FINAL

IDENTIFICATION AND SCREENING LEVEL EVALUATION OF MEASURES TO IMPROVE DISSOLVED OXYGEN IN THE SAVANNAH RIVER ESTUARY

SAVANNAH HARBOR EXPANSION PROJECT
&
SAVANNAH HARBOR ECOSYSTEM RESTORATION STUDY
CHATHAM COUNTY, GEORGIA

Prepared for:
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Savannah, Georgia

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GLOSSARY

ATS	Aero Transfer System
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
$CBOD_U$	carbonaceous ultimate biochemical oxygen demand
CFR	Code of Federal Regulations
CWA	Clean Water Act
DMR	discharge monitoring reports
DO	dissolved oxygen
EIS	Environmental Impact Statement
GADNR	Georgia Department of Natural Resources
GAEPD	Georgia Environmental Protection Division
IP	International Paper
ISO	In-situ Oxidation
kW-hr/ton	kilowatt hour per ton
LAS	Land application system
lbs O_2/hp-hr	pounds oxygen per horsepower-hour
lbs/day	pounds per day
m^3/ton	cubic meter per ton
MACTEC	MACTEC Engineering and Consulting, Inc.
mg/L	milligrams per liter
MGD	million gallons per day
MP	management practices
NA	not applicable / not available
$NBOD_U$	nitrogenous ultimate biochemical oxygen demand
NEPA	National Environmental Policy Act
NH_3	ammonia
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
O&M	operations and maintenance
O_2	oxygen
^oC	degree Celsius
PCS	Permit Compliance System
POTW	publicly owned treatment works
PS	point source
PSA	Pulsed swing adsorption
PSSO	Pressurized sidestream
RM	river mile
SOW	Statement of Work
$TBOD_U$	total ultimate biochemical oxygen demand
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UWR	Urban Water Reuse
WRDA	Water Resources Development Act
WWTP	wastewater treatment plant

Disclaimer

The following report contains references to specific products, vendors, and trade names. MACTEC used this information to provide examples of equipment that could be used to meet the objectives of the various alternatives presented. MACTEC is not recommending or endorsing a specific supplier or vendor.

EXECUTIVE SUMMARY

MACTEC Engineering and Consulting, Inc. (MACTEC) was contracted by the U.S. Army Corps of Engineers, (USACE) Savannah District to perform the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary** under Contract Number: W91278-04-D-0009, Delivery Order: CV01.

The screening level evaluation was completed to address two phases, each with multiple steps (identified in the Scope of Work [SOW] provided by the USACE) and to identify potential DO improvement measures that may be suitable for application in the Savannah Harbor Estuary. The Steps for Phase I were based on potential load allocations as presented in the **Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia** (Draft TMDL) (USEPA, 2004). Steps in Phase II were developed to identify DO improvement measures to mitigate for DO impacts from past and future deepening of Savannah Harbor.

Phase and Steps Completed for this Screening Level Evaluation			
Phase/ Step	**Description**	**BOD Offset Required (lbs/day)**	**Supplemental DO Required (lbs/day)**
Phase I			
Step 1	Current BOD loads / Current GA DO standard	290,250	
Step 2	Permitted BOD loads / Current GA DO standard	725,500	
Step 3	Current BOD loads / Recommended GA DO standard	68,250	
Step 4	Permitted BOD loads / Recommended GA DO standard	503,500	
Phase II			
Step 1	0.2 mg/L DO improvement in the Harbor		72,818
Step 2	0.4 mg/L DO improvement in the Harbor		145,636
Step 3	0.6 mg/L DO improvement in the Harbor		218,455
Step 4	0.8 mg/L DO improvement in the Harbor		291,273

These criteria were developed using two critical simplifying assumptions from data obtained in the Draft TMDL.

- 1 pound (lb) ultimate biochemical oxygen demand (BOD) discharged equates to 1 lb DO consumed.
- 0.1 mg/L supplemental oxygen increase in the harbor equates to 36,409 lbs/day BOD reduction or supplemental DO.

Results from the preliminary screening of potential technologies show injection of molecular oxygen to be the most cost-effective means for achieving incremental DO improvements in Savannah Harbor.

1.0 INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) was contracted by the U.S. Army Corps of Engineers, Savannah District (USACE) under Contract Number: W91278-04-D-0009, Purchase Request Number: W33SJG-4357-9959, Delivery Order: CV01 to conduct the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary**. The screening level evaluation was completed to address two phases each with multiple steps (identified in the Scope of Work [SOW] provided by the USACE [Appendix A]) and to identify potential DO improvement measures that may be suitable for application in the Savannah Harbor Estuary. This report presents the results of the evaluation.

1.1 BACKGROUND

The Savannah River Basin is located along in the eastern portion of Georgia and southwestern South Carolina, and has a drainage area of 10,577 square miles. The Savannah River defines the state boundary between Georgia and South Carolina and ultimately flows into the Atlantic Ocean. The headwaters of the Savannah River originate in the Blue Ridge Province in Georgia, North Carolina, and South Carolina. The Savannah River Basin contains parts of the Piedmont and Coastal Plain physiographic provinces of the southeastern United States (GADNR, 2005).

The harbor is on Georgia's Section 303(d) list for waters that do not comply with water quality standards for DO. The Savannah Harbor from Fort Pulaski (River Mile [RM] 0) to Seaboard Coastline Railway Bridge (RM 27.4) is identified on the State of Georgia's 2002 Section 303(d) List as impaired for DO. Figure 1.1 shows the location of the DO impaired stream segment from RM 0 to RM 27.4. Water bodies on the 303(d) list require a Total Maximum Daily Load (TMDL) evaluation be conducted to estimate the allowable site-specific loading of the constituent for which the water body is listed.

In August 2004, the U.S. Environmental Protection Agency (USEPA) Region 4 released the **Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia** for the harbor (Draft TMDL) (USEPA, 2004). To support the designated uses in the Harbor and to meet the current Georgia DO standard, the Draft TMDL calls for elimination of all point source waste loads exerted on the harbor, plus the addition of 90,000 pounds per day (lbs/day) of oxygen to the harbor system during warmer periods of the summer (mid-July through mid-

September [critical season]) and during periods of critical low flows in the Savannah River (critical flow) (critical season and critical flow are referenced herein as critical conditions). The Draft TMDL indicated that the waste load from point source discharges within the harbor placed a 99,000 lbs/day oxygen demand on the system, while the load from upriver point source discharges exerts an additional 100,000 lbs/day oxygen demand in the harbor. These combined loads equate to roughly a 0.55 milligram per liter (mg/L) contribution to the DO deficit in the critical harbor segment. Since the current Georgia DO standard was disapproved by USEPA, USEPA recommended an alternate DO standard in the Draft TMDL. Three-dimensional hydrodynamic and water quality modeling (Harbor Model) performed by the USEPA in support of TMDL activities identified a portion of the listed segment as being the critical segment (Figure 1.2). Additionally, modeling indicated that during critical conditions and with current point and non-point source biochemical oxygen demand (BOD) loads (as measured in the 1997 and 1999 data collection efforts) (USEPA, 2004), the recommended DO standards will not be met during critical conditions in the critical segment. Therefore, the Alternate TMDL (based on the EPA-recommended DO standard) consisted of a 30 percent reduction in the current point source waste load to the harbor (a reduction of about 68,250 lbs/day total ultimate BOD [$TBOD_U$] allowing a remaining load of 132,000 lbs/day $TBOD_U$).

Concurrent to development of the TMDL for the harbor, the USACE is investigating the feasibility of further expanding and deepening the Harbor. The Savannah Harbor Expansion Project is evaluating deepening the navigation channel in Savannah Harbor to allow passage of larger ships. The Georgia Ports Authority examined the economic justification for a deepening project under the authority of Section 203 of the Water Resources Development Act of 1996 (USACE, 2005). They prepared a feasibility report that resulted in a conditional Congressional authorization of the project. Although the economic feasibility of the project was identified, Congress stipulated that (1) the Secretary of the Army, in consultation with affected Federal State of Georgia, State of South Carolina, regional, and local entities, reviews and approves an EIS that examines the effects of project depth alternatives ranging from 42 feet through 48 feet, and a selected plan for navigation with an associated mitigation plan; and (2) that the Secretary of the Interior, the Secretary of Commerce, the Administrator of the USEPA, and the Secretary of the Army approve the selected plan and determine that the associated mitigation plan adequately addresses the potential environmental impacts of the project.

To identify ways to improve DO in the harbor over present conditions, the USACE and the City of Savannah are jointly conducting the Savannah Harbor Ecosystem Restoration Study. This study is also considering alternatives to improve DO levels in the harbor.

As components of both the Savannah Harbor Expansion Project and the Savannah Harbor Ecosystem Restoration Study, this study identifies and conducts a screening level evaluation of potential measures designed to improve DO in the Savannah River Estuary during critical conditions.

1.1.1 Regulatory History

The State of Georgia assesses waterbodies for compliance with water quality standards established for their designated uses as required by the Federal Clean Water Act (CWA) and implementing regulations in the Code of Federal Regulations 40CFR130. Assessed waterbodies are placed into three categories, supporting, partially supporting, or not supporting their designated uses, depending on water quality assessment results. These waterbodies are found on Georgia's 305(b) list as required by that section of the CWA that defines the assessment process. Some of the 305(b) partially and not supporting waterbodies assigned to Georgia's 303(d) list, also named after that section of the CWA. Waterbodies on the 303(d) list are required to have a TMDL evaluation for the constituent(s) causing exceedance of the water quality standard. The TMDL process establishes the allowable pollutant loadings or other quantifiable parameters for a waterbody based on the relationship between pollutant sources and instream water quality conditions. This allows water quality-based controls to be developed to reduce or mitigate pollution and to restore and maintain water quality.

The Department of Natural Resources (GADNR) Environmental Protection Division (GAEPD) water use classification for the Savannah Harbor segment of the Savannah River (i.e. from the Seaboard Coast Railroad Bridge [RM 27.4] to Fort Pulaski [RM 0] is designated as coastal fishing. The Coastal Fishing DO criteria are minimum instantaneous concentrations applicable throughout the water column as follows:

- No less than 3.0 mg/L in June, July, August, September, and October;
- No less than 3.5 mg/L in May and November; and
- No less than 4.0 mg/L in the remaining months (USEPA, 2004).

Upon review, USEPA Region 4 disapproved the GAEPD DO criteria for the Savannah Harbor segment on the basis that the 3 mg/L DO the criterion during the critical summertime conditions, is not adequately protective of aquatic life in the upper part of the water column and is overprotective of aquatic life in the lower parts of the water column. However, until such time that replacement criteria are adopted, the existing state criteria (even though disapproved by USEPA) remain in effect.

Certain waters of the State, including Savannah Harbor, may have conditions where DO is naturally less than the numeric criteria specified in the rules and therefore cannot meet these DO criteria unless naturally occurring loads are reduced or such naturally low DO streams are artificially oxygenated. This is addressed in Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6- .03(7): Natural Water Quality.

> *It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation.* (GAEPD, 2005)

USEPA DO criteria are used to address these naturally occuring low DO situations. Alternative USEPA limits are defined as 90 percent of the naturally occurring DO concentration at critical conditions.

> *Where natural conditions alone create DO concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the naturally occurring concentration.*

Accordingly, if the naturally occurring DO concentration exceeds the Georgia Department of Natural Resources (GADNR), Environmental Protection Division (GAEPD) numeric limits at critical conditions, then the GAEPD numeric limits apply. If naturally occurring DO is less than the GAEPD numeric limits, then the 90 percent of the natural DO will become the minimum allowable. Based on the Draft TMDL report low natural DO is a limiting factor for Savannah Harbor DO criteria (USEPA, 2004).

1.2 USEPA DRAFT TMDL

In August of 2004, the USEPA released the draft TMDL report (USEPA, 2004) that provided allowable BOD loads for the Savannah River system. Additionally, the Draft TMDL recommended a new DO standard for the harbor/estuary that would replace the current Georgia DO standard. The recommended criteria combines the features of traditional water quality criteria with a new biological framework, one that integrates exposure to low DO over time rather than averaging DO exposure conditions into one single value (USEPA, 2004). The USEPA recommended DO criteria for Savannah Harbor are expressed as follows:

- One-day water column average DO = 2.3 mg/L
- Seven-day water column average DO = 3.0 mg/L
- Thirty-day water column average DO = 3.55 mg/L

The Virginian Province Saltwater Criteria, which served as the basis for USEPA's criteria recommendation for the Savannah Harbor, proposes a 30-day water column average of 4.8 as protective of aquatic life. Natural conditions water quality modeling of the Savannah Harbor in the Draft TMDL for DO indicated that the 30-day average DO of the Savannah Harbor under natural conditions in the critical segment was 3.95 mg/L due to the deepened physical configuration of Savannah Harbor and the high water temperatures experienced in the water column during the summer (greater than 30 degrees Celsius [^{o}C] for 30 days or longer).

As noted previously, GAEPD has established a 10 percent reduction below the natural minimum DO condition as the criteria for naturally low DO waters. Applying this policy to USEPA's recommendation for a site-specific criterion for the Harbor, a recommended 30-day water column average for protection of the aquatic life use is 3.55 mg/L or 90-percent of 3.95 mg/L (instead of the Virginian Province 30-day-average criterion of 4.8 mg/L).

USEPA's Draft TMDL also determined the natural DO conditions of the Harbor expressed as a 1-day water column average and a 7-day water column average. The 1-day water column "natural condition" is 3.5 mg/L and the 7-day water column "natural condition" is 3.6 mg/L. The Virginian Province criterion documentation demonstrates that aquatic species are protected at a 1-day water column average of 2.3 mg/L and a 7-day water column average of 3.0 mg/L. USEPA's recommended DO criteria for the Savannah Harbor adopted the Virginian Province criteria for the 1 day and 7 day water column averages (USEPA, 2004).

