened using the models. Plans 4 and 5 were eliminated from further consideration because they reduced the tidal range in Back River and Middle River. As a result the frequency, duration and depth of marsh flooding would be reduced and wetland function would be adversely impacted. Eight plans, designated 3, 3a, 3b, 3c, 6, 6a. 6b and 7, were most effective, of those evaluated, in reducing project impacts. These plans are presented in figures 6 – 13.

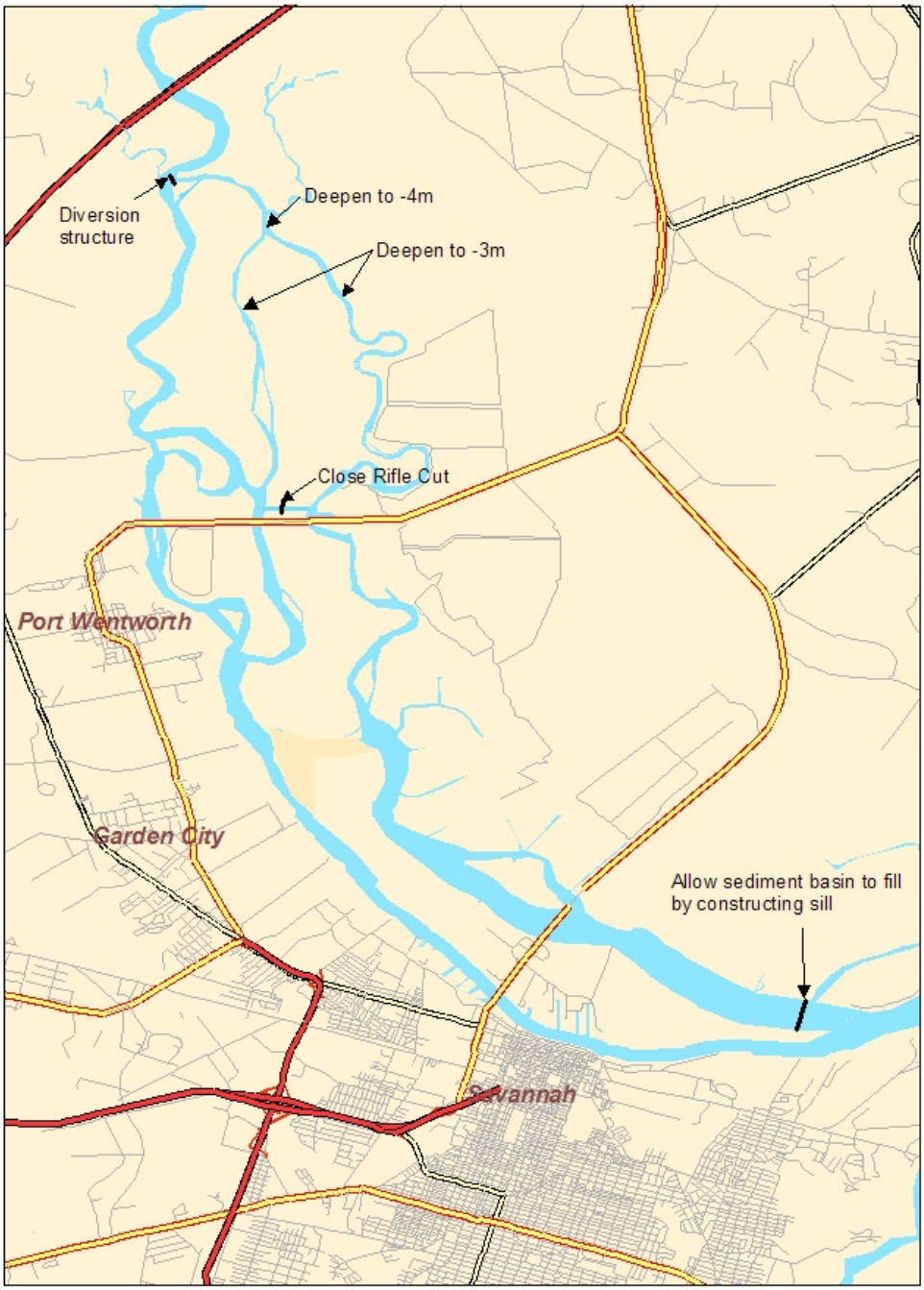

Figure 6. Savannah River estuary and mitigation plan 3 for Savannah Harbor deepening. Plan 3 includes a diversion structure at McCoys Cut, deepening of upper Back River and Middle River downstream to the points shown, closing Rifle Cut and allowing sediment basin to fill.

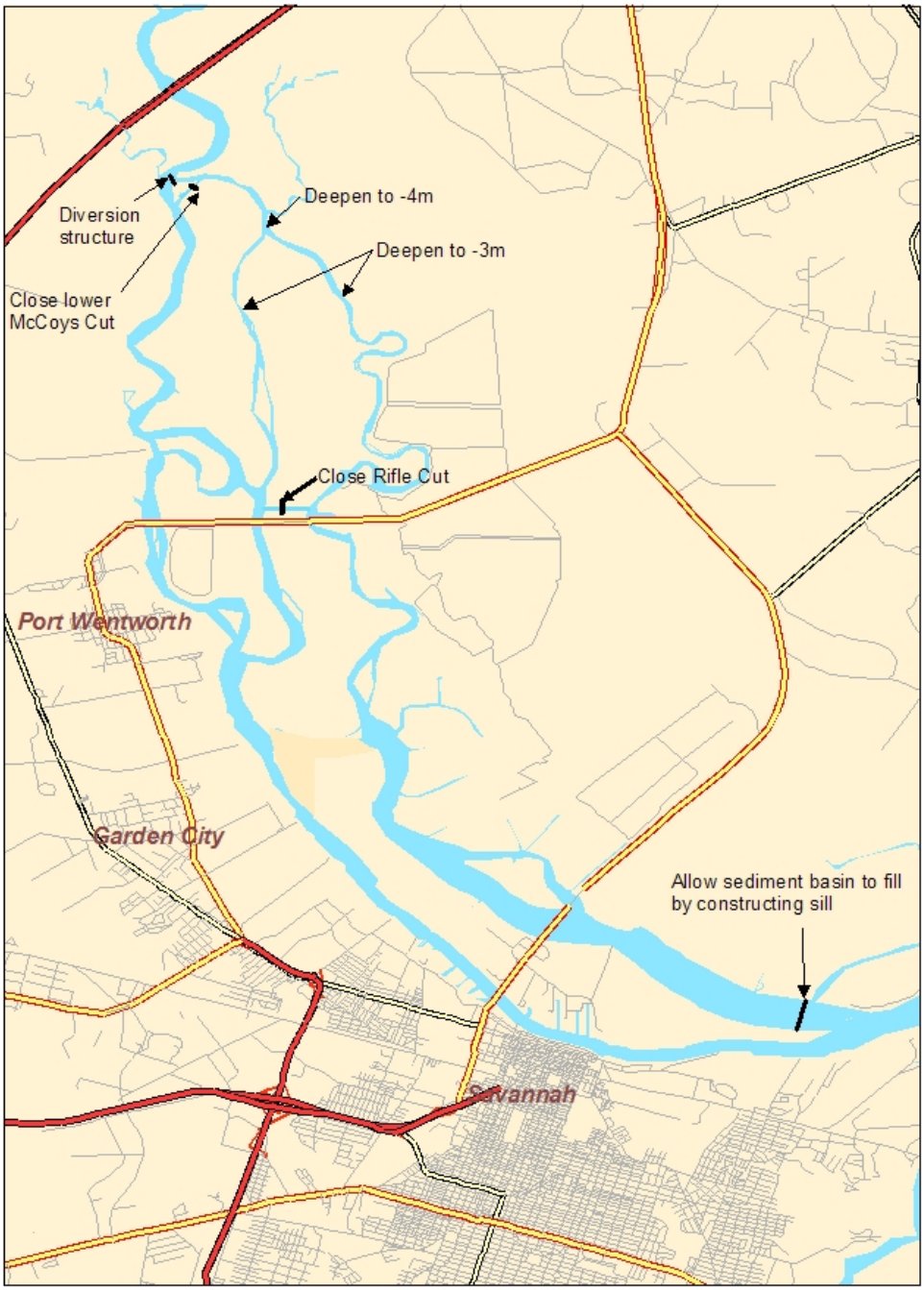

Figure 7. Savannah River estuary and mitigation plan 3a for Savannah Harbor deepening. Plan 3a includes a diversion structure at McCoys Cut, closing lower McCoys Cut, deepening of upper Back River and Middle River downstream to the points shown, closing Rifle Cut and allowing sediment basin to fill.

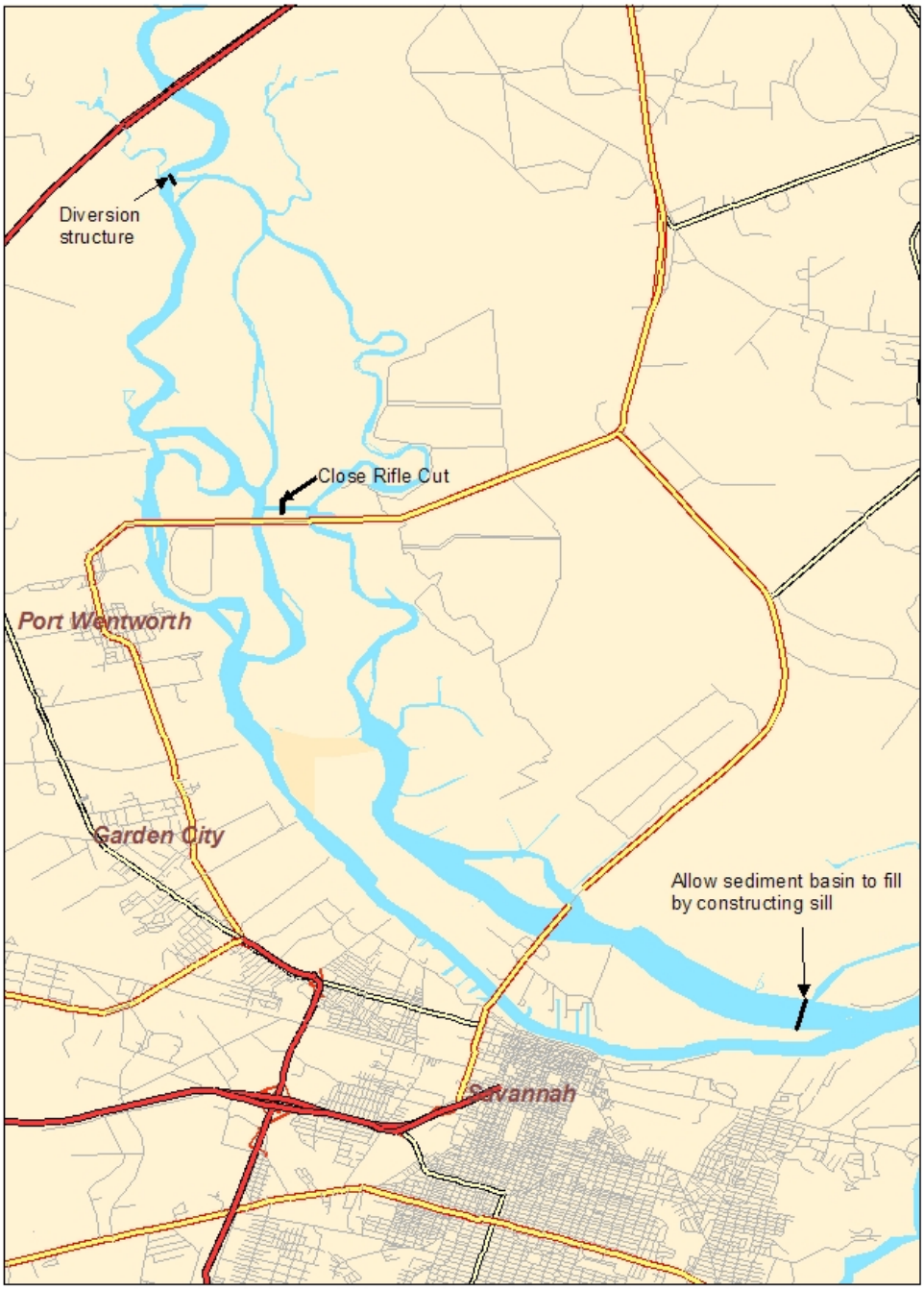

Figure 8. Savannah River estuary and mitigation plan 3b for Savannah Harbor deepening. Plan 3b includes a diversion structure at McCoys Cut, closing Rifle Cut and allowing sediment basin to fill.

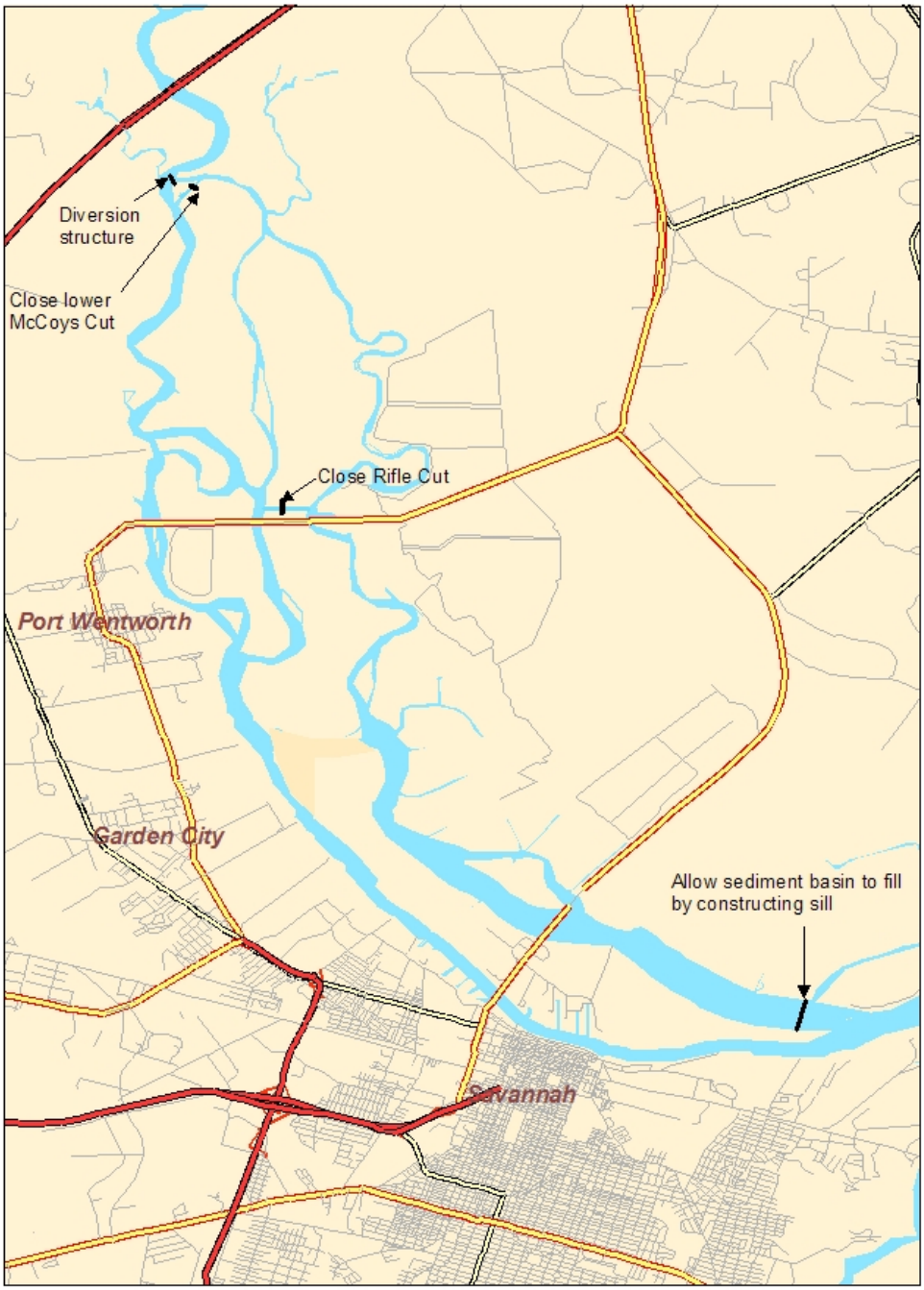

Figure 9. Savannah River estuary and mitigation plan 3c for Savannah Harbor deepening. Plan 3c includes a diversion structure at McCoys Cut, closing lower McCoys Cut, closing Rifle Cut and allowing sediment basin to fill.