As part of the Savannah Harbor Expansion Project and a Tier II, Environmental Impact Statement (EIS) in accordance with the National Environmental Policy Act (NEPA), is currently being developed. As part of the EIS, the effect of the deep-draft navigation channel on the system's ability to recover from point and non-point source waste loads is under investigation. As part of the deepening project activities, a Section 203 study in conjunction with the Water Resources Development Act (WRDA) examined the economic justification for the deepening project (USACE, 2005). With this first phase of the project completed, the deepening project was determined to be economically feasible and stipulated two conditions. The first condition required that the Secretary of the Army, in consultation with the affected Federal, State of Georgia, State of South Carolina, regional, and local entities, review and approve a Tier II EIS that includes an analysis of the impacts of project depth alternatives ranging from 42 feet through 48 feet; and a selected plan for navigation and an associated mitigation plan as required under federal law (33 U.S.C. 2283(a)). The second condition stipulated that the Secretary of the Commerce, the Administrator of the USEPA, and the Secretary of the Army approve the selected plan that adequately addresses the potential environmental impacts of the project.

1.3 OBJECTIVE

The objective of the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary** is to identify and conduct a screening level evaluation of potential measures that could improve DO in the Savannah River Estuary. This analysis includes an assessment of the engineering feasibility and cost effectiveness of potential improvement measures, as well as an initial identification of potential implementation problems. This effort is directed toward both the portion of the harbor (critical segment) and the time of year (critical season) that were identified in the Draft TMDL as having recurring low levels of DO. The analysis will allow the USACE to consider alternate methods of improving DO from present levels and to identify methods for incremental DO improvement for both the Savannah Harbor Expansion Project and the Savannah Harbor Ecosystem Restoration Study.

1.4 METHODOLOGY

This study was conducted in two phases, each with multiple steps. For Phase I, these steps were developed to address the current and recommended DO standards and the current and potential BOD loading scenarios presented in the Draft TMDL and included considerations for non-point BOD sources of DO demands.

- Phase I, Step 1 considered measures that would potentially allow the harbor to comply with the present Georgia DO standard and provided potential options for addressing the excess total ultimate BOD ($TBOD_U$) load of 290,250 pounds per day (lbs/day) from current BOD_U loads from point sources (99,000 lbs/day from the Harbor area dischargers and 75 percent of the 135,000 lbs/day [101,250 lbs/day] from the upstream river dischargers) and a portion of the load coming from non-point sources (90,000 lbs/day).

- Phase I, Step 2 considered measures that would allow the harbor to comply with the present Georgia DO standard and provided potential options for addressing a total BOD_U load of 725,500 lbs/day from the National Pollutant Discharge Elimination System (NPDES) permitted loads (367,000 lbs/day from the Harbor area dischargers and 75 percent of the 358,000 lbs/day [268,500 lbs/day] from the upstream river dischargers) and a portion of the load from non-point sources (90,000 lbs/day).

- Phase I, Step 3 considered measures to improve DO levels in the harbor to meet the revised DO standard recommended in the Draft TMDL. This step addressed the current BOD_U loads and measures that equated to an approximate 30 percent reduction in the current BOD_U loads (68,250 lbs/day) from point source dischargers.

- Phase I, Step 4 considered measures that would allow the harbor to comply with the recommended DO standard and considered the effects of the excess NPDES permitted BOD_U load of 503,500 lbs per day.

Phase II consisted of assessing potential measures to improve DO levels in the harbor by 0.2 mg/L increments to a maximum increase of 0.8 mg/L and are related to DO impacts that may be caused by future deepening of the harbor. Thus, this phase develops four potential design alternatives to improve DO, the first capable of improving DO levels by 0.2 mg/L, the second improving DO levels by 0.4 mg/L, the third improving DO levels by 0.6 mg/L, and the fourth improving DO levels by 0.8 mg/L. Phase II assumed that the DO levels in the harbor meet the recommended DO standard presented in the Draft TMDL.

Table 1.1 presents a summary of Phase I and II BOD load reductions. For this screening level evaluation, one pound of $TBOD_U$ equates to one pound of supplemental DO required, thus equal amounts of oxygen are applied to fully satisfy the theoretical $TBOD_U$ loads discharged. This simplifying assumption inherently over estimates the amount of supplemental oxygen required. Point source BOD loads and flows are based on information contained in the Draft TMDL (USEPA, 2004) and the USEPA EnviroFacts Database (USEPA, 2005). For Phase II, the required incremental DO increase was estimated using a relationship taken from the Draft TMDL in which 0.55 mg/L of critical DO deficit equates the 200,250 lbs of BOD from all the point source dischargers combined. Using this deficit-load relationship, the supplemental DO needed for each 0.2 mg/L of DO improvement equates to 72,818 lbs of added oxygen required. Of course, these simplifying deficit load assumptions are subject to refinement once the final TMDL water quality model is made available by USEPA for general use.

2.0 ASSESSMENT OF DISSOLVED OXYGEN DEFICIT FROM POINT SOURCE AND NON-POINT DISCHARGE

2.1 ASSESSMENT OF POINT SOURCE DISCHARGERS

According to the Draft TMDL, the NPDES permitted cumulative oxygen-demanding substance load for facilities authorized to discharge into the Harbor (Harbor Dischargers), expressed as $TBOD_U$, is 367,000 lbs/day. Of this authorized 367,000 lbs/day, facilities were cumulatively discharging approximately 99,000 lbs/day of $TBOD_U$ in the summer of 1999. This 99,000 lbs/day is known as the “existing” load; the load authorized by point-source NPDES permits (i.e., the 367,000 lbs/day) is known as the “permitted” load.

Loadings of oxygen-demanding substances from sources upstream of the Harbor (Upstream Dischargers), below Thurmond Dam, also impact the Harbor DO levels and are taken into account in the Draft TMDL. The majority of these dischargers are located in the Augusta, Georgia area. The total loading of oxygen-demanding substances for the upstream sources authorized by point-source NPDES permit is 358,000 lbs/day $TBOD_U$ (permitted load). The total loading of existing oxygen-demanding substances discharged in the summer of 1999 was 135,000 lbs/day (existing load). Approximately 75 percent or 101,250 lbs/day of the oxygen-demanding substances discharged in the Augusta area reach the upstream portion of the Harbor according to the Draft TMDL (USEPA, 2004).

As part of the assessment of point source dischargers, the dischargers listed in the Draft TMDL from the Harbor and the Upstream areas were tabulated. Permit loads as presented in the Draft TMDL were verified using the USEPA Database, EnviroFacts (USEPA, 2005).

According to the Draft TMDL, “Oxygen-demanding loads from City of Savannah municipal storm water, and heat loads from the three Savannah Electric power facilities were evaluated in the model and shown to have no measurable impact on the DO levels in the critical areas of concern” (USEPA, 2004).

Notably, the current Draft TMDL does not provide separate explicit allocations for those stormwater dischargers subject to a general NPDES permit.

2.2 ASSESSMENT OF NON-POINT SOURCE DISCHARGE

The non-NPDES loadings of oxygen-demanding substances are from natural background sources including detritus transported in the stream, detritus from marsh areas flowing directly into the Harbor, and tidally-transported detritus from the ocean. The Draft TMDL describes natural background oxygen demanding substance loads as follows.

- Marsh 150,000 lbs/day
- Upstream 85,000 lbs/day
- Ocean $CBOD_U$ = 6 mg/L;
  Ammonia = 0.1 mg/L

The Draft TMDL identified the critical segment of the Savannah Harbor system as the segment of the Harbor with the lowest daily DO average. This segment is an approximate four mile segment of the Savannah Harbor from RM 9.3 to RM 14.3 (Figure 1.2). This segment is the primary focus of the DO improvement technologies and is also a segment proposed to be further deepened. In order to identify screening level evaluation measures for technologies, the river system was divided into an upstream zone referring to the Augusta area (Upstream Area) and the harbor area referring to the critical segment (Critical Harbor Area). Next non point discharge was identified as natural background oxygen demanding substances (marsh, upstream, ocean and stormwater).

2.3 RANKING OF TOP FIVE POINT SOURCE DISCHARGERS

In order to summarize the effect that point source dischargers have in the Savannah Harbor, a list was compiled using information from the Draft TMDL Table 1 and Appendix D (of that document), respectively that included harbor and upstream point source dischargers. For each discharger as available, the permitted flow, BOD (load or discharge concentration), and ammonia-nitrogen (load or concentration) capacities were obtained from the Draft TMDL tables and/or the USEPA EnviroFacts Data Warehouse Water Discharge Permits (PCS) Database. The resulting compilation is presented in Appendix B. The top five dischargers with the largest permitted loads are presented in Table 2.1. These “top five” dischargers with the greatest permitted BOD loading were (in order of greatest to least) International Paper – Savannah Mill (IP Savannah), International Paper – Augusta Mill (IP Augusta), Georgia Pacific, Weyerhaeuser, and the City of Savannah President Street wastewater treatment plant (WWTP). Though these dischargers were identified as the top five based on permit conditions, they may not necessarily cause the “top five” impacts to the DO deficit due to:

- Actual BOD loadings may be substantially less than permit limits,
- Other dischargers with lower permit limits may have a current load that exceeds the current load of one of the identified "top five" dischargers,
- Degradation rates of BOD loads vary greatly between types of effluents and were not considered in this evaluation. However, a discharge with a lower BOD and a relatively rapid BOD decay rate may cause more impact in the critical segment than a higher BOD discharge with a slower BOD decay rate, and
- This analysis assumes that 1-pound of BOD loading from any point source discharge will have an equal effect on DO deficit in the critical area. This may not be true because the BOD decay rates differ between discharges and their location with respect to the critical area differs. More detailed analyses with an accepted three-dimensional hydrodynamic and water quality model of theriver and harbor should be performed before decisions are made regarding a specific DO improvement.

2.3.1 Next Two Traditional Steps for BOD Reduction - Top Five Dischargers

A request for information from the identified "top five" permitted dischargers was sent on January 31, 2005 requesting information on treatment processes currently being used and potential upgrades under consideration to potentially meet the allocations proposed in the Draft TMDL (Appendix C).

MACTEC reviewed GAEPD permit files for permit applications, wastewater treatment process diagrams, and other relevant information. This investigation provided information such as permit limits, wastewater generation diagrams, and discharge monitoring reports (DMRs). However, specific information on the design or processes of the wastewater treatment facilities for each discharger was not obtained.

As part of the public comments submitted to USEPA on the Draft TMDL, the IP Savannah and Augusta Mills (through their Corporate Environment office) provided estimated costs required to reduce existing loads from their two mills by 30 percent, "Both IP mills would have to significantly reconfigure their wastewater treatment system to achieve the improved removal efficiencies. This action could only be achieved at a significant capital cost to each mill. Using standard engineering assumptions, the estimates to increase BOD removal efficiency at the Augusta and Savannah Mills, respectively, are $28,275,000 and $37,492,000." The type of treatment measures and design were not specified (Appendix C).

The City of Savannah President Street WWTP is currently implementing an urban water reuse program. Urban water reuse programs are used to irrigate large open areas such as golf courses, industrial parks, recreational parks, etc. Wastewater treatment standards for reuse water are more stringent than wastewater treated to secondary treatment standards and generally require advanced treatment such as membrane filtration. At this time a portion of the flow from the President Street WWTP, is treated to reuse standards and is used to irrigate two major golf courses. Irrigation is typically needed during the DO critical season for the harbor and would reduce flows and loading from the President Street WWTP. Increasing reuse demand would potentially allow further reduction in BOD loading to the Harbor during the summer and is currently under investigation by City officials (http://www.ci.savannah.ga.us/cityweb/webdatabase.nsf). MACTEC requested additional information from the City to use in the various design scenarios (Appendix C).

Although source-specific information was not obtained, several typical approaches to reducing BOD loads from point sources are available for consideration and include technologies and management/operations such as:

- Membrane filtration of effluents
- Oxidation technologies
- Constructed wetlands treatment (polishing)
- Additional storage with intermittent controlled releases based on receiving water conditions
- Changes in water management within a facility that results in waste stream generation reductions and thereby reduces the total flow and BOD load discharged
- Land application of treated effluent
- Seepage lagoons
- Water conservation education for the community to reduce flows to the municipal WWTP
- Technologies that result in delignification of effluents allowing faster degradation of carbon sources.

From a DO improvement perspective alone, the Draft TMDL modeling by USEPA shows that total elimination of all point source discharges in both the Savannah and Augusta areas, would improve the critical harbor DO by only 0.55 mg/L.

Independent of this present DO improvement screening study, USEPA Region 4 is presently considering the potential for treatment improvement at the paper industry facilities. No information was available from USEPA for this report.

3.0 DISSOLVED OXYGEN IMPROVEMENT TECHNOLOGY ASSESSMENT

This section presents the screening level evaluation of DO improvement measures designed to improve DO levels in the harbor during critical summer months. The screening was divided into two levels of screening to assess the viability of a given alternative. These alternatives for DO improvements for the Savannah Harbor were organized by technology or process. The tabulated information is provided as Tables 3.1 and 3.2 and includes information on the Level I & II - Assessment of Dissolved Oxygen Technology, respectively.

3.1 LEVEL I ASSESSMENT

Level I screening of DO improvement alternatives involved listing reasonable, available technologies to increase DO concentrations in surface waters and evaluating the technical feasibility of each alternative based on potential effectiveness and applicability with current site conditions. Twenty improvement technologies were initially identified as potential solutions. Those technologies include:

- Membrane Filtration of Effluents
- Cascade Aerator
- CleanFlo-Natural Inversion
- Coarse Bubble Diffuser
- Fine Bubble Diffuser
- Linde-Soaker Hose
- Mechanical Surface Aerators
- Rolling Maintenance Shutdown during Critical Season
- Increased Releases from Upstream Reservoirs
- ECO2-SuperOxygenation (Speece Cone)
- Fine Bubble Diffuser using High Purity Oxygen
- Hydroflo-Aero Transfer System
- Praxair-In-Situ Oxygenation
- Sidestream Pressurized Oxygenation
- U-Tube Oxygenation
- Venturi Oxygenation
- Aquatic Treatment Systems
- Constructed Wetland Treatment Systems
- Discharge Collection Network With Supplemental Oxygen Injection
- Inflatable Weir
- Land Treatment Systems/Water Reuse
- Mechanical Pumps
- Seaward Pipeline with Timed Tidal Discharge
- Storage and Controlled Discharge System
- Tidal Gate

These technologies are listed in Table 3.1 and fall into the following categories:

- Advanced Treatment
- Aeration
- Management
- Oxygen Injection
- Physical Modifications

The technologies were classified as potentially effective for implementing in the harbor system and/or at the location of a point source discharge. The first screening level took into account site-specific conditions and requirements for either upstream or harbor implementation. Screening of the identified technologies considered the shipping channel traffic, the zone of influence, applicability to moving or stagnant water, power needs, required space for application of technology, and the ability to effectively dissolve oxygen into water.