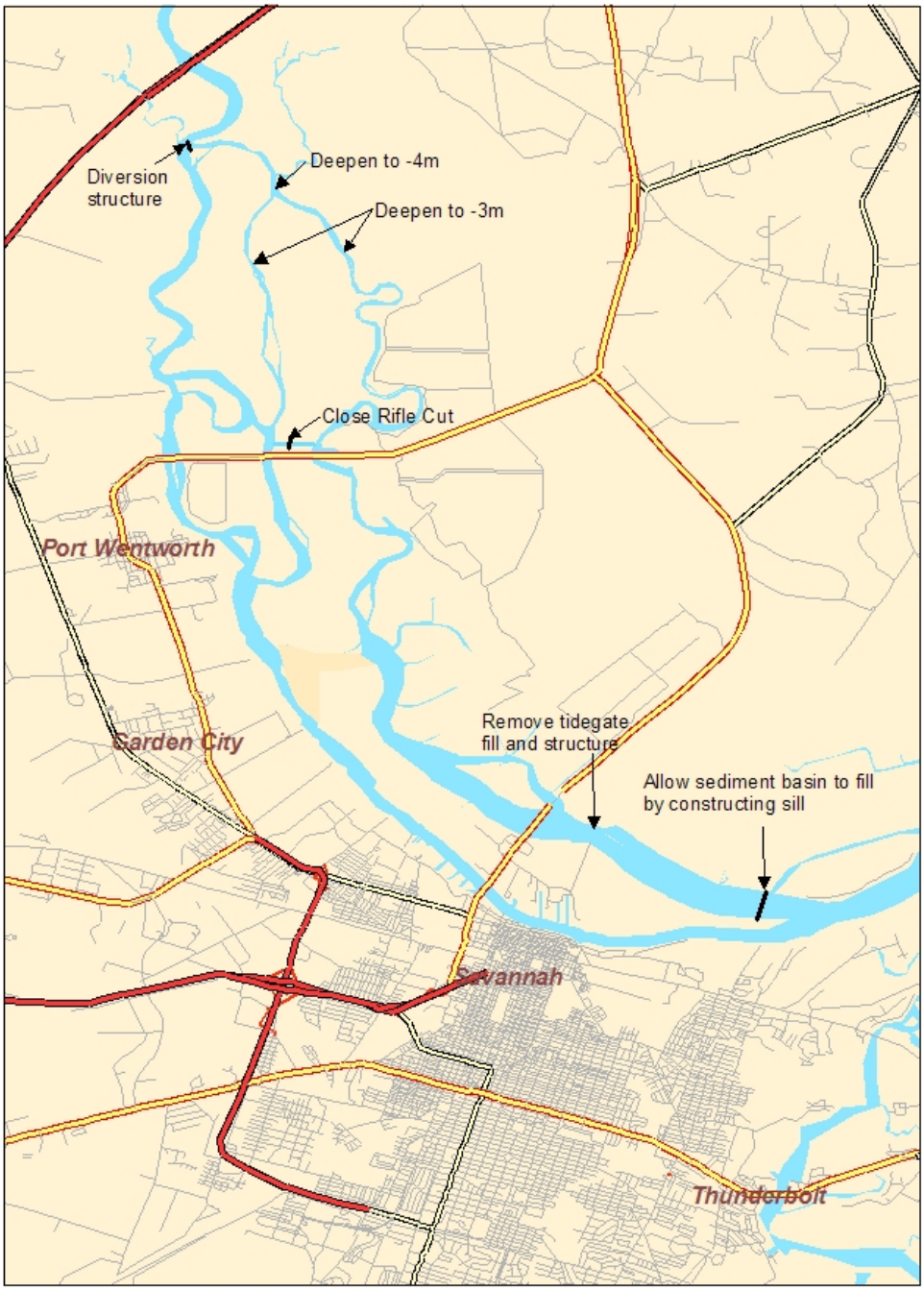

Figure 10. Savannah River estuary and mitigation plan 6 for Savannah Harbor deepening. Plan 6 includes a diversion structure at McCoys Cut, deepening of upper Back River and Middle River downstream to the points shown, closing Rifle Cut, allowing sediment basin to fill and removing tidegate abutments and structure.

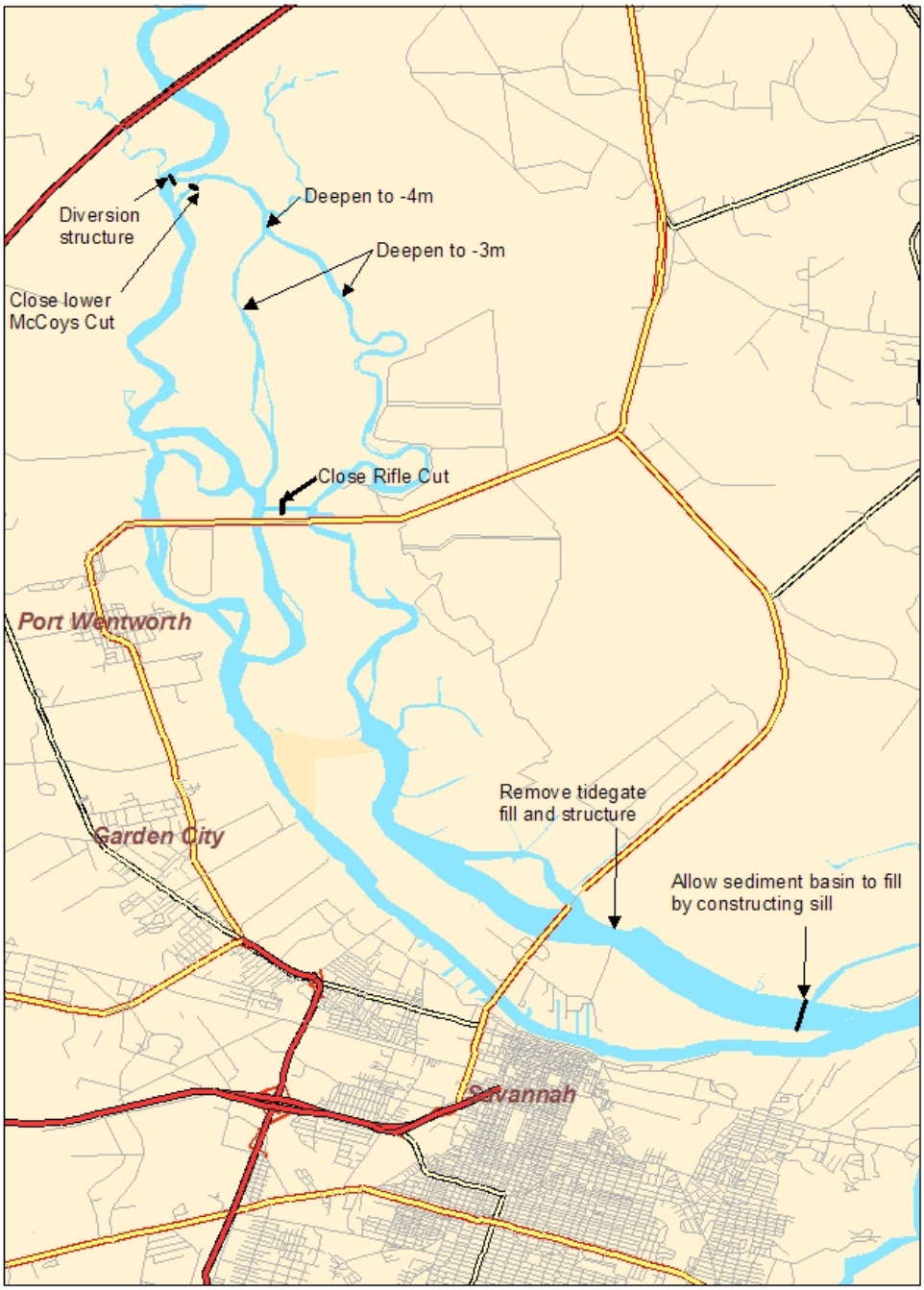

Figure 11. Savannah River estuary and mitigation plan 6a for Savannah Harbor deepening. Plan 6a includes a diversion structure at McCoys Cut, closing lower McCoys Cut, deepening of upper Back River and Middle River downstream to the points shown, closing Rifle Cut, allowing sediment basin to fill and removing tidegate.

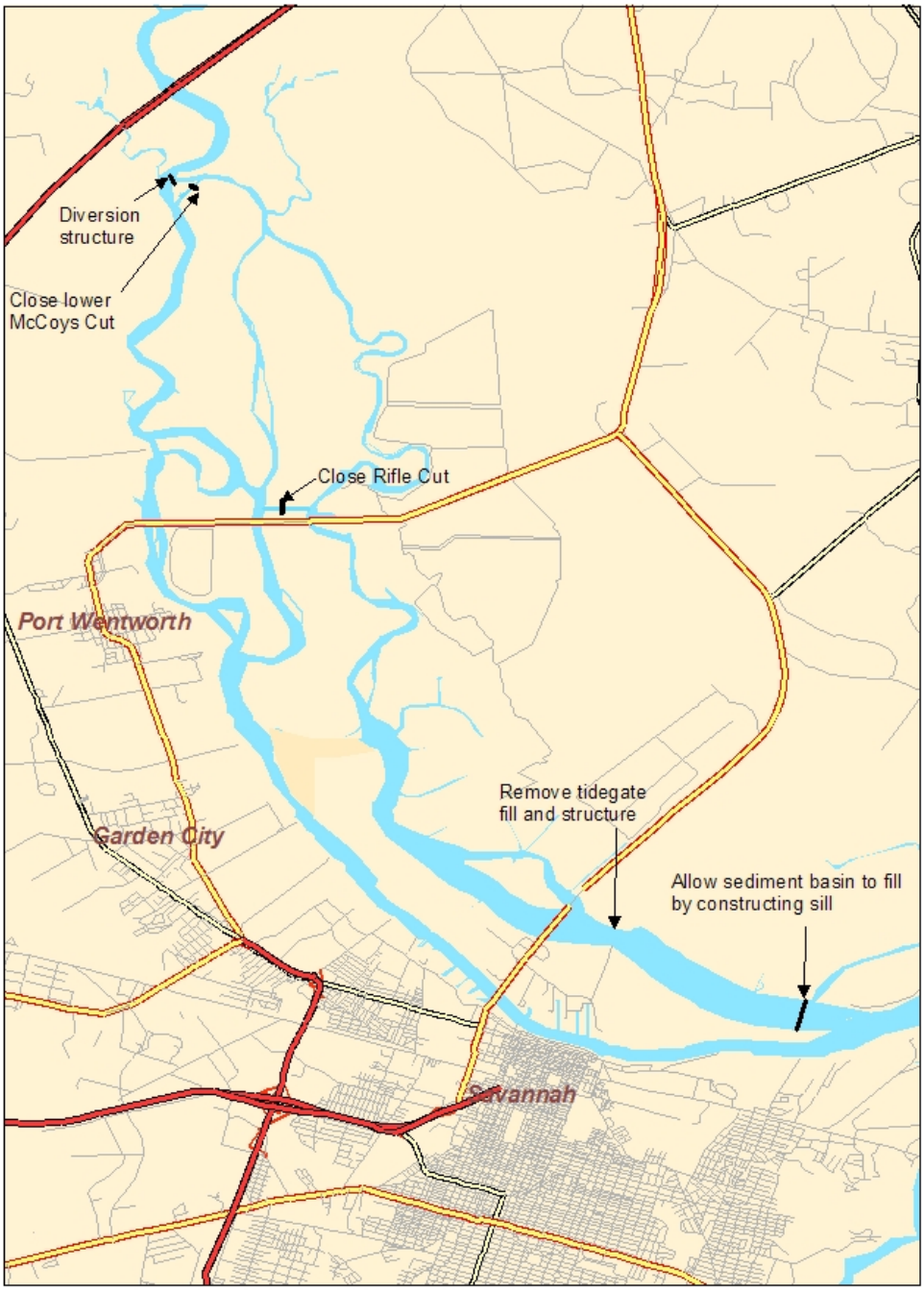

Figure 12. Savannah River estuary and mitigation plan 6b for Savannah Harbor deepening. Plan 6b includes a diversion structure at McCoys Cut, closing lower McCoys Cut, closing Rifle Cut, allowing sediment basin to fill and removing tidegate.

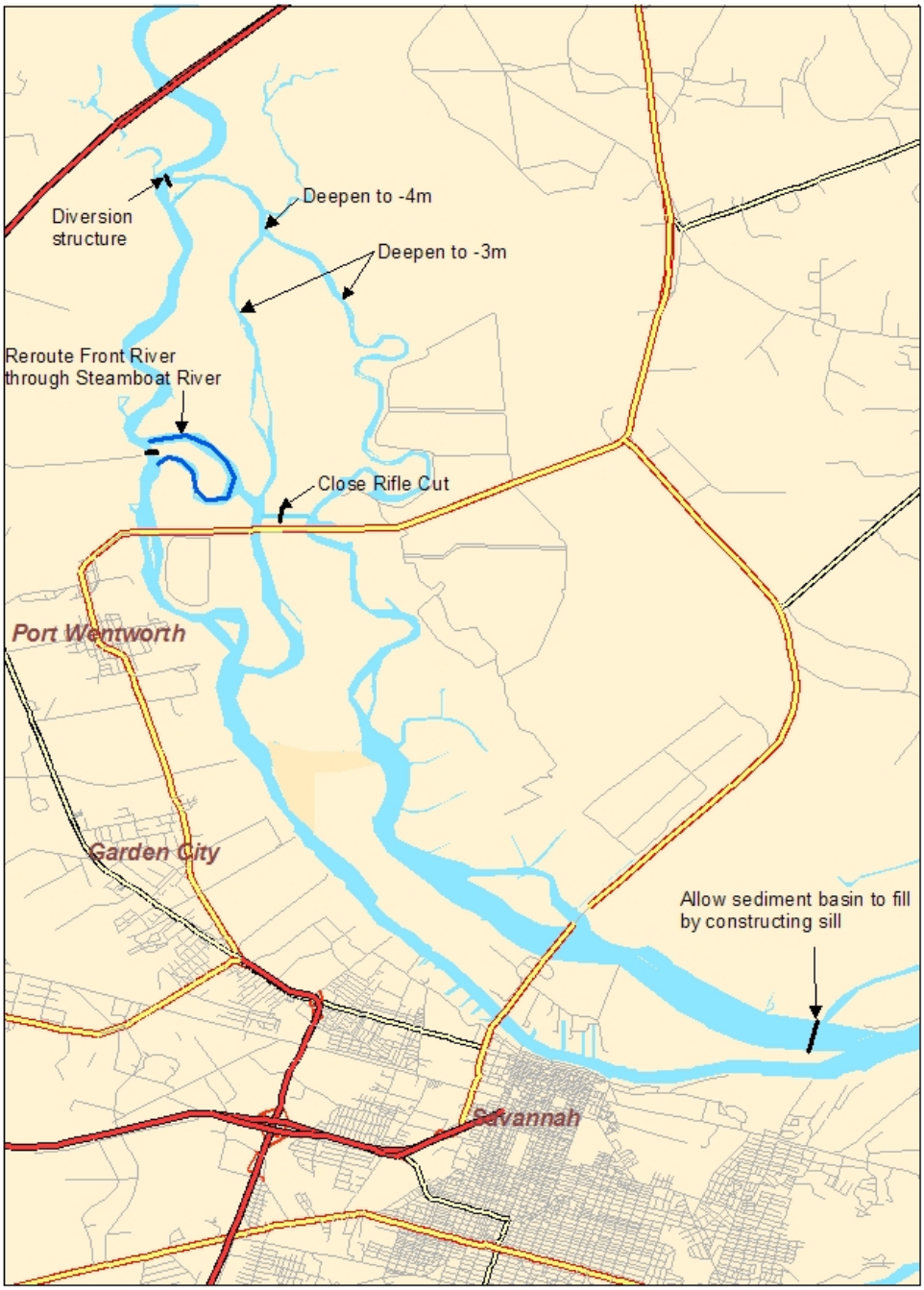

Figure 13. Savannah River estuary and mitigation plan 7 for Savannah Harbor deepening. Plan 7 includes a diversion structure at McCoys Cut, deepening of upper Back River and Middle River downstream to the points shown, closing Rifle Cut, allowing sediment basin to fill and rerouting Front River through Steamboat River by closing Drakies Cut.

Acquisition

The Corps has also proposed land acquisition and management to offset salinity impacts for the 45 foot and deeper alternatives. Because the impacted lands are Federal property and are open for appropriate public use, fee title acquisition is the only way to ensure replacement of public use value. The most suitable tracts are near or adjacent to Savannah National Wildlife Refuge. Therefore these lands would be provided to the refuge for protection, wildlife management and appropriate public use. The lands considered for acquisition are presented in Figure 14 and Table 16. The Savannah District Standard Operating Procedures (SOP) for regulatory actions (http://www.sas.usace.army.mil/SOP.04.doc) were used by the Corps to determine loss of functional value and amount of lands needed to replace these values. The Service has identified some potential errors in the SOP application and concerns with the assumptions that were used in the SOP calculations by the Corps. Continued agency coordination will be needed to resolve these issues. Until that time, the Service does not concur with compensation acreage figures calculated by the Corps for this project

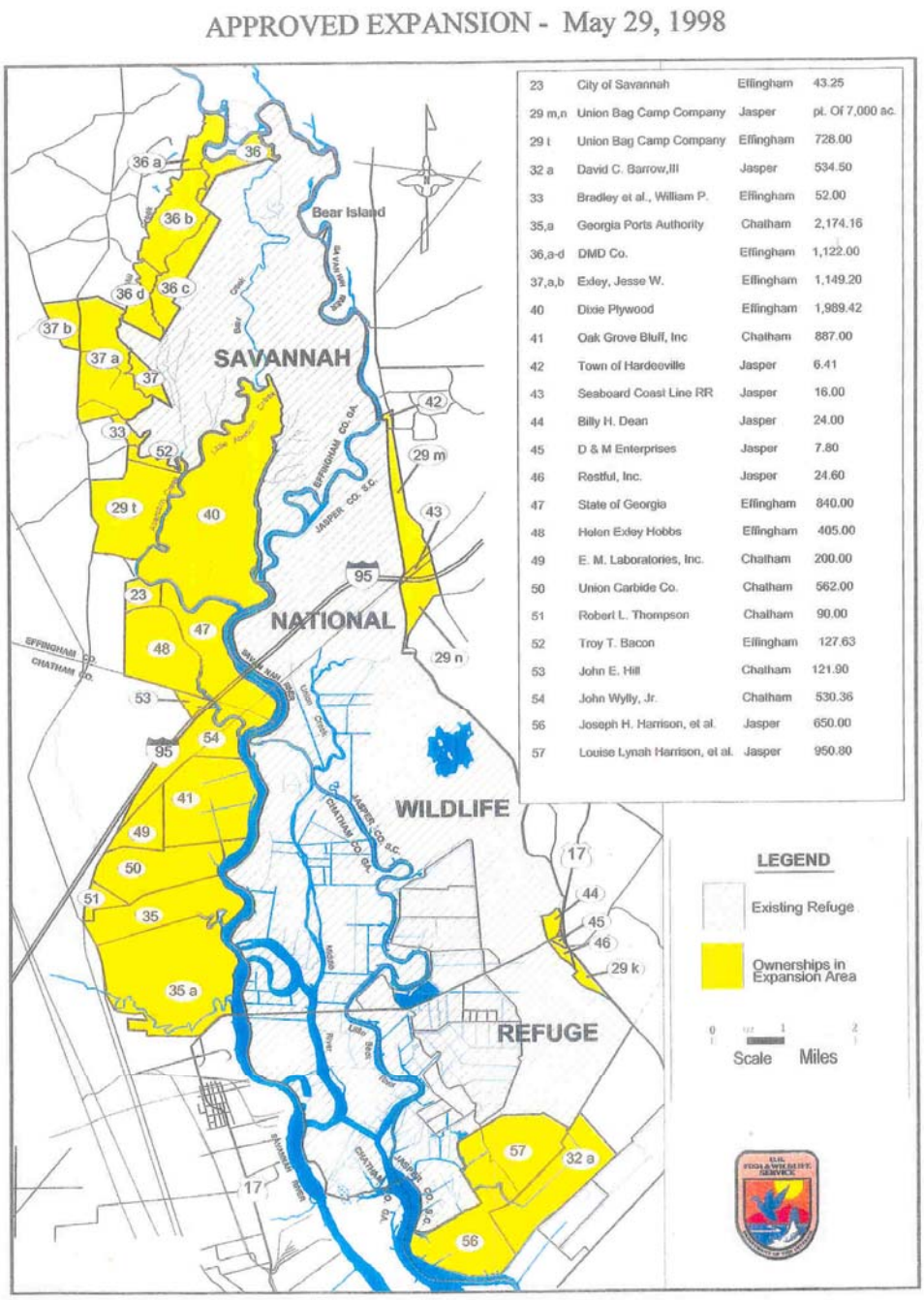

Figure 14. Lands that could be acquired and managed as compensation for Savannah Harbor deepening. All lands are within approved expansion area for Savannah NWR.