Aeration/Oxygenation Technology Comparison – Types of oxygenators were evaluated on their ability to provide large quantities of oxygen to surface water bodies. The specific design goals for oxygenation technologies included:

- High oxygen absorption efficiency
- Low unit energy consumption kilowatt hour per ton of DO (kW-hr/ton DO)
- Side stream superoxygenation (50 to 100 mg/L) at reasonable capital cost

Aeration (with air) and superoxygenation (using commercial "pure" oxygen) technologies dissolve oxygen into the water. It may appear counterintuitive to utilize commercial oxygen when air is available from the atmosphere for free. However, the use of commercial oxygen may prove to be more economical than air. For instance, dissolving oxygen from air into water involves considerable capital and operating costs. Some adverse effects are also associated with the use of air which are negated using commercial oxygen (Speece, 2005-Appendix D). The use of air in contact with water under more than ambient pressure, on the other hand, may result in supersaturation of the water column with dissolved nitrogen gas, potentially adversely impacting fish. Air as the oxygen source also restricts the maximum DO concentration achievable, and therefore increases the aeration required to achieve a given daily oxygen supplementation mass rate. In addition, the use of air necessitates almost an order of magnitude greater energy expenditure per ton of DO dissolved into solution when compared to commercial oxygen use.

Commercial oxygen can also be dissolved even in stratified water columns and generally becomes more economically competitive when the target dissolved oxygen requirement exceeds 4 to 5 mg/L (Speece, 2005-Appendix D).

Technologies that require large amounts of River surface area or submerged River bed area were generally eliminated. These types of area-extensive technologies would likely interfere with routine maintenance dredging and future Harbor expansion projects. Also, velocities in the river may be great enough that some of these large area technologies would not be able to withstand the dynamic forces and may be swept away. Technologies eliminated for these reasons include: Cascade aerators, CleanFlo – Natural Inversion Technology, coarse and fine bubble diffusers, soaker hose technologies, and mechanical surface aerators.

Management Options - Application of employing increased releases from upstream reservoirs was eliminated based on modeling runs completed by the USEPA observing only local increases in DO by the increased DO levels at the dam and no noticeable increase in DO at Clyo, RM 61 (USEPA, 2003). Also, during critical flows, the potential for release from the upstream reservoirs may be severely limited by drought conditions and the required water volumes needed to substantially increase flows in the critical segment may not be available.

3.2 LEVEL II ASSESSMENT

The Level I screening evaluation eliminated those technologies which if implemented would not feasibly achieve the desired BOD reduction improvement goals or the TMDL DO requirements for the critical segment of Savannah Harbor or did not have convincing evidence for current application. Based on the results of the Level I screening evaluation, the following alternatives were retained for further consideration:

3.2.1 Membrane Filtration

Membrane filtration is a tertiary treatment applied to wastewater treatment processes which removes residual sedimentary particles and particulate organics from treated wastewater. Site specific wastewater characterization (total dissolved solids, total suspended solids, nitrates, sulfates, dissolved organic carbon, etc.) is needed to design membrane filtration systems in order to predict potential performance and relative costs. Membrane filtration systems have been employed at publicly owned treatment works (POTWs) (Zenon, 2005).

3.2.2 ECO_2 Speece Cone

The Speece Cone oxygenation device uses water pumps to move large quantities of water or treated effluent into a cone shaped device. High purity oxygen is injected into the center of the cone. The high velocity downflow of water inside the cone creates a "bubble swarm" which increases the concentration of oxygen absorbed into the water. Upon exiting the Speece Cone, the high DO water may be injected back into the harbor at various depths (minimum 10 feet to greater than 50 feet) to increase DO concentrations. The Speece Cone has been implemented at a variety of locations including lakes and river water bodies. Case studies include East Bay Municipal District at Comanche Reservoir, CA, Newman Lake Homeowners Association at Newman Lake, WA, and Alabama Power at Logan Martin Dam, GA. In comparison to a U-Tube, the main advantage of a Speece cone is that no deep excavation costs would be required for the Savannah Harbor because the approximate 50 foot depth and associated water pressure of the harbor can be utilized for achieving superoxygenation of the returned flow.

3.2.3 Deep U-Tube

The U-Tube technology requires installation generally into an excavation approximately 150 to 200 feet in depth. A large pipe is fitted into the hole, and water is pumped down the length of the pipe. High purity oxygen is injected into the bottom of the pipe as the water travels downward. The velocity of descent exceeds the bubble rise velocity, which creates a long contact time and results in a high transfer rate of oxygen to the water stream. As the water travels to greater depths, the pressure increases, which also increases the absorption of oxygen into the water. The superoxygenated water rises through a middle pipe, where it is discharged (at varying depths) into the receiving surface water being oxygenated. This deep U-Tube application is being demonstrated at the Stockton Deep Water River Channel near San Joaquin River at the mouth of the San Francisco Bay in California (Civil Engineering News, 2005).

3.2.4 Pressurized Side Stream Oxygenation (PSSO)

The PSSO system uses industrial water pumps to move water at high pressure through a series of looping pipes. The length of the pipe increases residence/contact time (approximately 100 seconds) and backflow valves increase water pressure. High purity oxygen is injected into the influent stream of water. Oxygen absorption into the water is driven by the high residence time and high pressure. High DO water is then discharged and dispensed into the critical segment at depth. The PSSO systems require large tracts of land to accommodate the length of piping necessary to achieve the desired residence time under high pressure.

3.2.5 HydroFlo Aero Transfer System

HydroFlo technology withdraws a side stream of water into which high purity oxygen is injected, then directed through equipment in which the oxygen absorption takes place, and sent back into the harbor. The HydroFlo system utilizes a proprietary Aero Transfer System (ATS) to inject high purity oxygen into the water. The HydroFlo system is able to achieve high transfer efficiencies with low power consumption requirements. The superoxygenated water would be discharged into varying depths of the water body to increase DO concentrations at critical depths.

3.2.6 Praxair In-situ Oxidation (ISO)

The Praxair ISO system uses a surface mounted aerator with an impellor and high purity oxygen injection. The oxygen is injected into the surface water, where an impellor mixes the oxygen into the water body. This movement also pushes the oxygenated water downward and away from the aerator. The system requires low energy input per ton of oxygen dissolved and has good oxygen transfer efficiency (>90%). However, the Praxair system is limited in coverage to the area that can be oxygenated by a single unit, requiring several units be located within close proximity. Because these are floating aerators, they are not the best solution for the Savannah Harbor, as they would potentially interfere with right-of-way water traffic but may be considered for off stream storage pond aeration.

3.2.7 Venturi Injection

Venturi injection nozzles have been developed in which water is passed through a section of pipe into which high purity oxygen is injected. The high velocity water through the venturi nozzle increases the amount of oxygen absorbed. The residence time within the Venturi is very short even though the bubbles are tiny and a high gas/water interface, thus the brief contact time precludes efficient absorption. Vendors utilizing the Venturi aspiration principle to achieve absorption of purity oxygen include Air Products, Mazzei, and Linde.

3.2.8 Rolling Maintenance Shutdown during Critical Months

Many of the manufacturing facilities discharging to the Savannah River both upstream near Augusta and within the harbor area conduct periodic planned maintenance shutdowns of their facilities. These maintenance shutdowns generally take some or all of the production lines off-line to clean, test, and repair major equipment. These shutdowns are scheduled in advance and may last from several days to a week or more depending on the requirements of the facility. As such, it may be feasible to organize the industrial point source dischargers along the Savannah River to coordinate these shutdowns to occur during the DO critical season to minimize treated effluent flow discharged to the river during the critical season. As possible, these industries along the middle and lower reaches of the Savannah River/Harbor may be able to coordinate a maintenance shutdown to occur at staggered intervals maximizing the length of time and the load reductions to the system during summer critical conditions.

Some of the constraints that may be applicable to this management scenario include:

- Coordination and agreement among dischargers along the river/harbor,
- Maintenance requirements may not be required by a facility during the applicable critical season, or hot weather shutdowns may not be feasible from a health and safety perspective for maintenance workers.
- Contingencies for emergency shutdowns and completing other maintenance activities during this period thereby eliminating a need for another shutdown, and
- Actual BOD load during shutdowns is not known (and may not be substantially different from normal discharges) and would require further investigation.

3.2.9 Urban Water Reuse Plan

Urban water reuse (UWR) is a type of land application utilizing highly treated municipal effluent as an irrigation source. Two golf courses in the Savannah area are currently being irrigated by UWR effluent from the President Street WWTP. Potentially, this program could be expanded to provide irrigation for parks, recreational areas, office parks, and other open areas to reduce the total load to the Harbor. Demand for reuse water is at a maximum during the critical summer period when rainfall is limited creating a complimentary situation. Also, in the cooler months when demand is low, flows in the Savannah should be sufficient to allow the facility to discharge according to limits specified in their NPDES permit. GAEPD rules have specific water quality limits for effluents used for UWR.

3.2.10 Constructed Wetlands

Constructed wetlands are man-made systems that imitate the functions of natural wetland systems. Constructed wetlands often perform better for treatment than natural wetlands of equal area because the constructed system is specifically managed and controlled for treatment effectiveness. Emergent plants provide significant amounts of reactive surface area for microbial activity that can further degrade BOD. Additionally, depending on the design, a constructed wetland may provide habitat for wildlife. Constructed wetlands have the potential for treating moderate to high organic loads with a BOD effluent characteristic of 5 to 40 mg/L (Reed, 1995).

3.2.11 Oxidation/Partial-mix Aerated Pond

Oxygen in an aerated pond is supplied mainly through mechanical or diffused aeration. Aerated ponds are generally 6-20 feet in depth with detention times of 3-10 days. The main advantage of aerated ponds is that they require less land area in comparison to systems without aeration technology. However, as the size of ponds increase capital and operations and maintenance (O&M) costs significantly increase. Aerated ponds that may have application in the Savannah Harbor area would be polishing ponds to provide further reduction of BOD from the treated wastewater collected and to provide additional storage of treated effluents during the DO critical period for subsequent release.

The four Savannah area discharges blended together in an aerobic[1] effluent storage pond would have a CBOD decay rate of about 0.033/day (base e, $20^{o}C$ – volume weighted average decay rate) based on the Savannah Harbor Wastewater Characterization Study (LAW, 2000) effluent characterization study. Adjusting this rate to $30^{o}C$ (expected effluent temperature during the critical season) this decay rate would be about 0.052/day.

The percent (%) reduction of $CBOD_U$ as a function of storage time is as follows:

Days Storage	% $CBOD_U$ reduction
1	2.5
10	21
30	40
60	48
90	50

[1]Aeration/Oxygenation of the storage pond would be added as necessary to maintain aerobic conditions throughout the storage pond contents.

The August IP effluent in aerobic[1] storage would decay at about 0.036/day (base e, 20°C). At 30°C this rate would increase to about 0.057/day.

The percent (%) decay at $CBOD_U$ in storage would be as follows:

Days Storage	% $CBOD_U$
1	3
10	22
30	41
60	49
90	50

[1]Aeration/Oxygenation of the storage pond would be added as necessary to maintain aerobic conditions throughout the storage pond contents.

3.2.12 Discharge Collection Network with Supplemental Oxygen Injection

Pipelines may be constructed to convey treated effluent from selected facilities to a centralized storage lagoon. High purity supplemental oxygen may be injected into the pipe network to maintain aerobic conditions and provide for further degradation of BOD during conveyance. A collection system would connect the discharge collection lines into one main terminal. The discharge collection network would be used in conjunction with a seaward pipeline scenario in the Savannah area (Section 3.2.13) or with the effluent storage and controlled discharge scenario (Section 3.2.14).

3.2.13 Savannah Area Seaward Pipeline with Timed Tidal Discharge

This approach utilizes a pipeline to discharge Savannah area treated effluent from the centralized storage lagoon (Section 3.2.14) downstream (seaward) of the DO critical segment. Discharges from this system would be timed so that releases are coordinated with outgoing tides to maximize seaward transport and dispersion. As part of this alternative, the centralized storage lagoon would need a minimum 12 hours detention time to be able to time the release to occur on outgoing tides. Supplemental oxygen may also be injected in the pipeline to superoxygenate the discharge before release.

3.2.14 Storage and Controlled Discharge Pond

Storage and controlled discharge ponds would be operated and constructed in addition to the discharge collection pipe network (Section 3.2.12). Rather than discharging at a seaward location, the storage ponds would be designed to store treated effluents during the critical season for post-critical-season release. Controlled discharge ponds have long retention times (in this case up to 90 days), and the effluent is discharged (at varying rates) to coincide with instream river conditions. A variation of the controlled discharge pond is a hydrograph controlled release lagoon. The pond discharge is matched to periods of high flow in the receiving stream, using the stream hydrograph as the control (Reed, 1995). Typical storage areas needed for corresponding flows are estimated below.