Table 16. Lands that could be acquired and managed as compensation for Savannah Harbor deepening. All lands are within approved expansion area for Savannah NWR.

USFWS/Corps Ranking	USFWS Tract Designation	Size (Acres)	Ownership
1	40	1,989.42	Dixie Plywood
2	Hardeeville Tract	973	JPR Land Company
3	42	6.41	Town of Hardeeville
4	29m	?	International Paper Company
5	43	16	Seaboard Coastline RR
6	46	24.6	Restful, Inc.
7	45	7.8	D & M Enterprises
8	44	24	Billy H. Dean
9	36,a-d	1,122	DMD Co.
10	29t	728	Union Bag Camp Company
11	48	405	Billy Exley
12	33	52	Bradley et al., William P.
13	52	127.63	Troy T. Bacon
14	37	388	Billy Exley
15	53	121.9	John E. Hill
16	Poindexter/Clydesdale Plantation	720	Robby Harrison, et.al.
17	56 and 57	1555.8	Robby Harrison

Dissolved oxygen

To address dissolved oxygen impacts the Corps has proposed to install and operate a re-oxygenation system using Speece cones (Tetra Tech, Inc. 2006). This system would inject oxygen near the river channel bottom at various locations. The oxygen injection locations and amounts would be selected to offset estimated dissolved oxygen reduction for each depth alternative. In August-September 2007 a demonstration project was conducted in Savannah Harbor with two barge-mounted Speece cones. During this ReOx demonstration project, 27,000 pounds of oxygen was injected per day for 39 days. Dissolved oxygen monitoring was conducted before, during and after the test using transects and continuous stations (MACTEC Engineering and Consulting, inc. 2008).

Fish mitigation

Fish mitigation measures would include constructing and operating a fish bypass channel (fishway) at the New Savannah Bluff Lock and Dam (NSBLD) near Augusta, GA to compensate for impacts to shortnose sturgeon habitats. This structure would be intended to allow passage of sturgeon and other migratory fish to access potential upstream spawning and nursery habitat. In addition, funding would be provided for a striped bass stocking program to compensate for adverse impacts to striped bass spawning and nursery habitats within estuary.

Table 17. Summary of Corps proposed fish and wildlife mitigation measures for the Savannah Harbor project. Corps acquisition calculations (acres) are subject to change.

	CHANNEL DEPTH ALTERNATIVE			
	44-FOOT	**45-FOOT**	**46-FOOT**	**48-FOOT**
FLOW RE-ROUTING	Plan 6b	Plan 6a	Plan 6a	Plan 6a
WETLAND ACQUISITION	136 Acres	1,129 Acres	1,219 Acres	2,230 Acres
DISSOLVED OYXGEN SYSTEM	52,800 lbs/day	39,600 lbs/day	46,200 lbs/day	61,600 lbs/day
FISH BYPASS CHANNEL	Yes	Yes	Yes	Yes
STRIPED BASS STOCKING PROGRAM	Yes	Yes	Yes	Yes
ADAPTIVE MANAGEMENT -- FLOW CHANGES	Yes	Yes	Yes	Yes
ADAPTIVE MANAGEMENT -- LAND ACQUISITION	14 Acres	113 Acres	122 Acres	223 Acres

ALTERNATIVES EVALUATION WITH MITIGATION

Each channel and flow modification feature has positive and negative impacts (Table 18). A necessary result of salinity reduction in selected areas of the estuary is the increase in other areas. The goal of the plan was to reduce the salinity in Back River to minimize impacts of tidal freshwater marsh and the freshwater supply system. Therefore most of the mitigation measures would increase salinity in Front River. Filling of the sediment basin would reduce salinity intrusion up Back River but would require more advanced maintenance (deeper channel) in some areas of the navigation channel and more frequent maintenance dredging. These issues are discussed further in the risk and uncertainty section in this report.

Table 18. Summary of positive and negative impacts for channel and flow modifications evaluated for mitigation of Savannah Harbor deepening.

Mitigation	Positive impact	Negative impact
Install diversion structure (h)	Reduces salinity in Little Back River and upper Middle River	Increases salinity in Front River
Dredge Little Back River/Middle River (h)	Reduces salinity in Little Back River and upper Middle River	Increases salinity in Front River; Dredging impacts on habitat and water quality
Close Drakies Cut/reroute through Steamboat (g)	Decrease salinity in Front River	Increase salinity in Middle River
Close Houston Cut (f)	Reduces salinity in Middle River	Reduces tidal range in Back River and Middle River
Enlarge Rifle Cut (e)	Increases salinity in Little Back River	Decreases salinity in lower Middle River
Close Rifle Cut (d)	Reduces salinity in Little Back River	Increases salinity in lower Middle River: limits small boat access to Back River
Close Middle River/ open New Cut (c)	Reduces salinity in Back and Middle River	Reduces tidal range in Back River and Middle River
Remove tide gate (b)	Increases tidal exchange and sediment flushing in Back River; improves small boat access	Temporary blasting impacts
Fill sediment basin (a)	Reduces salinity in Back River	Increases salinity in Front River; Increases advanced maintenance and dredging in Front River

Managed wetlands

Tables 19-25 present model predicted salinity levels at the entrance to the diversion canal on Little Back River with the existing channel depth and various flow and sea level conditions. Predicted salinity at the entrance ranges from 0.02 to 1.52 ppt and the worst case condition is represented by the 10% exceedence at low flow and 50 cm sea level rise. Of the information available, the low flow 10% exceedence provides the best comparison of the plans because mean flows are too high to be realistic for fall conditions when water is needed in the managed wetlands. This information is presented at existing sea level, at +25 cm sea level and at +50 cm sea level to provide a range of probable conditions throughout the life of the project (50 years). The average salinity of water entering the diversion canal would likely be between the 10% exceedence and the 50% exceedence predictions.

None of the depth alternatives, with proposed mitigation, increase the model predicted salinity at the diversion canal entrance. Because of the cumulative impacts of repetitive harbor deepening, even at the current channel depth the average salinity of water entering the diversion canal could exceed the freshwater limit as sea level rises (Table 19). The 44 foot, 45 foot and 46 foot alternatives with associated mitigation plans would be most likely to maintain freshwater conditions at the entrance. With the 48 foot alternative, the freshwater limit could be exceeded at the entrance as sea level rises.

Table 19. Model predicted salinity (ppt) at the freshwater diversion canal entrance at existing Savannah Harbor channel depth (42 feet)

Flow and sea level	**Salinity ppt 50 % exceedence**	**Salinity ppt 10 % exceedence**
Low flow (2001) existing sea level	0.15	0.57
Low flow (2001) + 25 cm sea level	0.31	0.95
Low flow (2001) + 50 cm sea level	0.57	1.52
Mean flow (1997) existing sea level	0.02	0.14
Mean flow (1997) + 25 cm sea level	0.05	0.26
Mean flow (1997) + 50 cm sea level	0.11	0.45

Table 20. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 44 foot Savannah Harbor channel depth and mitigation plan 6b.

Flow and sea level	**Salinity ppt 50 % exceedence**	**Salinity ppt 10 % exceedence**
Low flow (2001) existing sea level	0.05	0.33
Low flow (2001) + 25 cm sea level	0.11	0.61
Low flow (2001) + 50 cm sea level	0.24	1.02
Mean flow (1997) existing sea level	0.00	0.04
Mean flow (1997) + 25 cm sea level	0.01	0.08
Mean flow (1997) + 50 cm sea level	0.03	0.17

Table 21. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 45 foot Savannah Harbor channel depth and mitigation plan 6a.

Flow and sea level	Salinity ppt 50 % exceedence	Salinity ppt 10 % exceedence
Low flow (2001) existing sea level	0.05	0.36
Low flow (2001) + 25 cm sea level	0.12	0.65
Low flow (2001) + 50 cm sea level	0.25	1.10
Mean flow (1997) existing sea level	0.00	0.04
Mean flow (1997) + 25 cm sea level	0.01	0.08
Mean flow (1997) + 50 cm sea level	0.02	0.17

Table 22. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 46 foot Savannah Harbor channel depth and mitigation plan 6a.

Flow and sea level	Salinity ppt 50 % exceedence	Salinity ppt 10 % exceedence
Low flow (2001) existing sea level	0.06	0.42
Low flow (2001) + 25 cm sea level	0.14	0.73
Low flow (2001) + 50 cm sea level	0.29	1.23
Mean flow (1997) existing sea level	0.00	0.04
Mean flow (1997) + 25 cm sea level	0.01	0.10
Mean flow (1997) + 50 cm sea level	0.02	0.19

Table 23. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 46 foot Savannah Harbor channel depth and mitigation plan 7.

Flow and sea level	Salinity ppt 50 % exceedence	Salinity ppt 10 % exceedence
Low flow (2001) existing sea level	0.11	0.55
Low flow (2001) + 25 cm sea level	0.22	0.81
Low flow (2001) + 50 cm sea level	0.38	1.14
Mean flow (1997) existing sea level	0.01	0.10
Mean flow (1997) + 25 cm sea level	0.03	0.18
Mean flow (1997) + 50 cm sea level	0.05	0.30

Table 24. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 48 foot Savannah Harbor channel depth and mitigation plan 6a.

Flow and sea level	Salinity ppt 50 % exceedence	Salinity ppt 10 % exceedence
Low flow (2001) existing sea level	0.09	0.55
Low flow (2001) + 25 cm sea level	0.18	0.91
Low flow (2001) + 50 cm sea level	0.38	1.49
Mean flow (1997) existing sea level	0.00	0.05
Mean flow (1997) + 25 cm sea level	0.01	0.12
Mean flow (1997) + 50 cm sea level	0.03	0.24

Table 25. Model predicted salinity (ppt) at the freshwater diversion canal entrance with 48 foot Savannah Harbor channel depth and mitigation plan 7.

Flow and sea level	Salinity ppt 50 % exceedence	Salinity ppt 10 % exceedence
Low flow (2001) existing sea level	0.11	0.50
Low flow (2001) + 25 cm sea level	0.20	0.77
Low flow (2001) + 50 cm sea level	0.36	1.10
Mean flow (1997) existing sea level	0.01	0.09
Mean flow (1997) + 25 cm sea level	No model run	No model run
Mean flow (1997) + 50 cm sea level	No model run	No model run

Tidal freshwater wetlands

The M2M used for impact analysis was developed by data mining techniques that used channel salinity data and interstitial salinity data at several locations in the estuary (Conrads et al 2006). However, this empirical model uses relations among marsh salinity and channel salinity based on existing channel morphology and flow patterns. All of the mitigation alternatives include substantial changes in channel morphology and flow patterns. Because the alteration of the channel configuration changes the relations used in the M2M, it could not be used with any confidence to evaluate mitigation plans. Use of the marsh succession model was dependent on the M2M; therefore, the MSM could not be used to evaluate the mitigation plans.

As an alternative method, EFDC predicted salinity in the river channels (Front, Middle and Back) was projected across the marsh surface based on drainage patterns determined from aerial photos. Marsh acreage in each salinity category was calculated by the geographic information system used for project analysis (Bill Bailey, Corps, personal communication 2008). As discussed earlier in this report and presented in Table 1, commonly used marsh classifications are usually based on average channel salinity not interstitial salinity (Odum et al 1984). The communities with a channel salinity of <0.5 are considered to be tidal freshwater marsh with

differing species composition. We focused our analysis on minimizing conversion of tidal freshwater marsh (0-0.5 ppt) to higher salinity marsh. The magnitude of marsh change predicted by the EFDC with the various depth alternatives and mitigation plans is presented in Tables 26-29.

Table 26. The existing marsh acres by salinity category and the marsh area predicted by the EFDC and surface projection based on drainage pattern with the 44 foot depth alternative and mitigation plans.

Salinity Ppt	Existing acres	Project Acres	Plan 3	Plan 3A	Plan 3B	Plan 3C	Plan 6	Plan 6A	Plan 6B
0-0.5	4072	3496	4093	3973	3821	3872	4792	4844	4394
0.6-1.0	864	1189	1605	1722	1278	1236	1110	1111	1137
1.0-2.0	555	480	594	594	646	782	523	488	749
2.1-4.0	834	775	809	850	863	723	723	733	855
>4	2506	2892	1732	1692	2225	2219	1685	1656	1698

Table 27. The existing marsh acres by salinity category and the marsh area predicted by the EFDC and surface projection based on drainage pattern with the 45 foot depth alternative and mitigation plans.

Salinity ppt	Existing acres	Project Acres	Plan 3	Plan 3A	Plan 3B	Plan 3C	Plan 6	Plan 6A	Plan 6B
0-0.5	4072	3105	3718	3798	3572	3626	4038	4040	3865
0.6-1.0	864	1319	1827	1733	1368	1347	1845	1781	1459
1.0-2.0	555	630	732	726	816	783	559	588	774
2.1-4.0	834	906	763	780	855	856	712	745	589
>4	2506	2873	1792	1794	2221	2219	1689	1678	2145

Table 28. The existing marsh acres by salinity category and the marsh area predicted by the EFDC and surface projection based on drainage pattern with the 46 foot depth alternative and mitigation plans.

Salinity Ppt	Existing acres	Project Acres	Plan 3	Plan 3A	Plan 3B	Plan 3C	Plan 6	Plan 6A	Plan 6B	Plan 7
0-0.5	4072	3015	3753	3840	3521	3599	3817	3871	3610	4285
0.6-1.0	864	1050	1298	1535	1195	1070	1677	1650	1512	1054
1.0-2.0	555	921	991	892	952	1066	893	862	891	866
2.1-4.0	834	789	616	774	860	762	703	700	642	739
>4	2506	3057	2174	1790	2304	2335	1743	1749	2177	1788

Table 29. The existing marsh acres by salinity category and the marsh area predicted by the EFDC and surface projection based on drainage pattern with the 48 foot depth alternative and mitigation plans.

Salinity ppt	Existing acres	Project acres	Plan 3	Plan 3A	Plan 3B	Plan 3C	Plan 6	Plan 6A	Plan 6B	Plan 7
0-0.5	4072	2860	3584	3531	3406	3383	3715	3735	3610	3772
0.6-1.0	864	830	766	949	871	784	1419	1340	885	1145
1.0-2.0	555	1215	1587	1489	1221	1368	1141	1191	1384	1024
2.1-4.0	834	739	682	673	938	892	793	790	770	605
>4	2506	3188	2213	2190	2396	2405	1764	1776	2183	2186

Based on model predictions, tidal freshwater marsh impacts of the 44 foot channel would be eliminated by mitigation plan 3 and any of the plan 6 variations would result in an increase of tidal freshwater marsh. With the 45 foot channel, tidal freshwater marsh impacts would be almost offset by plan 6A; the predicted loss is 32 acres. With the 46 foot channel, only plan 7 would eliminate tidal freshwater marsh impacts and would result in an increase. With the 48 foot channel, none of the plans would eliminate tidal freshwater marsh impacts. The 46 foot channel with the Corps proposed plan 6a would result in a loss of 201 acres of tidal freshwater marsh. The 48 foot channel with the Corps proposed plan 6a would result in a loss of 337 acres of tidal freshwater marsh.

Fish

The predicted impacts to shortnose sturgeon habitat for depth alternatives with associated mitigation plans are presented in Table 30. Predicted impacts are due to salinity and dissolved oxygen changes in the various branches of the river system. Winter habitat for juveniles and adults is predicted to change two percent or less either positive or negative. Adult summer habitat is expected to increase by 11% for the 44 foot/6b alternative and to decrease by 10% for the 48 foot alternative. The proposed mitigation features substantially reduced the shortnose sturgeon impacts, which ranged from -30 to -55 percent without mitigation (Table 10). The cumulative impact on shortnose sturgeon was calculated by using the procedure for independent events described earlier in this report. Impacts with the mitigation plan ranged from +11 % for the 44 foot plan to -13 % for the 48 foot plan. It is difficult to assess how effective the Corps proposed fishway would be as mitigation. This measure would potentially provide access to the Augusta shoals and other riverine spawning areas. A much more effective measure would be removal of the NSBLD which would provide spawning access as well as river restoration.

Table 30. Predicted impact to shortnose sturgeon juvenile winter (January) habitat, adult winter (January) habitat and adult summer (August) habitat and cumulative impact for depth alternatives with associated mitigation plan.

Channel depth/ Mitigation plan	Juvenile winter percent change	Adult winter percent change	Adult summer percent change	Cumulative impact
42 feet (baseline)	0	0	0	0
44 feet/6b	1	-1	11	+11
45 feet/6a	2	-1	-3	-2
46 feet/6a	0	-1	-4	-5
48 feet/6a	-2	-1	-10	-13

The predicted impacts to striped bass spawning, egg and larval habitat for depth alternatives with associated mitigation plans are presented in Tables 31-33. Predicted impacts are due to salinity and dissolved oxygen changes in the various branches of the river system. For successful recruitment all of these habitat components are needed.

Table 31. Predicted percent change in striped bass spawning habitat for depth alternatives and associated mitigation plan at 20th , 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted mean percent
42 feet (baseline)	0	0	0	0
44 feet/6b	-15	-3	-3	-6
45 feet/6a	-14	-9	-9	-10
46 feet/6a	-19	-10	-11	-13
48 feet/6a	-24	-16	-13	-17

Table 32. Predicted percent change in striped bass egg habitat for depth alternatives and associated mitigation plan at 20th , 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted mean percent
42 feet (baseline)	0	0	0	0
44 feet/6b	-22	-9	8	-8
45 feet/6a	-18	5	8	0
46 feet/6a	-8	0	7	0
48 feet/6a	-5	-11	3	-6

Table 33. Predicted percent change in striped bass larval habitat for depth alternatives and associated mitigation plan at 20th, 50th, and 80th percentile flows.

Channel depth	Percent change 20th percentile flow	Percent change 50th percentile flow	Percent change 80th percentile flow	Weighted mean percent
42 feet (baseline)	0	0	0	0
44 feet/6b	175	-6	-14	37
45 feet/6a	187	2	8	50
46 feet/6a	191	6	10	53
48 feet/6a	155	4	30	48

To assess overall impact to striped bass we first determined a weighted average, assigning twice as much value to the 50th percentile flow than the other two flows. Cumulative impact was determined by multiplication of life stage as described earlier in this report. Positive impacts in larval habitat were not included because the loss of spawning and egg habitat would reduce the earlier life stages that would utilize that habitat. Table 34 summarizes the striped impacts for depth alternatives and associated mitigation plan. The 45 foot depth with plan 6a is predicted to have the least overall impact (-10 percent). The 48 foot alternative has a higher impact, a 22 percent loss of habitat.