				Pond Area (Acres) (assume 9 feet deep)					
Facility Name	**NPDES ID**	**Full Permit Flow[a] (MGD)**	**Assumed Flow (MGD)**	**12-HRS Retention**		**30-Day Retention**		**60-Day Retention**	
				Surface	**Total***	**Surface**	**Total***	**Surface**	**Total***
International Paper (Savannah)	GA0001988	38.00	30.00	5	9	307	340	614	650
International Paper (Augusta)	GA0002801	40.00	40.00	7	12	409	453	819	867
Fort James Paper (GA Pacific)	GA0046973	33.00	33.00	6	10	338	374	675	715
Weyerhaeuser-Port Wentworth	GA0002798	22.00	20.00	3	6	205	227	409	433
President Street	GA0025348	27.00	10.00	2	3	102	113	205	217

				Pond Area (Acres) (assume 9 feet deep)					
Facility Name	**NPDES ID**	**Actual Flow[e] (MGD)**	**Assumed Flow (MGD)**	**12-HRS Retention**		**30-Day Retention**		**60-Day Retention**	
				Surface	**Total***	**Surface**	**Total***	**Surface**	**Total***
International Paper (Augusta)	GA0002801	30.00	30.00	5	9	307	340	614	650
International Paper (Savannah)	GA0001988	28.00	28.00	5	8	287	317	573	607
Fort James Paper (GA Pacific)	GA0046973	19.00	19.00	3	6	194	215	389	412
Weyerhaeuser-Port Wentworth	GA0002798	11.75	11.75	2	4	120	133	240	255
President Street	GA0025348	25.83	25.83	4	8	264	293	529	560

* Total area includes berm footprint.

Those alternatives that were considered applicable for the Savannah Harbor area were passed to the next screening process and were further evaluated based on the criteria listed below.

3.3 LEVEL II ASSESSMENT OF LIMITATIONS

The overall objective of the Level II screening is to identify appropriate, effective and economical alternatives capable of achieving the required improvement. The detailed screening of potential remedies consisted of ranking the various DO improvement alternatives according to the following criteria:

- Performance/Effectiveness – Addresses the degree to which the alternative will achieve the improvement measure (i.e. increase Harbor DO during critical conditions).
- Reliability – Addresses the ability of the alternative to consistently maintain effectiveness and operate continuously.
- Oxygen (O_2) Transfer Efficiency – Addresses the degree to which the technology is capable of transferring oxygen into the water stream.
- Unit Energy per ton DO – Addresses the energy required to introduce one ton of DO.
- DO Concentration – Addresses the DO output concentration that may be achieved by a given technology.
- Capital and Added Operation and Maintenance Cost – Addresses the cost of implementing each alternative.
- Physical/Logistical – Addresses the location for installation of each alternative.
- Seasonal Application – Addresses the application of each alternative on a seasonal or annual operating basis.

The second screening evaluation, Level II, considered the individual characteristics in a more detailed analysis. Each technology is evaluated and ranked for each characteristic and a numerical ranking is assigned. These rankings were assigned based on the overall achievement of the project goals and objectives for DO improvement.

For the technologies under consideration, each criterion listed above was assigned a qualitative ranking factor based on a 3-point rating scale (3 = good; 2 = fair; 1 = poor). The ranking for each alternative was tallied and totals were compared to facilitate selection of applicable technologies. The results of the improvement technology screening evaluations are summarized in Table 3.2 and Table 3.3. Criteria for assigning a numerical value to a given characteristics are as follows:

- Harbor Improvements Oxygen Injection Performance/Effectiveness
    - 3 – low maintenance; high oxygen transfer efficiency (>90%); high production of oxygen per horsepower hour (>10 lbs O_2/hp-hr); high sidestream O_2 concentration (>50 mg/l); and low capital cost.
    - 2 – moderate maintenance; medium oxygen transfer efficiency (60-90%); medium production of oxygen per horse power hour (6-9 lbs O_2/hp-hr); medium sidestream O_2 concentration (10-50 mg/l); and medium capital cost.
    - 1 - high maintenance; low oxygen transfer efficiency (<60%); low production of oxygen per horse power hour (<6 lbs O_2/hp-hr); low sidestream O_2 concentration (<10 mg/l); and high capital cost
- Harbor Improvements Physical Performance/Effectiveness
    - 3 – most applicable to DO improvement goals; low maintenance; and low capital cost.
    - 2 – somewhat applicable to DO improvement goals; moderate maintenance; and medium capital cost.
    - 1 – further research needed to assess DO improvement goals; high maintenance; and high capital cost
- Point Source Performance/Effectiveness
    - 3 – most benefit to DO improvement goals; low maintenance; and high BOD reduction (250,000 to 500,000 lbs/day); low capital costs; no area constraints; and most effective during summer critical season.
    - 2 – moderate benefit to DO improvement goals; moderate maintenance; and medium BOD reduction (100,000 to 250,000 lbs/day); medium capital costs; some area constraints; and most effective during summer critical season.
    - 1 – further research needed to assess DO improvement goals; high maintenance; and low BOD reduction (<100,000 lbs/day); high capital costs; area constraints; and limited seasonal application.

Although the ranking is somewhat subjective, the process provides a structured format to assess alternatives for elimination, and often a clear-cut alternative emerges. The results of the Level II Assessment of Limitations for Alternatives are summarized in Table 3.2 and 3.3.

In summary, the top three oxygen injection technologies ranked from greatest to least are: Speece Cone, U-Tube, and Sidestream Pressurized Oxygenation. Each of the physical treatment options ranked equally. The inflatable weir, the tidal gate technology, and the mechanical pumps may apply to control salt water intrusion and/or provide for increased mixing as the harbor is deepened but more research is needed to be able to evaluate the potential effectiveness for DO improvements with these options.

The top three point source technologies ranked from greatest to least are: the seaward pipeline with timed tidal discharge, storage and controlled discharge pond, and rolling maintenance shutdowns during critical months.

4.0 CONCEPTUAL DESIGN ALTERNATIVES

Brief descriptions of the conceptual designs retained for further evaluation are presented in the following subsection with a discussion of application of selected technologies.

4.1 MAXIMUM TECHNOLOGY CAPABILITIES

The following section breaks each technology into a specific range of BOD loadings it is capable of meeting per single application.

4.1.1 0 to 100,000 lbs/day

Rolling Maintenance Shutdowns for BOD Load Management (2 weeks assumption per facility) - The Rolling Maintenance Shutdown Program is a management practice (MP) that is potentially applicable for certain manufacturing facilities in Augusta and Savannah. It is not applicable for municipal WWTP or POTWs or for facilities that do not require scheduled periodic shutdowns for maintenance. Each summer from late July to early September, the major dischargers could coordinate maintenance activities allowing a period of time with reduced loadings. Facility shutdowns could be timed so that shutdowns would follow one another reducing the overall load during the critical season. For this study and to develop the application of this scenario, an assumption that each discharger would require 2 weeks to complete maintenance activities at their facility and that there is a total BOD load reduction of approximately 50 percent during a scheduled shutdown period was used. For example (in a given year), of the four applicable top five facilities, IP Savannah does not require extensive maintenance activities and therefore does not schedule a maintenance shutdown, the remaining three manufacturing facilities will require a brief period to shutdown part of the manufacturing process to replace and repair equipment and agree to conduct these activities during the DO critical season. Total BOD reductions within the 0 to 100,000 lbs/day range potentially provide total BOD reductions of: Weyerhaeuser ~15,000 lbs/day (end of July); Georgia Pacific ~21,700 lbs/day (first 2 weeks in August), and IP Augusta, ~67,500 lbs/day (last part of August). Using data from the top five ranked facilities and the assumptions previously stated, this alternative may provide a BOD loading reduction ranging from 15,000 to 67,500 lbs BOD/day.

Speece Cone Oxygenation - A single Speece Cone is capable of introducing approximately 10,000 to 12,000 lbs O_2/day, but multiple cones may be used to supply more than 10,000 to 12,000 lbs O_2/day. The Speece Cone could be mounted on the shore alongside the river channel. No more than 4 mounted cones are recommended in one location (supplying approximately 40,000 to 50,000 lbs/day) though multiple groups may be applicable for the Harbor. A mobile barge arrangement capable of traveling to an area predicted to have critical low DO levels may have up to 8 cones supplying approximately 80,000 to 96,000 lbs/day. The discharge stream of the cones would be directed to a particular water depth to allow for best oxygen transfer into the varying depths in the harbor. The land requirements for an oxygenation station should be more preferably referred as dock requirements. The Speece Cone principal is to operate under the maximum hydrostatic head available i.e. in the bottom of the harbor. Therefore it is preferably located where it has access to the full depth of the harbor and this will probably be off the edge of a dock where the harbor depth is maximum. Each cone is 12 ft in diameter and about 15 ft high. Each cone has a 50 HP pump that withdraws water from the depth of the harbor and moves it through the cone. If liquid commercial oxygen is utilized, then a storage tank of approximately 6 ft diameter by 40 ft high would hold 7 days supply. Access to the site by a LOX tanker truck would be required. If mobile Speece cone units were considered, two complete units fit on a standard fifty foot barge. Mixing would be provided mainly by tidal action. The superoxygenated discharge would be horizontally directed perpendicular to the dock and would be transported over 0.5 miles away. Depending on the output of the tidal mixing model, if additional transport of the superoxygenated discharge was desired, a 10 HP low tip speed, 6 ft diameter mixer could be located at the cone discharge to supplement the tidal mixing.

Storage and Controlled Discharge Pond - Phase I, Steps 1 and 2 require a 100 percent reduction of the current load or the permitted BOD loads, respectively. Storage and controlled discharge ponds would consist of earthen ponds constructed to periodically store treated wastewater effluent from large facilities discharging to the Savannah River and Harbor. These ponds may be designed to hold effluents for varying lengths of time and be engineered to allow discharge under various scenarios such as on outgoing tides, based on the river/harbor hydrograph, etc. The availability of land is directly proportional to the costs for this technology. Dredged sediment storage facilities may be potential areas available for such storage. Available areas for storage options in the Augusta region as well as storage capacities at each point source are unknown at this time to be considered as an alternative. Storing Weyhaeuser or President Street WWTP discharge would divert approximately 30,000 lbs BOD/day from the critical segment.

Supplemental Oxygen Injection (with Pipeline Alternative) - Supplemental Oxygen Injection involves a mixture of high purity oxygen injected into an extended discharge pipeline. Injection technologies are available for O_2 injection at the pipe inlet or O_2 injection at incremental lengths in the pipeline to maintain aerobic conditions within the entire length of the pipeline. Oxygen injection in a pipeline creates a plug-flow reactor which will also allow further degradation of BOD loadings. The hydraulic residence time is determined by the length of the pipe and the flow velocity. Because most proposed pipelines are less than 15 miles, complex organics are not expected to further degrade in the pipe system. Preliminary designs predict a 10 mile segment may be superoxygenated feasibly with approximately 80,000 lbs/day (provided by Mazzei, 2005 – Appendix E)

Urban Water Reuse Plan - Municipal discharges may be reduced by the implementation or expansion of urban water reuse programs. The City of Savannah President Street facility has implemented an urban water reuse program. Wastewater treated to urban water reuse standards is used to irrigate two golf courses in the Savannah Area. Potentially, this program could be expanded to provide irrigation for parks, recreational areas, office parks, and other open areas to reduce the total load to the Harbor on a seasonal basis. Demand for reuse water is at a maximum during the critical summer period when rainfall is limited. Also, in the cooler months when irrigation demand is low, flows in the Savannah should be sufficient to allow the facility to discharge according to limits specified in their NPDES permit.

Currently, the City of Savannah has identified several areas where expansion may be feasible. Cost and material estimates for implementing the water reuse expansion program are not known at this time. Expansion of the reuse program for the City of Savannah would decrease the volume of effluent that may otherwise require another reduction alternative. Also, other municipalities or POTWs located along the Savannah River may be able to implement reuse programs (depending on the availability of customers to accept the water) reducing the overall loading of BOD during the critical summer months.

4.1.2 100,000 to 300,000 lbs/day

Discharge Collection Network (Single 36” Pipeline) - A 36 inch diameter pipeline from the IP – Savannah facility on Hutchinson Island could be constructed to carry treated effluent wastewater east toward an existing dredge resource location where a temporary storage pond would be constructed. The discharge network would follow a direct route to the dredge resource location, including a segment traveling under the Back River channel. This would route some (~267,500 lbs/day) of BOD loadings to a storage and controlled discharge system or to a point well past the DO critical segment through a seaward discharge pipeline with tide-coordinated discharge. Rerouting IP Savannah’s discharge to temporary storage ponds would involve approximately 7,500 feet of pipe. Rerouting IP Savannah’s discharge toward a seaward discharge point #1, would involve approximately 54,000 feet of pipe.

Rolling Maintenance Shutdowns (2 weeks per facility) - The Rolling Shutdown Program management practice (MP) is applicable for this scenario.

Storage and Controlled Discharge Pond - Phase I, Steps 1 and 2 require a 100 percent reduction of the current load or the permitted BOD loads, respectively. Storage and controlled discharge ponds would consist of earthen ponds constructed to seasonally store treated wastewater effluent from facilities otherwise discharging to the Savannah River and Harbor. These ponds may be designed to hold effluents for varying lengths of time and be engineered to allow discharge under various scenarios such as on outgoing tides, based on the river/harbor hydrograph, etc. The availability of land is directly proportional to the costs for this technology. Dredged sediment storage facilities may be potential areas available for such storage. Depending on the retention time preferred, storing IP Savannah's discharge alone would divert approximately 267,500 lbs BOD per day from the critical segment. Twelve hour retention would require approximately 5 acres, 30-days retention approximately 307 acres, and 60-days retention approximately 614 acres of area assuming a pond depth of 9 feet.