Table 34. Striped bass spawning habitat, egg habitat, larval habitat and cumulative impact predicted for Savannah Harbor deepening with associated mitigation plans.

Channel depth	Spawning habitat impact (%)	Egg habitat impact (%)	Larval habitat impact (%)	Cumulative impact (%)
42 feet (baseline)	0	0	0	
44 feet/6b	-6	-8	37	-14
45 feet/6a	-10	0	50	-10
46 feet/6a	-13	0	53	-13
48 feet/6a	-17	-6	48	-22

The model predicted impacts to southern flounder with mitigation are presented in Table 35. Habitat is predicted to improve because of dissolved oxygen increase due to the Speece cone system. The American shad model predicted impacts of less than two percent for all depth alternatives and associated mitigation plans.

Table 35. Predicted Southern flounder habitat for depth alternatives and associated mitigation plans.

Channel depth	Mitigation Plan	Percent change
42 feet (baseline)	None	
44 feet	6b	91
45 feet	6a	64
46 feet	6a	70
48 feet	6a	63

Cadmium

Based on our detailed review of the project risk assessment (EA Engineering, Science and Technology 2008), the Service believes the information supports the need to cap all new work sediment containing elevated cadmium concentrations (identified as "high" and "low" in the risk assessment). This action is particularly needed because the upland placement site serves a dual function as an upland confined disposal facility for dredged material placement as well as a managed wetland mitigation area to provide wildlife habitat. Thus, establishment of a viable ecological community is an important factor in site management, beyond what is usually considered during risk assessment. If all sediments containing elevated cadmium concentrations are capped with clean material, substantial adverse impacts to both plants and wildlife would be avoided.

Summary plan evaluation

The 44 foot, 45 foot and 46 foot alternatives with associated mitigation plans would be most likely to maintain freshwater conditions at the diversion canal entrance and managed wetlands. With the 48 foot alternative, the freshwater limit (0.5 ppt) could be exceeded at the canal entrance and in managed wetlands (Table 24).

Based on model predictions, tidal freshwater marsh impacts of the 44 foot channel would be eliminated by mitigation plan 3 and any of the plan 6 variations would result in an increase of tidal freshwater marsh. With the 45 foot channel, tidal freshwater marsh impacts would be almost offset by plan 6A; 32 acres would be impacted. With the 46 foot channel, only plan 7 would eliminate tidal freshwater marsh impacts and would result in an increase. The 46 foot channel with the Corps proposed plan 6a would result in a loss of 201 acres of tidal freshwater marsh. With the 48 foot channel, none of the plans would eliminate tidal freshwater marsh impacts. The 48 foot channel with the Corps proposed plan 6a would result in a loss of 337 acres of tidal freshwater marsh. Because of the cumulative loss and high wildlife value of tidal freshwater marsh in the Savannah estuary, the Service has placed great emphasis on avoiding or minimizing additional loss of this rare habitat. The only plans that accomplish this objective are the 44 foot and 45 foot depths with associated mitigation plans.

With regard to fish, the Service must place emphasis on protecting trust resources (interjurisdictional fish), in this case American shad, shortnose sturgeon and striped bass. The American shad model predicted impacts of less than two percent for all depth alternatives and associated mitigation plans. Shortnose sturgeon habitat is expected to increase by 11% for the 44 foot/6b alternative, decrease by 2% for the 45 foot/6a alternative and to decrease by 13% for the 48 foot/6a alternative. For the striped bass, the 45 foot depth with plan 6a is predicted to have the least overall impact (-10%) and the 48 foot depth is predicted to decrease habitat by 22 %.

Table 36 summarizes impacts of the various plans on important fish and wildlife resources. The 44 and 45 foot plans (with mitigation) avoid or minimize impacts to tidal freshwater marsh and the freshwater supply system. The 45 foot depth minimizes impacts to striped bass habitat and the 44 foot depth minimizes impacts to shortnose sturgeon. The loss of freshwater marsh could be compensated by land acquisition as proposed by the Corps. However, land acquisition will not replace the wetland ecosystem function and diversity lost due to project impacts. Striped bass loss could be compensated to some degree by stocking of phase II fish (about eight inches in length). However this action does not address habitat degradation or meet the Service goal of restoration and maintenance of a self-sustaining striped bass population. In addition, it would not be practical to stock enough striped bass to equal the numbers of striped bass that could be produced by a healthy self-sustaining striped bass population. Based on the information obtained for the specific purpose of evaluating this project, it is clear that the 44 and 45 foot alternatives would have much lower impacts on fish and wildlife resources. Impacts of the project increase substantially at the 46 and 48 foot depths.

Table 36. Tidal freshwater marsh (0-0.5 ppt) predicted impact, freshwater supply impact at low flow and 25 cm sea level rise, striped bass habitat impact and shortnose sturgeon habitat impact for the Savannah Harbor project alternatives.

Alternative	Tidal freshwater marsh impact	Freshwater supply impact	Striped bass habitat impact	Shortnose sturgeon habitat impact
44 foot	+21 acres	-0.34 ppt	-14%	+11%
45 foot	-32 acres	-0.22 ppt	-10%	-2%
46 foot	-201 acres	-0.14 ppt	-13%	-5%
48 foot	-337 acres	-0.04 ppt	-22%	-13%

UNCERTAINTY AND RISK

The EFDC model, the primary tool to evaluate project impacts and mitigation alternatives, is a mathematical representation of the Savannah River estuary, a highly complex system. The spatial, physical, chemical and biological complexity makes modeling of this system a significant challenge. The high tidal range, significant and variable freshwater inflow, salinity

stratification and highly branched channel geometry with marsh storage result in a non-linear system that continuously varies over time and space. The EFDC/WASP model has known errors in its simulation of actual measured conditions and the simulation of the mitigation scenarios are an extrapolation of the model to an imagined system. It is unlikely that a model of this complexity will provide predictions that are accurate for all conditions and in all geographic areas. If there are errors in the model simulating the dynamics of the existing conditions, there will be greater errors in simulating a completely different system as represented by the mitigation alternatives. Caution needs to be used in interpolating mitigation scenarios, especially ones that are substantially different than the existing system. The most responsible use of the model is for inference of the possible impacts to the system and not as an absolute prediction of the impacts. Although the EFDC/WASP model provides the best available estimate of mitigation effectiveness, the model salinity and dissolved oxygen predictions may be quite different from the post-project measured impacts in the estuary.

The EFDC model was extensively reviewed by scientists from a number of agencies including the Service, U.S. Geological Survey (USGS), U.S. EPA, South Carolina Department of Health (SCDEHEC) and Environmental Control and Georgia Department of Natural Resources. These agencies concluded that the EFDC model was adequate to evaluate the deepening project, but certain cautions were identified. The Service stated in letter of July 5, 2005: "Therefore, even if a model is judged to be acceptable for use there will always be some level of uncertainty in its performance. One important area of uncertainty will be in evaluating the predicted effects of mitigation plans involving flow diversions from the Front River to the Middle and Back River." The USGS stated in letter of June 28, 2005: "Modeling of the Middle, Little Back and Back Rivers is very difficult due to the complexity of this branched network of shallow tidal rivers and creeks…The flow predictions have improved from previous applications of the model but are only satisfactory. Possible mitigation scenarios include diverting a portion of the flow from the Savannah River to the Middle and Little Back Rivers. The inability of the model to capture the ebb-tide flow dynamics should be remembered while interpreting scenarios where increased flows in the vicinity of SNWR are significant." The SCDHEC, in letter of March 10, 2006, discussing the under prediction of ebb flows in the Middle River and Back River, stated: "…this issue is not considered significant …for application to deepening impacts; however, application to mitigation scenarios that alter channel connections—and attempt to predict resulting changes to the flow regime and the effect on salinity—may require additional evaluation of model capability."

All of the proposed mitigation alternatives include flow diversion as a basic and highly important component. The predicted reduction of salinity in the Middle River and Back River is due in large part to the proposed flow diversion from Front River. The model uncertainty in this geographic area is of concern, particularly because most of the remaining freshwater tidal marsh and the entrance to the diversion canal are located there. In addition the diversion structure is modeled by constricting the Front River at McCoys Cut. Even though this constriction is essentially what a diversion structure would do, when the structure is actually constructed it may not alter flow distribution as predicted in the model. The design and construction of a diversion structure that would quantitatively alter flows exactly as predicted in the model is highly

unlikely. Flow into the Little Back River will also be influenced by channel gradient and tidal progression in the river system (Wiley Kitchens, USGS, personal communication, 2005).

Another area of concern involves the potential for increased sedimentation in McCoys Cut, Middle River and Little Back River caused by the diversion structure at McCoys Cut. Several studies indicate that increasing flow into river cutoff bends increases the siltation rate in the bend and decreases its duration as an aquatic system (Shields 1987). While the tributaries involved are not cutoff bends, sedimentation patterns are likely to be similar. Diversion structures divert most water when river flows and sediment loads are high. As sediment laden water reaches areas of lower velocity, sediment is deposited. The risk of sedimentation is high in the vicinity of McCoys Cut and Little Back River near Union Creek because of the presence of a tidal null point in this location. Large sediment bars are currently at this location and diversion of water from the Front River may accelerate sedimentation. If sedimentation increases, periodic maintenance dredging would be required to maintain the mitigation features. Maintenance dredging has impacts on benthic invertebrates and potential impacts on wetlands; depending on how dredging is performed and where dredged material is placed.