	Pond Acreage ft (assume 9 feet deep)		
Facility Name	**12-HRS Retention**	**30-Day Retention**	**60-Day Retention**
International Paper (Savannah) 30 MGD	5.1	307	614

4.1.3 300,000 to 500,000 lbs/day

Discharge Collection Network (3 - 36" Pipelines) – Three 36 inch diameter pipelines each from Weyerhaeuser, IP Savannah, and the President Street facilities could be constructed to convey treated wastewater effluent east toward a centralized storage lagoon (from a converted existing dredge resource site). The discharge network would follow a direct route to the dredge resource location, including segments traveling under the river channel. This could potentially route approximately 327,500 lbs/day of BOD loadings to a centralized storage lagoon. Discharges from the centralized storage lagoon may be made using a controlled discharge or a seaward discharge pipeline with timed tidal discharge. Rerouting the three closest dischargers to a temporary storage pond would involve approximately 36,500 feet of pipe for Weyerhaeuser, approximately 7,500 feet of pipe for IP Savannah, and approximately 10,800 feet of pipe for President Street WWTP.

Storage and Controlled Discharge Pond – Utilizing the storage and controlled discharge pond is applicable for this scenario.

	Pond Acreage ft (assume 9 feet deep)		
Facility Name	**12-Hrs Retention**	**30-Day Retention**	**60-Day Retention**
International Paper (Savannah) 30 MGD	10	614	1228
Weyerhaeuser-Port Wentworth 20 MGD			
President Street 10 MGD			

4.1.4 500,000 to 750,000 lbs/day

No single technology is available to meet or exceed a 500,000 lbs/day requirement. Only a combination of the above listed technologies can achieve this range of oxygen addition or BOD offset. For example, routing BOD loadings to a storage pond and multiple Speece cones along the Harbor are considered combinations of technologies.

4.2 DEVELOPMENTAL CONCEPTUAL DESIGN ALTERNATIVES PHASE I

In general, constructing a pipeline to convey the point source discharges to the ocean is a high capital cost but an effective solution that could be utilized year round. The cost of such a pipeline is directly proportional to its length so considering shorter pipelines is a more feasible solution. The technologies available for oxygen injection are more cost effective for providing oxygen in the range of 0-300,000 lbs/day if 90 days of O&M is required for 20 years. As oxygen supply requirements exceed this range other technologies may prove more feasible thus pipelines and effluent storage systems could be considered. The direct oxygen injection is most feasible for treating background BOD loads. In concept, one or two injection systems could compensate for non-point source BOD loads of 90,000 lbs/day. Management practices like scheduled maintenance shut downs are potentially the least expensive BOD reducing measure. However, total elimination of all point sources in the Savannah and Augusta areas would only decrease the loading by 234,000 lbs/days and, thereby, increase the critical DO deficit in the harbor by only 0.55 mg/L.

4.2.1 Phase I, Step 1, (~290,250 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase 1, Step 1 require an elimination of 99,000 lbs/day BOD from Harbor point source dischargers and 135,000 lbs/day BOD (equating to 101,250 lbs/day in the Harbor) from upstream point source dischargers. This step also requires removal or improvement alternatives for an additional 90,000 lbs/day BOD loading from non-point source loads.

Concept 1 Alternative 1A – Harbor Injection Technology (29 Speece Cones)

In order to provide 290,250 lbs/day of oxygen to the critical segment of the harbor, 29 Speece cones could provide up to 290,000 lbs/day of oxygen for the critical season. This alternative could be used to further increase DO levels in the Harbor at any period in the seasonal cycle.

Concept 1 Alternative 1B – Harbor Injection Technology (29 Speece Cones with scheduled maintenance shut downs)

A similar conceptual design (Concept 1-1B) would use Speece cones in combination with scheduled maintenance shut downs in four of the top five dischargers. This could reduce the need for Speece cones to operate the entire 90 days. Utilizing a shutdown scenario should reduce the supplemental oxygen requirements, thereby lessening the number of days that all the Speece cones need to be operated and the total annual O&M costs.

Concept 1 Alternative 1C –Discharge Collection Network

Another design to provide a similar level of DO improvement is a discharge collection network in conjunction with either storage, a controlled discharge pond, or a seaward discharge pipeline with timed tidal discharge (Concept 1-1C). A discharge collection network could be installed connecting one of the top five dischargers resulting in a potential reduction of BOD loading of up to 327,000 lbs/day (more than needed for this phase and step) and would be capable of transferring a combined total of 30 million gallons per day to a centralized storage lagoon during the critical season. The discharge collection network could be injected with pure oxygen to maintain aerobic conditions. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of effluent flow and would require approximately 650 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. The discharge collection network and storage pond could potentially eliminate most of the 367,000 lbs/day BOD from Harbor point source dischargers.

4.2.2 Phase I, Step 2, (~725,500 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase 1, Step 2 require an elimination of 367,000 lbs/day BOD from Harbor point source dischargers and 358,000 lbs/day BOD from upstream point source dischargers (equating to 268,500 lbs/day in the Harbor) and an additional 90,000 lbs/day BOD loading removal for non-point source loads.

Concept 1 Alternative 2A – Harbor Injection Technology (73 Speece Cones)

In order to provide 725,500 lbs/day of oxygen to the critical segment of the harbor, 73 Speece cones could provide up to 730,000 lbs/day of oxygen for the critical season. Though the Speece cone injection technology is the most cost effective technology for seasonal application, other scenarios and combinations of alternatives become potentially feasible as more off set of BOD is needed. Costs between 73 Speece cones and costs of other technologies begin to become comparable based on +/- 50 percent accuracy in the estimated preliminary costs. Technologies that offer an annual treatment option include the discharge collection network in conjunction with either storage and controlled discharge pond or a seaward discharge pipeline with timed tidal discharge.

Concept 1 Alternative 2B – Speece Cones with Discharge Network and Storage System

Utilizing a combination of technologies, a discharge network and storage system in conjunction with Speece cones to provide 725,500 lbs/day BOD reduction is another alternative. A discharge collection network could be installed connecting three of the top five dischargers resulting in a potential reduction of BOD loading of up to 327,000 lbs/day and would be capable of transferring a combined total of 60 million gallons per day (MGD) to a centralized storage lagoon during the critical season. The discharge collection network would be injected with approximately 80,000 lbs/day of pure oxygen to maintain aerobic conditions. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of flow and would require approximately 1200 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. The discharge collection network and storage pond could potentially eliminate most of the 367,000 lbs/day BOD from Harbor point source dischargers. Oxygen injection using Speece cones may be appropriate to provide a DO offset for the remaining load from Harbor sources and the 268,500 lbs/day residual BOD from upstream point source dischargers as well as the 90,000 lbs/day BOD from non-point source loads. Utilizing scheduled maintenance shut downs among four of the top five dischargers could reduce the need for Speece cones to operate the entire 90 days. Utilizing a shutdown scenario may allow some number of Speece cones to be turned off thereby reducing the supplemental oxygen requirements and O&M costs. Approximately 40 Speece cones would be needed for this alternative.

4.2.3 Phase I, Step 3 (~68,250 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase 1, Step 3 require an elimination of 68,250 lbs/day of oxygen to the critical segment of the harbor.

Concept 1 Alternative 3A – Harbor Injection Technology – (7 Speece cones)

Seven Speece cones could provide up to 70,000 lbs/day of oxygen for the critical season. This alternative could be used to further increase DO levels in the Harbor at any period in the seasonal cycle. This would account for the elimination of 68,250 lbs/day BOD from point source dischargers.

Concept 1 Alternative 3B – Harbor Injection Technology – (7 Speece cones with scheduled maintenance shut downs)

A similar conceptual design would use the Speece cones in combination with use scheduled maintenance shut downs in four of the top five dischargers. This would reduce the need for Speece cones to operate for the entire 90 days. Utilizing a shutdown scenario should reduce the supplemental oxygen requirements, thereby lessening the number of days that all the Speece cones need to be operated and the total annual O&M costs.

Concept 1 Alternative 3C – Seaward Discharge pipeline with tide-coordinated discharge

Another design capable of providing this required level of DO improvement is a harbor discharge relocation. Relocating the discharge from the largest point source discharger to a seaward location outside the critical area could meet the DO improvements required for this step. A seaward discharge pipeline would have to be constructed that is a little over 10 miles long.

4.2.4 Phase I, Step 4 (~503,500 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase 1, Step 4 require an elimination of of 503,500 lbs/day BOD loading (point source dischargers set a full permitted flow) in the Savannah River Estuary during the critical period.

Concept 1 Alternative 4A – Harbor Injection Technology – (50 Speece cones)

In order to provide 503,500 lbs/day of oxygen to the critical segment of the harbor, fifty Speece cones could provide up to 500,000 lbs/day of oxygen

Concept 1 Alternative 4B – Harbor Injection Technology – (50 Speece cones with scheduled maintenance shut downs)

As with the previous levels of DO improvement, a variation of this design the use of Speece cones in combination with scheduled maintenance shut downs in four of the top five dischargers. This could reduce the need for all the Speece cones to operate for the entire 90 days.

Concept 1 Alternative 4C – (Speece cones with Discharge Network and Storage System)

A further modification of that design would be to use Speece cones, scheduled maintenance shut downs, and a Discharge Collection Network." Seventeen Speece cones could provide up to 170,000 lbs/day of supplemental oxygen for the critical season. The upkeep and capital costs of the oxygen injection technologies, used for 90 days for 20 years, would become comparable to costs for the permanent pipeline and storage option as presented in Phase I, Step 2 (Section 4.2.2). The combined collection network and storage pond would reduce 327,023 lbs/day BOD from Harbor point source dischargers and the Speece Cones would offset up to 170,000 lbs/day. Oxygen supplied to the pipeline will be needed to keep the discharge in an aerobic state. Utilizing scheduled maintenance shut downs between four of the top five dischargers would reduce the O&M costs for the Speece Cones.

4.3 DEVELOPMENTAL CONCEPTUAL DESIGN ALTERNATIVES PHASE II

The second phase of the screening level evaluation considers potential effects of future deepening of the deep-draft harbor on DO levels. The alternatives purposed in Phase II of this report will address an incremental increase of 0.2 mg/L DO concentration in the bottom waters of the Savannah Harbor. These design alternatives may be used in addition to the Phase I design requirements to meet and exceed the recommended DO concentrations in the critical segment of the Savannah River Estuary during the critical summer period.

The Phase II conceptual design requires incremental increases of 0.2 mg/L up to 0.8 mg/L DO in Savannah Harbor. Proposed high purity oxygen technology systems have been designed to increase the DO concentration in the Harbor. Speece Cone technology can be used to inject a superoxygenated side-stream discharge into the bottom levels of the Savannah Harbor.

4.3.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A 0.2 mg/L increase would require ~72,818 lbs/day of oxygen during the critical season. Concept 2 Alternative 1A consists of the use of eight (8) Speece cones to supplement the oxygen at various locations in the harbor. If mounted on barges Concept 2 Alternative 1B, the barges could be moved to supply supplemental oxygen to various areas of the harbor depending on model predictions or real-time monitoring data. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.1 to address loadings of up to 100,000 lbs/day.

4.3.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A 0.4 mg/L increase would require ~145,636 lbs/day of oxygen during the critical season. Concept 2 Alternative 2A consists of the use of fifteen (15) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 2B is very similar and consists of the use of two mobile barges, each with eight (8) Speece cones each may be used to supplement the oxygen. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day.

4.3.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A 0.6 mg/L increase would require ~218,455 lbs/day of oxygen during the critical season. Concept 2 Alternative 3A consists of the use of twenty-two (22) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 3B is very similar and consists of the same total number of Speece cones, but in this concept the cones would be grouped together as 7-8 cones mounted on mobile barges that could be moved where most needed in the harbor. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day.

4.3.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A 0.8 mg/L increase would require ~291,273 lbs/day of oxygen during the critical season. Concept 2 Alternative 4A consists of the use of twenty-nine (29) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 4B is very similar and consists of the same total number of Speece cones, but in this concept the cones would be grouped together as 7-8 cones mounted on mobile barges that could be moved where most needed in the harbor. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day..

5.0 COST-EFFECTIVENESS EVALUATION

The "Opinion of Construction Cost" Tables 5.1 were prepared using MACTEC's best judgment as experienced and qualified professionals generally familiar with the construction industry. However, since MACTEC has no control over the cost of labor, materials, equipment, or services furnished by others, or over the construction contractor's methods of determining prices, or over competitive bidding or market conditions, MACTEC cannot and does not guarantee that proposals, bids, or actual construction cost will not vary from the Opinion of Probable Construction Costs prepared by MACTEC. We have attempted to consider major aspects of the work and site conditions based on information made available to us at this stage of the project. Costs will need to be modified during subsequent stages as the level of project definition increases.

The cost estimating classification for the "Opinion of Construction Costs" is an "Order of Magnitude" or "Study" level of estimate. Construction component items and estimated quantities were based on available information and assumptions as indicated on the backup detailed cost tables (Appendix E). Unit prices were obtained from published cost information, manufacturers, project experience, and other sources as noted on the backup tables. The source and methods of pricing were consistent with the preliminary level of project definition. The expected accuracy is in the range of plus or minus 50 percent using the assumptions presented. Various combinations of discharge networks, storage options (12-hour retention, 30-day retention, and 60-day retention), and seaward pipeline discharge points are included in Appendix E.

5.1 PHASE I

There are several assumption in the development of the "Opinion of Construction Costs" that are applicable to the various design scenarios presented and are provided below.

ASSUMPTIONS:

- 15 percent oversight
- 50 percent capital cost contingency
- 30 percent annual cost contingency
- no land acquisition required for proposed collection network pipelines
- dredge resource areas available without cost for storage pond(s) and pipelines
- 50 foot barge(s) available for use with no storage expenses

- alternatives are required for a maximum of 90 days (summer critical season)
- costs associated with land acquisition and acquisition of right-of-ways and required local, state and federal permitting are not included
- costs associated with construction of electrical service or costs for diesel generators are not included.

5.1.1 Phase I, Step 1 (~290,250 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 290,250 lbs/day during the critical summer months is through the use of oxygen injection technology in the harbor. Three designs are presented. The first (Design 1-1A) is the use of twenty-nine (29) Speece cones for the 90 days of the summer period, injecting a total of 290,000 lbs/day. At $425,000 per cone, the capital cost would be $12,325,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately $35,887,500. During the operating period from mid-July through mid-September DO critical period, O&M and energy costs for each Speece cone are 200 kWh/ton (operation of Speece cone) and 600 kWh/ton (energy cost for pulsed swing adsorption (PSA)) respectively or $24/ton per day O_2 and $72/ton per day O_2.

The Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will occur during periods when critical low flows coincide with high temperatures in the Savannah River. For example, an oxygen injection system on the Tombigbee River in Alabama has had several years where it was not needed (high flows). For other years there was limited use (a few weeks). Periods where continuous use was needed coincided with extreme rare drought conditions (Appendix D).

Assuming 30 percent oversight for O&M, the total annual costs are approximately $1,628,640 for Design 1-1A. The total opinion of probable cost construction and implementation is $37,516,140. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $68,460,300. The cost breakdown for Design 1-1A is presented in Table 5.1, Figure 5.1. Speece cone locations in this configuration are spaced in groups of 2-3 cones along the Harbor.

A variation on that design (Design 1-1B) consists of twenty-nine (29) Speece cones to inject DO into the system, in combination with rolling maintenance shutdowns of four major industrial point source dischargers (IP Augusta, GA Pacific, Weyerhaeuser, and IP Savannah). It typically requires a plant two weeks to perform its annual maintenance shutdown, so the loads could be reduced for four two-week periods each summer. Implementing the rolling maintenance shutdown program from the upstream area and the harbor would limit the oxygen supplementation needed by the Speece cones and potentially reduce O&M costs as shown below.

Table 5.0
Potential Oxygenation Cost Savings during Scheduled Maintenance Shutdown

Facility	Potential Oxygenation Cost Savings per Day ($)
IP Augusta	3360
GA Pacific	960
Weyerhaeuser	480
IP Savannah	6240

Assuming 30 percent oversight for O&M, the total annual costs are approximately $1,427,712 for Design 1-1B. The total opinion of probable cost construction and implementation is $37,315,212. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $64,441,740. The cost breakdown for Design 1-1B is presented in Table 5.1, Figure 5.1.

Another design (Design 1-1C) is the use of a Discharge Collection Network. A discharge collection network could be installed connecting one of the top five dischargers, routing their effluent to a storage pond, and then pumping the effluent for discharge downstream of the critical area to around River Mile 5.5. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of flow and would require approximately 650 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. Roughly 10 miles of pipeline would be required. The total opinion of probable costs for construction and implementation are $71,671,710. Assuming a 30 percent oversight for O&M, the total annual costs are approximately $213,525. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $75,728,685. This alternative assumes a retention time of only 60 days rather than 90 days treatment as compared to the Speece Cone estimates. Storing the effluent for only 30 days reduces the pond size and this alternative approaches similar costs as compared to the Speece cone alternative with the total opinion of probable costs for construction and implementation of $62,709,483. Assuming a 30 percent oversight for O&M, the total annual costs are approximately $213,525. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $66,766,458.

5.1.2 Phase I, Step 2 (~727,500 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 727,500 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-2A) is to provide the total oxygen requirement of 725,000 lbs/day during the critical summer months through the use of oxygen injection technology in the harbor. Seventy-three (73) Speece cones would be used to meet the required 727,500 lbs/day oxygen at a probable cost of $94.4 million for the first year. Assuming 30 percent oversight for O&M, the total annual costs are approximately $4,099,680 for Design 1-2A. The total opinion of probable costs for construction and implementation are $94,437,180. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $172,331,100. The cost breakdown for Design 1-2A is presented in Table 5.2 Alternative 2A.

The second alternative (Design 1-2B) is to provide the total oxygen requirement of 725,000 lbs/day during the critical summer months through the use of oxygen injection technology in the harbor. Seventy-three (73) Speece cones would be used in combination with rolling maintenance shutdowns to meet the required 727,500 lbs/day oxygen at a probable cost of ~$94.2 million for the first year. Assuming 30 percent oversight for O&M, the total annual costs are approximately $3,898,752 for Design 1-2B. The total opinion of probable costs for construction and implementation are $94,236,252. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $168,312,540. The cost breakdown for Design 1-2B is presented in Table 5.2 Alternative 2B.

A variation on that design is Design 1-2C. This is the combination of 40 Speece cones and a Discharge Network collecting Weyerhaeuser, IP Savannah, and President Street effluent (Appendix E, Option I-B) and routing it to a storage pond (approximately 614 acres) for 30-day retention for subsequent discharge. This design has a cost that is comparable to that of the use of the 73 Speece cones described above in the previous paragraph. Figure 5.2 shows possible Speece cone locations as well as the Discharge Collection Network, and Storage pond options depending on retention time required (12-hour, 30-day, or 60-day).

This technology may reduce loading for 30 days during the critical season. Approximately, 400,000 lbs/day is offset with 40 Speece cones and ~327,500 lbs/day is rerouted through the Discharge Network for three dischargers at a cost of ~$118 million for the first year. For this combination, assuming 30 percent oversight for O&M, the total annual costs are approximately $2,258,997 for Design 1-2C. The total opinion of probable cost construction and implementation is $117,695,094. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $160,616,037. The cost breakdown for Design 1-2C is presented in Table 5.2 Alternative C.

If Speece cones were used for either alternative, rolling maintenance shutdowns may be used to limit the number of cones operating during the shutdowns with similar operating cost savings as presented in Table 5.0.

As previously mentioned, the Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will typically occur during periods when critical low flows coincide with high temperatures in the Savannah Harbor.

5.1.3 Phase I, Step 3 (~68,000 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 68,250 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-3A) is through the use of 7 Speece cones to provide the total supplemental oxygen requirement for the system during the critical summer months in the harbor. For 90 days of the summer, the 7 Speece cones would be required to inject approximately 70,000 lbs/day. The capital cost for those cones is $425,000 each, for a total capital cost of $2,975,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $2,275,000. Assuming 15 percent oversight cost and 50 percent contingency cost, total capital costs for 7 Speece cones is approximately $8,662,500. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton, respectively or $24/ton per day O_2 and $72/ton per day O_2.

Assuming 30 percent oversight for O&M, the total annual costs are approximately $393,120 for Design 1-3A. The total opinion of probable cost construction and implementation is $9,055,620. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $16,524,900. Design 1-3A is presented in Figure 5.3.

The second design (Design 1-3B) is the use of Speece cones in combination with rolling maintenance shutdowns of the four largest industrial point source dischargers. This would reduce O&M costs, as estimated in Table 5.3. For 34 days of the summer, the 7 Speece cones would be required to operate at their full capacity and inject approximately 70,000 lbs/day. If Speece cones were used, rolling maintenance shutdowns may be used to reduce O&M costs as estimated in Table 5.0.

Assuming 30 percent oversight for O&M, the total annual costs are approximately $244,608 for Design 1-3B. The total opinion of probable cost construction and implementation is $8,907,108. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $13,554,660. The cost breakdown for Design 1-3B is presented in Table 5.3 and Figure 5.3.

5.1.4 Phase I, Step 4 (~503,500 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 503,500 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-4A) is through the use of Speece cones. Fifty (50) Speece cones would meet the required 503,500 lbs/day oxygen need at a probable capital cost of $61,875,000 (Table 5.4 Alternative A). To estimate annual operating costs, the system is assumed to operate at full capacity for 90 days. The annual costs for this design are estimated to be $2,808,000 while the total probable cost to construct and operate this alternative over a 20-year period is $118,035,000.

A variation is Design 1-4B, the use of Speece cones in combination with rolling maintenance shutdowns. Again, fifty (50) Speece cones would meet the required 503,500 lbs/day oxygen for the majority of the critical summer period. However, the rolling maintenance shutdowns would reduce the number of days the Speece cones would have to operate at full capacity. This would reduce annual operating costs. To estimate annual operating costs, the injection system is assumed to operate at full capacity for 34 days. For the remaining 56 days, injection requirements would be lower because of the reduced point source loading. The annual costs for this design are estimated to be $2,607,072, while the total probable costs to construct and operate this alternative over a 20-year period is $114,016,440.

Another variation is Design 1-4C, the use of twentyfour (24) Speece cones, rolling maintenance shutdowns, and a Discharge Network collecting the IP Savannah (Appendix E, Option II-A-1) effluent and routing to a timed tidal discharge outfall near RM 5.5 is approximately $86..3 million for the first year. This would transport the effluent past the critical DO segment. The annual costs for this design are estimated to be $1,360,437, while the total probable costs to construct and operate this alternative over a 20-year period is $112,218,416. See Table 5.4 Alternative C and Figure 5.4.

Another variation is Design 1-4D, the use of twentyfour (24) Speece cones; rolling maintenance shutdowns; a Discharge Network collecting Weyerhaeuser, IP Savannah, and President Street effluent (Appendix E, Option I-B); and routing to a storage pond for 30-day retention with direct discharge in the Back River. The capital cost for this design is estimated to be ~$97 million for the first year. The $10 million additional capital cost over the previous design is the result of the costs to construct the detention pond for 30-day storage of effluent from the three industrial facilities. The multiple features in this design would reduce loading for 30 days during the critical season. The annual costs for this design are estimated to be $1,360,437, while the total probable costs to construct and operate this alternative over a 20-year period is $122,844,837. See Table 5.4 Alternative D and Figure 5.4.

As previously mentioned, the Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will occur during periods when critical low flows coincide with high temperatures in the Savannah Harbor.

5.2 PHASE II

ASSUMPTIONS:

- 15 percent oversight
- 50 percent capital cost contingency
- 30 percent annual cost contingency
- 50 foot barge(s) available for use with no storage expenses
- alternatives are required for 90 days (summer season)
- costs associated with land acquisition and acquisition of right-of-ways and required local, state and federal permitting are not estimated
- costs associated with construction of electrical service or costs for diesel generators are not estimated

5.2.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A DO incremental increase of 0.2 mg/L equates to approximately 72,818 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 72,818 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 8 Speece cones would be required to inject 80,000 lbs/day at $425,000 per cone for a capital cost of $3,400,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $2,600,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 8 Speece cones is approximately $9,900,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2.

Assuming a 90 day operation and 30 percent oversight and reporting for O&M, the total annual costs are approximately $449,280 for Phase II, Step 1. The total opinion of probable cost construction and implementation is $10,349,280. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $18,885,600. The cost breakdown for Phase II, Step 1 is presented in Table 5.5 and Figure 5.5.

5.2.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A DO incremental increase of 0.4 mg/L equates to approximately 145,636 lbs/day. As stated previously, one of the more cost-effective methods for meeting the total oxygen requirement of 145,636 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 15 Speece cones would be required to inject 150,000 lbs/day at $425,000 per cone for a capital cost of $6,375,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $4,875,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 15 Speece cones is approximately $18,562,500. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $842,400 for Phase II, Step 2. The total opinion of probable cost construction and implementation is

$19,404,900. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $35,410,500. The cost breakdown for Phase II, Step 2 is presented in Table 5.6 and Figure 5.6.

5.2.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A DO incremental increase of 0.6 mg/L equates to approximately 218,455 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 218,455 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 22 Speece cones would be required to inject 220,000 lbs/day at $425,000 per cone for a capital cost of $9,350,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $7,150,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 22 Speece cones is approximately $27,225,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2. Assuming a summer month treatment time period of 90 days, 22 Speece cones would run for 56 days providing approximately 220,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $1,235,520 for Phase II Step 3. The total opinion of probable cost construction and implementation is $28,460,520. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $51,935,400. The cost breakdown for Phase II, Step 3 is presented in Table 5.7 and Figure 5.7.

5.2.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A DO incremental increase of 0.8 mg/L equates to approximately 291,273 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 291,273 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 29 Speece cones would be required to inject 290,000 lbs/day at $425,000 per cone for a capital cost of $12,325,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately $35,887,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O_2 and \$72/ton per day O_2. Assuming a summer operating period of 90 days, 29 Speece cones would run for 90 days providing approximately 290,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$1,628,640 for Phase II Step 4. The total opinion of probable cost construction and implementation is \$37,516,140. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$68,460,300. The cost breakdown for Phase II, Step 4 is presented in Table 5.8 and Figure 5.8.

6.0 FINAL SELECTION OF CONCEPTUAL DESIGN ALTERNATIVES

The conceptual design alternatives are a collection of selected DO improvement technologies, which together will achieve the current and needed DO concentrations in the Savannah Harbor. Technologies were evaluated based on requirements to meet current and proposed TMDL DO requirements in the critical segment of the Savannah River Estuary. These technologies were evaluated on several characteristics, including cost, energy consumption, and oxygen transfer efficiency. Those technologies that scored best in the second level screening evaluation have been incorporated into the conceptual design phase.

6.1 PHASE I

The following Phase I final selections are conceptual designs based on the cost effectiveness of oxygen injection technologies for achieving required TMDL DO concentrations to counteract discharges from Upstream and Harbor BOD point sources and BOD from non-point sources.

6.1.1 Phase I, Step 1(~200,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 290,250 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. During the critical season, 29 Speece cones would be required to inject 290,000 lbs/day at $425,000 per cone for a capital cost of $12,325,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $9,425,000. The rolling maintenance shutdown program could be applied on a basin wide scale and potentially result in long-term cost savings as shown in Table 5.0.

The total opinion of probable cost construction and implementation is $37,713,324. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $72,403,980. The cost breakdown for Phase 1, Step 1 was presented in Table 5.1 and Figure 6.1. Speece cones would be grouped in 3 to 4 cones per fixed location or with up to 8 cones per barge.

6.1.2 Phase I, Step 2 (~725,500 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 725,500 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. During the critical season, 73 Speece cones would be required to inject 725,500 lbs/day at $425,000 per cone for a capital cost of $31,025,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $23,725,000. The O&M and energy costs are directly proportional to the days the oxygen injection is needed. Further study using the Harbor Model may help to refine where, when, and how much oxygen is needed

The total opinion of probable cost construction and implementation is $95,451,921. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $192,625,920. The cost breakdown for Phase 1, Step 2 was presented in Table 5.2 Alternative A and Figure 6.2.

6.1.3 Phase I, Step 3 (~68,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 68,250 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. For 56 days of the summer months 7 Speece cones may be used to inject 70,000 lbs/day at $425,000 per cone a capital cost of $2,975,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $2,275,000. Rolling maintenance shutdowns may be used to reduce the total O&M costs.

The total opinion of probable cost construction and implementation is $9,216,729. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $19,747,080. The cost breakdown for Phase 1, Step 3 was presented in Table 5.3 and Figure 6.3.

6.1.4 Phase I, Step 4 (~504,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 503,500 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. Fifty (50) Speece cones may be used to meet the required 503,500 lbs/day oxygen. During the critical season, 50 Speece cones would be required to inject 503,500 lbs/day at $425,000 per cone for a capital cost of $21,250,000.

Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $16,250,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 73 Speece cones is approximately $61,875,000. The O&M and energy costs are directly proportional to the days the oxygen injection is needed. Further study using the Savannah Harbor model may help to refine where, when, and how much oxygen is needed

Application of the Rolling Maintenance BMP may result in an O&M savings. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately $132,014,940. The cost breakdown for Phase 1, Step 4 is presented in Table 5.4 Alternative A and Figure 6.4

6.2 PHASE II

6.2.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A DO incremental increase of 0.2 mg/L equates to approximately 72,818 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 72,818 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 8 Speece cones would be required to inject 80,000 lbs/day at $425,000 per cone for a capital cost of $3,400,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $2,600,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 8 Speece cones is approximately $9,900,000. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2. Assuming a summer month treatment time period of 90 days, 8 Speece cones would run for 90 days providing approximately 80,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $449,280 for Phase II Step 1. The total opinion of probable cost construction and implementation is $10,349,280. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $18,885,600. The cost breakdown for Phase II, Step 1 is presented in Table 5.5 and Figure 6.5.

6.2.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A DO incremental increase of 0.4 mg/L equates to approximately 145,636 lbs/day. As stated previously, one of the more cost-effective methods for meeting the total oxygen requirement of 145,636 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 15 Speece cones would be required to inject 150,000 lbs/day at $425,000 per cone for a capital cost of $6,375,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $4,875,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 15 Speece cones is approximately $18,562,500. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2. Assuming a summer month treatment time period of 90 days, 15 Speece cones would run for 90 days providing approximately 150,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $842,400 for Phase II Step 2. The total opinion of probable cost construction and implementation is $19,404,900. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $35,410,500. The cost breakdown for Phase II, Step 2 is presented in Table 5.6 and Figure 6.6

6.2.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A DO incremental increase of 0.6 mg/L equates to approximately 218,455 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 218,455 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 22 Speece cones would be required to inject 220,000 lbs/day at $425,000 per cone for a capital cost of $9,350,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $7,150,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 22 Speece cones is approximately $27,225,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2. Assuming a summer month treatment time period of 90 days, 22 Speece cones would run for 90 days providing approximately 220,000 lbs/day of oxygen added.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $1,235,520 for Phase II Step 3. The total opinion of probable cost construction and implementation is $28,460,520. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $51,935,400. The cost breakdown for Phase II, Step 3 is presented in Table 5.7 and Figure 6.7.

6.2.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A DO incremental increase of 0.8 mg/L equates to approximately 291,273 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 291,273 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 29 Speece cones would be required to inject 290,000 lbs/day at $425,000 per cone for a capital cost of $12,325,000. Each Speece cone would require an oxygen plant at $325,000 per cone for a capital cost of $9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately $35,887,000. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or $24/ton per day O_2 and $72/ton per day O_2. Assuming a summer month treatment time period of 90 days, 29 Speece cones would run for 90 days providing approximately 290,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately $1,628,640 for Phase II Step 4. The total opinion of probable cost construction and implementation is $37,516,140. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately $68,460,300. The cost breakdown for Phase II, Step 4 is presented in Table 5.8 and Figure 6.8.

7.0 RECOMMENDED DESIGN ALTERNATIVES

Conclusions reached during this screening of technologies applicable to the Savannah Harbor for improving DO concentrations as well as providing for future expansion of the harbor are as follows.

Tertiary treatment costs for each discharger may need to be researched because treatment options such as membrane filtration requires specific effluent characterization for an effective design. Some BOD characterization has been performed thus far in the Savannah Harbor Wastewater Characterization Study which analyzed samples from August 1999 for select dischargers. In any event, the complete elimination of all point source discharges in Augusta and Savannah would only reduce the critical DO deficit by 0.55 ug/L.

Capital costs for technologies to reroute or store BOD loadings from the top five dischargers exceed the capital costs for direct oxygen injection to supplement reaeration in the harbor. Therefore, recommendations for each phase involve oxygen injection technology. Rolling maintenance shutdowns may have an impact on reducing the BOD loadings but are only effective for a period of an individual shutdown. This managerial implementation is the most cost effective technology besides direct oxygen injection. Combined together these two technologies may satisfy any phase and step considered in this study.

In summary, a 12 feet diameter Speece Cone 15 feet tall with the discharge placed 50 feet below the water surface may provide the following results:

- 60 mg/L DO Concentration in the discharge
- 34 cfs cone flow
- 10,000 to 12,000 lbs O_2/day injected
- 45 horsepower (hp) pump utilized
- >90% oxygen absorption
- <200 kW hr/ton DO consumed depending on depth
- Cost of units - $85,000/ton DO/day ($500,000 per 12 feet diameter unit with pump)

The results of this system’s high efficiency and low unit energy consumption occur in part because turbulence is confined to the inside of the cone with no bottom scouring. These results are also achieved without interfering with ship channel traffic. Other advantages of the Speece cone technology are the ability to become a self contained mobile or stationary oxygenation barge.

Oxygen injection technologies may also be used to superoxygenate municipal and industrial discharges. Using this technology, sufficient DO may be added to a discharge to provide sufficient oxygen to offset a portion of the BOD contribution thereby limiting the impact to the harbor DO sources. (Appendix D, Section 6).

The final selection conceptual design figures here in represent a conceptual distribution of locations for oxygen injection technologies. Further study utilizing the Harbor Model is recommended to optimize the locations and operating parameters for oxygen injection. One Speece cone may provide approximately 10,000-12,500 lbs/day oxygen. Combining more Speece cones in one area (up to four) may provide 40,000-50,000 lbs/day oxygen. Using a mobile injection station such as a barge with up to 8 Speece cones providing approximately 80,000-96,000 lbs/day oxygen allows flexibility by providing oxygen to an area based on real-time DO monitoring. Another scenario that may optimize the use of Speece cones is injecting oxygen into the Harbor only during incoming tides.

It is also recommended to study the feasibility of using direct power for energy needs versus diesel generators. Availability of electrical service may also help determine the locations for harbor injection technology. A key consideration in supplementing oxygen to the harbor is the availability of land at key location defined by DO deficient conditions within the harbor, upon which the oxygenation system may be placed. The availability of electricity is another consideration. Generally it is quite expensive to bring in electrical service. These two factors; the availability of real estate in the vicinity of the needed oxygen supplementation and the availability of electricity will be significant initial cost factors. A self contained unit, with its own PSA oxygen generation source, may be driven by an internal combustion engine which does not require an electrical power source. Furthermore, the pumps required to move water through the oxygen transfer vessel may be powered by combustion engine driver pumps. Thus, the barge units may only need to be supplied with diesel fuel. Propane may also be substituted for diesel fuel.

For future expansion of the harbor, the Speece cone technology also satisfies the supplemental oxygen need at varying depths. Speece cones have been implemented in lakes and river bodies at depths over 50 feet (Speece, Appendix D).

For more detailed analysis of the different oxygenation technologies considered in this screening please refer to Appendix D.

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TABLES

Table 1.1

Phase I and Phase II Requirements[1]
Identification and Screening Level Evaluation
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

		TMDL DO Standard Case	DO Standard (mg/L)	BOD_U Loading Case	BOD Load (lbs/day)	Allowable BOD Discharge (lbs/day)	Required PS BOD Load Reduction (lbs/day)	Oxygen Requirement PS BOD[a] (lbs/day)	Required NPS BOD Load Reduction (lbs/day)	Total Oxygen Requirement (lbs/day)
Phase I										
Step 1	Harbor[b]	Present[c]	3	Current (1999)[d]	99,000	NA	200,250	200,250	90,000	290,250
	Upstream[e]				101,250					
Step 2	Harbor[b]	Present[c]	3	Full Permitted	367,000	NA	635,500	635,500	90,000	725,500
	Upstream[e]				268,500					
Step 3	Harbor[b]	Proposed[f]	3.55/3.0/2.3	Current (1999)[d]	NA	132,000	68,250	68,250	NA	68,250
	Upstream[e]									
Step 4	Harbor[b]	Proposed[f]	3.55/3.0/2.3	Full Permitted	NA	132,000	503,500	503,500	NA	503,500
	Upstream[e]									

		TMDL DO Standard Case	DO Standard (mg/L)	DO Level Increase[g] (mg/L)	Total Oxygen Requirement[(i)] (lbs/day)
Phase II					
Step 1	Harbor[b]	Phase 1[h]	3.55/3.0/2.3	0.2	72,818
Step 2	Harbor[b]	Phase 1[h]	3.55/3.0/2.3	0.4	145,636
Step 3	Harbor[b]	Phase 1[h]	3.55/3.0/2.3	0.6	218,455
Step 4	Harbor[b]	Phase 1[h]	3.55/3.0/2.3	0.8	291,273

Notes:

▭ Selected design criteria.
TMDL - Total Maximum Daily Load
DO - Dissolved Oxygen
mg/L - milligrams per liter
BOD_u - Biochemical Oxygen Demand (Ultimate)
BOD - Biochemical Oxygen Demand
lbs/day - pounds per day
PS - Point Source
NPS - Non-Point Source
NA - Not Applicable

Prepared By: ____________
Checked By: ____________

(1) Loads and standards are based on information provided in the August 2004 Draft TMDL for Dissolved Oxygen (USEPA, 2004).
(a) O_2 requirements based on a 1:1 ratio of 1 lb BOD_u discharged approximately equal to 1 lb O_2 required.
(b) Refers to the Harbor segment of Savannah River.
(c) The current standard of 3.0 mg/L has been disapproved by USEPA but remains until a new standard is promulgated.
(d) Current (1999) BOD loadings as measured in summer of 1999 and reported in the August 2004 Draft TMDL.
(e) Refers to the upstream channel of Savannah River. BOD loading assumes 75% of the total discharge BOD loads impact critical segment.
(f) The proposed standard is based on the information provided in the Draft Savannah TMDL (USEPA, 2004) and must be promulgated prior to finalizing a TMDL.
(g) Dissolved oxygen levels in the bottom of the Harbor segment.
(h) Assumes that the Phase I TMDL oxygen requirements have been met.
(i) Oxygen requirements are based on an assumption that 0.55 mg/L DO deficit is caused by 200,250 lbs of BOD as reported in the Draft TMDL. Therefore, an 1 mg/L DO increment equates to 364,091 lbs O_2 needed.

USEPA, 2004. Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia. U.S. Environmental Protection Agency. August 2004.

Table 2.1

Top Five Point Source Dischargers[1]
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

		Full Permit Limits					Oxygen Demanding Load Based on Current Permit Limits				
Facility Name	**NPDES ID**	**Flow[a] (MGD)**	**TMDL Flow[b] (MGD)**	**BOD_5[c] (lbs/day)**	**NH_3 (mg/L)**	**NH_3 (lbs/day)**	**F-Ratio**	**$CBOD_U$ (lbs/day)**	**$NBOD_U$ (lbs/day)**	**$TBOD_U$ (lbs/day)**	**Permit Limit $TBOD_U$ (lbs/day)**
International Paper (Savannah)	GA0001988	38.00	1.30	25,000	NA	NA	10.7	267,500	NA	267,500	267,500
International Paper (Augusta)	GA0002801	40.00	NA	30,000	NA	NA	6	180,000	NA	180,000	135000[d]
Fort James Paper (GA Pacific)	GA0046973	33.00	0.80	10,850	NA	NA	5	54,250	NA	54,250	54,250
Weyerhaeuser-Port Wentworth	GA0002798	22.00	0.10	6,700	NA	NA	4.5	30,150	NA	30,150	30,150
President Street	GA0025348	27.00	27.00	4,166	12.9	2,905	3.9	16,247	13,276	29,523	29,523

Facility Name	**NPDES ID**	**Flow[e] (MGD)**
International Paper (Augusta)	GA0002801	30.00
International Paper (Savannah)	GA0001988	28.00
Fort James Paper (GA Pacific)	GA0046973	19.00
Weyerhaeuser-Port Wentworth	GA0002798	11.75
President Street	GA0025348	25.83

Prepared By: ____________
Checked By: ____________

Notes:
NPDES - National Pollutant Discharge Elimination System
MGD - million gallons per day
TMDL - Total Maximum Daily Load
BOD_5 - Biochemical Oxygen Demand
lbs/day - pounds per day
mg/L - milligrams per liter
$CBOD_U$ - Carbonaceous Ultimate Biochemical Oxygen Demand
$NBOD_U$ - Nitrogenous Ultimate Biochemical Oxygen Demand
$TBOD_U$ - Total Ultimate Biochemical Oxygen Demand
NA - Not Applicable
RM - River Mile
m^3/ton - cubic meters per ton

(1) Based on current permit limits as reported in USEPA EnviroFacts Database. For upstream dischargers 75% of the permitted load was used to complete the ranking.
(a) As reported in the Draft TMDL (USEPA, 2004). Values for IP-Savannah, GAPAC, Weyerhaeuser are assumed to be erroneous. Permit limits and discharge monitoring report (DMR) data were used to provide flow information for design.
(b) Indicates the following flow assumptions:
IP Augusta maximum capacity taken from USEPA EnviroFacts Database, 2005 (80.05 m^3/ton flow to surface water multiplied by 1900 tons/day consumer packaging)
GA Pacific & IP Savannah taken from yearly maximum actual flow as reported in the facilities 1999 DMR.
Weyerhaeuser taken from yearly maximum actual flow as reported in the facilities 2000 DMR.
President Street NPDES permitted flow criteria (taken from EPA Envirofacts website)
(c) USEPA, 2004. Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia. U.S. Environmental Protection Agency. August 2004.
(d) Assumes 75% $TBOD_U$ reaches the upper estuary area.
(e) Indicates the following flow assumptions:
IP Augusta 1997-2001 average flow and $CBOD_U$ was taken from a graph from the Middle Savannah River Model from the Augusta Lock and Dam (RM 199.1) to Clyo, Georgia (RM 59) (USEPA, 2003). USEPA, 2004. PowerPoint Presentation provided by Steve Whitlock, USEPA R4.
GA Pacific & IP Savannah taken from yearly average actual flow and BOD as reported in the facilities 1999 DMR.
Weyerhaeuser taken from yearly average actual flow as reported in the facilities 2000 DMR.
President Street yearly maximum flow as reported in the facilities 1999 DMR.