Filling of the sediment basin will result in more rapid sedimentation in the Front River navigation channel, higher advanced maintenance in some areas, and more frequent dredging. The model runs used to predict impacts and mitigation effects did not include the two to four feet of increased advanced maintenance dredging proposed for several reaches of the inner harbor (Bill Bailey, COE, personal communication 2008) (Table 5). The model results could under predict the salinity increase in the Front River because the actual channel in some areas would be two to four foot deeper than the channel used in the model. Limited comparison runs were made between the channel with and without the increased advanced maintenance and there was no measurable change in the results (Bill Bailey, Corps, personal communication 2008). However, these comparisons were made on only a few conditions. For example, there could be an interaction between filling the sediment basin or other mitigation features and the deeper advanced maintenance reaches. Therefore, some uncertainty remains as to the reliability of the predictions. Sedimentation rate could be higher than predicted resulting in a call for even more advanced maintenance dredging in the future.

All of the mitigation features based on flow modification are intended to reduce salinity in the Back River because much of the tidal freshwater marsh and the freshwater diversion system are located there. However, diversion of fresh water into the Back River allows salt water to move further up the Front River and into the Middle River. As a result, in the Front River and lower Middle River mean and maximum salinity would be higher with the mitigation plan than without it. Closing of Rifle Cut helps address the risk of salinity increase in Back River by preventing flow from Middle River to Back River. The model may under predict the amount of salinity moving up Front and Middle River. Even a slight error in the model could result in salinity moving into Little Back River from the Middle River near McCoys Cut or entering McCoys Cut from Front River. If that event occurred, impacts to tidal freshwater wetlands, the freshwater diversion system and striped bass would be higher than expected. Tree mortality in tidal forested wetlands along Front River could occur if salinity increases more than predicted. In addition,

shortnose sturgeon, and striped bass which utilize the Front River and lower Middle River could be impacted more than expected. Salinity increases more with greater channel depth and the margin for error is reduced before impacts would occur to the Little Back River. Therefore, risk and uncertainty are highest with the 48 foot alternative.

As discussed earlier in this report, dissolved oxygen in the estuary will be reduced by harbor deepening and the Corps plans to mitigate this impact by using Speece cones to inject oxygen into the harbor. In August-September 2007 a full scale test on two Speece cones was conducted in Savannah Harbor and oxygen was injected over a 39 day period. The contractor report on the test concluded that the system could improve DO deficit by 0.6-0.7 mg/l, enough to effectively mitigate DO impact of harbor deepening (MACTEC 2008). An independent peer review by USGS found that this conclusion is not supported by monitoring data. It is important to note that the USGS review does not conclude that the Speece cone system could not be effective. However, the USGS review found that analysis of data in the report and other monitoring data did not convincingly quantify improvement of DO during the test period. The review indicated that the natural tidal cycle accounted for most of the variation in DO level during the demonstration (Paul Conrads, USGS written communication 2008). Another review of the test report and available data found that DO increased only at moderate temperatures at mid-depth at the point of injection and concluded that the Speece cones had a very limited effect on DO level (Civilized Engineering 2007).

Therefore, based on the available information, there is a high degree of uncertainty as to how effective oxygen injection would be. The fish habitat model results are based on predictions from the EFDC/WASP model. If the Speece cones are not as effective as previously assumed, the model predictions of harbor deepening fish impacts would be underestimated. Because dissolved oxygen is a key component of all aquatic habitats, underestimation of harbor deepening impact would be important. In addition, if the number of Speece cones had to be increased the cost of this mitigation feature could increase substantially. More data analysis and model runs are being conducted by the Corps in an attempt to resolve these questions. However, the available data may not be adequate to quantify the impact of the demonstration project on the highly variable dissolved oxygen dynamics of the system.

Another area of uncertainty is how the planned Jasper County Terminal would impact fish and wildlife resources and the potential to avoid upstream impacts that would occur through development of this project. It is very likely that deepening of the port only to river mile 7 would have much less impact on salinity intrusion into Savannah NWR and dissolved oxygen in the harbor compared to deepening to river mile 19. If that is the case, mitigation cost of the project would be substantially reduced because it is likely that most of the mitigation features would be unnecessary. In addition dredging quantity would be greatly decreased reducing initial cost and prolonging the life of dredged material disposal areas. These issues were not addressed in the Savannah Harbor Expansion Study.

MONITORING AND ADAPTIVE MANAGEMENT

The Corps has proposed pre-construction monitoring (one year), monitoring during construction (three years) and post-construction monitoring (five years). The monitoring would include water quality, channel morphology, wetlands, shortnose sturgeon tagging and tracking in the estuary, and fish passage at the New Savannah Bluff fishway. The wetland monitoring would be similar to pre-project impact evaluation studies that were initiated in the late 1990's and were carried on for several years. The shortnose sturgeon estuary monitoring would be similar pre-project impact

evaluation studies that were initiated in the late 1990's and were carried on for two years. The monitoring plan is described in detail by the Corps (2008).

The Corps (2008) described the following potential adaptive management measures as part of the Savannah Harbor Expansion Project.

- Enlarging the diversion structure at the mouth of McCoys Cut;
- Enlarging the deepened area at McCoys Cut, Middle & Back Rivers;
- Constructing a diversion structure at the junction of Middle and Back Rivers;
- Removing the tidegate sill;
- Raising or lowering the height of the submerged sill at the Sediment Basin;
- Increasing flow at the NSBL&D fish bypass; and
- Acquisition of up to another 5 percent of freshwater wetlands.

Most of these measures are proposed because of uncertainty regarding the channel and flow modifications. Post-construction monitoring and consultation with the Federal Cooperating Agencies would determine the need to implement these measures (Corps 2008). The Service strongly supports the proposed comprehensive monitoring program. In addition to a post-construction monitoring plan, a post-construction monitoring data-analysis plan needs to be established. For a highly altered system, as represented by the mitigation plans, how will the post-construction monitoring data be analyzed to determine the efficacy of the mitigation measures? A recent example of the need for such as plan is the re-oxygenation demonstration project. Monitoring data was collected but there was not an effective data analysis approach in place to analyze the data and quantify the impact of the demonstration project on the highly variable dissolved oxygen dynamics of the system.

SUMMARY AND CONCLUSIONS

Savannah NWR and the surrounding estuary support nationally important fish and wildlife resources. However, cumulative impacts of previous harbor modifications, primarily salinity intrusion, have severely impacted the resources that were present when the refuge was

established. A freshwater supply system for managed wetlands, installed as mitigation for the tidegate, has failed to function adequately. Tidal freshwater marsh has been reduced from about 12,000 acres to about 3,300 acres. Striped bass reproduction and recruitment were almost eliminated during tide gate operation but have recently begun to recover. Shortnose sturgeon habitat has been greatly impacted both by salinity increase and dissolved oxygen decrease.

The current inner harbor is 42 feet in depth. Impacts of project depths of 44, 45, 46, and 48 feet were evaluated using hydrodynamic, water quality and biological models. A number of mitigation measures have been proposed by the Corps. Most of these measures are based on channel and flow modifications in the estuary. In addition, a dissolved oxygen injection system, wetland acquisition, striped bass stocking and a fish bypass channel at New Savannah Bluff have been proposed.

There is a great deal of risk and uncertainty regarding impacts and the channel and flow modification and dissolved oxygen mitigation plans. The mitigation plans are unlikely to perform exactly as predicted. There could be unintended adverse consequences resulting from the channel and flow mitigation measures. All of the proposed mitigation alternatives include flow diversion as a basic and highly important component. The predicted reduction of salinity in the Middle River and Back River is due in large part to the proposed flow diversion from Front River. The EFDC model uncertainty in this geographic area is of concern, particularly because most of the remaining freshwater tidal marsh and the entrance to the diversion canal are located there. Diversion of fresh water into the Back River allows salinity to move further up the Front River and into the Middle River. As a result, in the Front River and lower Middle River mean and maximum salinity would be higher with the mitigation plan than without it. The model may under predict the amount of salinity moving up Front and Middle River.

Based on the available information, there is a high degree of uncertainty as to how effective oxygen injection would be. The fish habitat model results are based on predictions from the EFDC/WASP model. If the Speece cones are not as effective as previously assumed, the model predictions of harbor deepening fish impacts would be underestimated. Because dissolved oxygen is a key component of all aquatic habitats, underestimation of harbor deepening impact would be important. In addition, if the number of Speece cones had to be increased the cost of this mitigation feature could increase substantially.

Elevated cadmium levels have been found in several areas of the harbor from about river mile 4 to river mile 11. The project would result in potential exposure of fish and wildlife resources to cadmium levels that would cause adverse impacts. The Service believes available information supports the need to cap all new work sediment containing elevated cadmium concentrations (identified as “high” and “low” in the risk assessment) with clean material.

The 44 and 45 foot plans (with mitigation) avoid or minimize impacts to tidal freshwater marsh and the freshwater supply system. The 45 foot depth minimizes impacts to striped bass habitat and the 44 foot depth minimizes impacts to shortnose sturgeon. Based on the information

obtained for the specific purpose of evaluating this project, it is clear that the 44 and 45 foot alternatives would have much lower impacts on fish and wildlife resources. Impacts of the project increase substantially at the 46 and 48 foot depths. For any project implemented, the Service supports a comprehensive monitoring program to document actual impacts.

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