Table 3.1

Level I Assessment of Dissolved Oxygen Technology
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

DISSOLVED OXYGEN IMPROVEMENT TECHNOLOGY Harbor and Channel	Potentially Effective and Compatible with Site-specific Conditions - Additional Evaluation Necessary		Comment
	Harbor System	Point Source Discharger	
ADVANCED TREATMENT			
Membrane Filtration	NO	YES	Membrane filtration is effective as a tertiary treatment process by removing sedimentary particles and particulate organics from the wastewater. However, it is not effective in reducing BOD loadings from dissolved organics. Design criteria requires detailed wastewater characterization limiting cost analysis. To achieve effective BOD removal, biological waste water treatment occurs at a high mixed liquor suspended solids concentration and a shorter mean cell residence time. The high concentration of fast growing bacteria consume readily available organic matter and are then filtered out by the membrane filters. Use of this type of wastewater treatment processes are generally limited in pulp and paper mil effluents since the much of the organic matter present (tannins, lignums) is difficult to degrade and requires long residence time as well, aeration, and large storage volumes
AERATION ALTERNATIVES			
Cascade Aerator	NO	NO	Cascade aerators increase surface area of the water in contact with the atmosphere by routing water over a series of steps. This turbulence increases the surface area and aeration is through diffusion at the air/water interface. This type of aeration could not be located in navigable waterways or be applicable for the volumes and configuration of Savannah Harbor.
CleanFlo - Natural Inversion	NO	NO	The CleanFlo Natural Inversion process creates a vertical mixing zone by causing natural inversion where high DO surface waters mix with low DO deep waters. This technology is very useful for static water bodies such as storage lagoons or ponds but is not applicable in rivers or other fast flowing water bodies.
Coarse Bubble Diffuser	NO	NO	Coarse bubble diffusers release air bubbles at the bottom of a water column. Oxygen transfer is achieved by diffusion at the air/water interface as the bubble rise through the water column. Oxygen transfer is limited by the bubble size (bubble surface area), atmospheric oxygen content, and water depth. Larger air bubbles have less total surface area and, therefore oxygen transfer efficiencies are relatively low compared to other aeration technologies. Diffusers would need to be mounted in the bottom of the navigation channel making them unsuitable for application in the harbor.
Fine Bubble Diffuser	NO	NO	Fine bubble diffusers have higher oxygen aeration efficiencies (than Coarse Bubble) due to the smaller bubble size creating more surface area. These diffusers require a deep water column to maximize oxygen absorption. The diffusers would need to be mounted in the bottom of the navigation channel making them unsuitable for application in the harbor.
Mobley - Soaker Hose	NO	NO	Soaker hose technology is similar to coarse and fine bubble diffusers. Based on the pore size of the hose and the pressure on the air/oxygen delivery line, oxygen transfer rates are adjustable. The system is susceptible to pore clogs and requires periodic, regular hose replacement. Deep water columns (greater than 100 feet) are needed to maximize oxygen transfer. The hose would need to be mounted in the bottom of the navigation channel making them unsuitable for application in the harbor.
Mechanical Surface Aerators	NO	NO	Generally, mechanical surface aerators splash water to increase surface area to increase diffusion. Oxygen transfer is limited by the atmospheric oxygen content, not effective for deep water, and are capable of aerating only a small total area per unit. Surface aerators would need to be placed in and along the navigation channel making them unsuitable for use in the harbor.

Table 3.1

Level I Assessment of Dissolved Oxygen Technology
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

DISSOLVED OXYGEN IMPROVEMENT TECHNOLOGY Harbor and Channel	Potentially Effective and Compatible with Site-specific Conditions - Additional Evaluation Necessary		Comment
	Harbor System	Point Source Discharger	
MANAGEMENT ALTERNATIVES			
Rolling Maintenance Shutdown during Critical Season	NO	YES	Generally, many industries require a brief period of time to complete in depth maintenance activities at the facility that may last from several days to a few weeks. During this time, processes may be taken off-line reducing BOD loading to the wastewater treatment system and the ultimate BOD discharged in the effluent. As possible, industries along the middle and lower reaches of the Savannah River/Harbor may be able to schedule these maintenance shutdowns to coincide with the critical period in the harbor. The industries discharging to the river/harbor may be able to coordinate shutdowns maximizing the length of time and the load reductions to the system during drought conditions.
Increased Releases from Upstream Reservoirs	NO	NO	Increased releases from upstream reservoirs may be employed during low flow to increase water flow to the river channel from upstream reservoirs during critical period to reduce the impacts from BOD sources on critical segment.
OXYGEN INJECTION ALTERNATIVES			
ECO2 - SuperOxygenation (Speece Cone)	YES	YES	The superoxygenation Speece Cone draws water from the water body in a sidestream location. As water flows downward in the cone, pure oxygen in injected into the cone the resulting hydraulic turbulence creates a bubble swarm which greatly enhances oxygen transfer efficiency. The small bubbles have high surface area and long contact times that create a high oxygen adsorption efficiency (95%). The cones can provide oxygenated water delivered to any depth with a variety of applications and requires low system maintenance.
Fine Bubble Diffuser using High Purity Oxygen	YES	NO	Fine bubble diffusers using high purity oxygen have high oxygen transfer efficiencies and ability to satisfy high oxygen demands. These systems require a deep water column to maximize oxygen adsorption and diffusers are mounted to the bottom of the water column making the unsuitable for application in the harbor.
Hydroflo - Aero Transfer System	YES	NO	Hydroflo's technology provides high oxygen transfer rates with high dissolved oxygen levels sidestream concentrations. These systems can be mounted on the channel edge with the oxygenated water injected into harbor.
Praxair - In-Situ Oxygenation (ISO)	YES	NO	Praxair ISO technology provides efficient oxygen transfer and have relatively low energy consumption. These systems produce lower sidestream DO levels (than Speece Cones) and require close spacing due to a small coverage area. They can be mounted along the channel edge with the discharge directed perpendicular to channel.
sidestream Pressurized Oxygenation (PSSO)	YES	NO	sidestream pressurized oxygenation has efficient oxygen transfer rates with high dissolved oxygen levels. This system requires a large land area due to length of pipe. The system is suitable for discharging superoxygenated water into Savannah Harbor.
U-Tube	YES	YES	U-Tube technology combines high oxygen transfer efficiency and high dissolved oxygen levels with low energy consumption. These system require deep wells of 150 to 200 feet deep.
Venturi	NO	YES	Venturi nozzles provide reliable performance, efficient oxygen transfer, and require small land area. They are low maintenance and generally, applicable for pipeline injection.

Table 3.1

Level I Assessment of Dissolved Oxygen Technology
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

DISSOLVED OXYGEN IMPROVEMENT TECHNOLOGY Harbor and Channel	Potentially Effective and Compatible with Site-specific Conditions - Additional Evaluation Necessary		Comment
	Harbor System	Point Source Discharger	
PHYSICAL MODIFICATIONS			
Aquatic Treatment Systems	NO	YES	Aquatic treatment systems are generally able to meet secondary treatment goals. These systems can be designed with various detention times, and can produce BOD effluent characteristics as low as <10 mg/L. May be used in conjunction with storage systems.
Constructed Wetland System	NO	YES	Constructed wetland systems are generally able to meet secondary to tertiary wastewater treatment goals and BOD effluent characteristics are as low as 5 mg/L.
Discharge Collection Network with Supplemental Oxygen Injection	NO	YES	The discharge collection network could collect and route effluent from point source dischargers to a central storage system. Introduction of oxygen into pipeline would maintain or increase DO levels and may allow additional treatment of BOD during travel time prior to discharge. A discharge collection system would have a relatively high capital cost and would take require lengthy construction time.
Inflatable Weir	YES	NO	Inflatable weirs are intermittent control structures that can be mounted to the bottom of the river. When needed air bladders are expanded and the weir rises into position. The inflatable weir could be used to limit the saltwater wedge from intruding upstream during the tidal cycle and to increase mixing in the vertical direction by forcing incoming water to pass over the weir adding destratification of the harbor system and , thereby, potentially increase DO levels in the lower portion of the water column.
Land Application Systems (LAS)/Urban Water Reuse (UWR)	NO	YES	Land application systems or urban water reuse programs take treated effluent and apply it directly to land surfaces. Effluent quality for LAS generally meet secondary standards and spray effluents into restricted access areas. UWR effluents are highly polished with BODs generally as low as <2 mg/L. UWR effluents are used for irrigation in areas with public access. UWR demands (and LAS application rates) are highest when the need for BOD reductions would be greatest resulting in a complimentary situation.
Mechanical Pumps	YES	NO	Mechanical pumps could be used to increase mixing of low DO waters on the bottom with higher DO surface waters adding destratification.
Seaward Pipeline with Timed Tidal Discharge	NO	YES	The seaward pipeline builds upon the discharge collection network system by routing the treated effluent from point source dischargers further seaward, well past the critical DO segment. This system requires construction of a pipeline from the centralized storage pond to the discharge point. Additionally, discharges from the system could be timed to discharge with the out going tidal flow.
Storage and Controlled Discharge System	NO	YES	The storage and controlled discharge system builds upon the discharge collection network by routing of point source effluent to storage system where the treated effluents could be held for discharge. Discharge from the storage system would be done continuously during periods of higher flows and/or cooler temperatures. During drought conditions, discharge could be held until flows are higher.
Tidal Gate	YES	NO	The tidal gate control system could be used to limit the tidal flow into the harbor during tidal cycles reducing stratification. This system could be further studied as a method for controlling upstream salt water intrusion from further deepening.

Notes:
BOD - Biochemical Oxygen Demand
DO - Dissolved Oxygen
mg/L - milligram per liter
LAS - Land Application Systems
UWR - Urban Water Reuse

Prepared By: ____________
Checked By: ____________

Table 3.2

Level II Assessment of Limitations - Harbor Improvements
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

	Evaluation Criteria							
Alternatives	**Performance/Effectiveness**	**Reliability**	**O_2 Adsorption Efficiency (%)**	**Unit Energy per lbs. O_2 (lbs O2/hp-hr)**	**Sidestream O_2 Conc. (mg/L)**	**Capital Cost**	**Placement**	**Score**
OXYGEN INJECTION								
ECO$_2$® - SuperOxygenation (Speece Cone)	Effective in O_2 transfer	Low Maintenance	> 90	8	60 - 200	Medium	River Bank, Barge	
	3	3	3	2	3	2		16
Fine Bubble Diffuser using High Purity Oxygen	Requires deep water column. Bottom mounted not suitable for harbor expansion. Suitable for storage pond applications	Moderate Maintenance	60 (Assuming 40 ft water column)	NA	NA	Medium	River Bottom	
	1	2	1	0	0	2		6
Hydroflo - Aero Transfer System	Good Technical Specifications - limited by volume of DO required	Low Maintenance	60	5	?	High	River Bank	
	2	3	1	1	2	1		10
Praxair - In-Situ Oxygenation	Floating aerators - Not practical for river channel. Suitable for storage pond.	Low Maintenance	> 90	13	10	Medium	River Channel/Pond	
	1	3	3	3	1	2		13
Sidestream Pressurized Oxygenation	Effective in O_2 transfer	Low Maintenance	70 - 80	2	100	Medium	River Bank	
	3	3	2	1	3	2		14
U-Tube	Effective in O_2 transfer	Low Maintenance	75 - 90	16	50 - 100	High	River Bank	
	3	3	2	3	3	1		15
Venturi Nozzle	Good Technical Specifications - limited by quantity of DO required	Low Maintenance	60	5	10	Medium	River Bank	
	2	3	1	1	1	2		10
PHYSICAL MODIFICATIONS								
Inflatable Weir	Bottom mount not practical for harbor expansion. Measure for controlling salt water intrusion & increasing mixing	Low Maintenance	NA	NA	NA	Medium	River Channel	
	1	3	0	0	0	2		6
Mechanical Pumps	High energy mixing, low dissolved oxygen improvements	Low Maintenance	NA	NA	NA	Medium	River Channel	
	1	3	0	0	0	2		6
Tidal Gate	Measure for controlling salt water intrusion, not effective for increasing DO concentration.	Low Maintenance	NA	NA	NA	Medium	Side Channels	
	1	3	0	0	0	2		6

Notes:
NA - Data is Not Available or Not Applicable
lbs O_2/hp-hr - pounds of oxygen per horsepower hour
lbs/day - pounds per day
DO - Dissolved Oxygen
ECO2 - Eco Oxygen Technologies, LLC

Physical Ranking **xygen Injection Ranking Summary:** Prepared By: ____________
Inflatable Weir 6 - SuperOxygenation (Speece Cone) 16 Checked By: ____________
Mechanical Pumps 6 U-Tube 15
Tidal Gate 6 destream Pressurized Oxygenation 14

Ranking Scale: Harbor Improvements Oxygen Injection Performance/Effectiveness
Good / High = 3 — 3 – Low Maintenance; High Oxygen Transfer Efficiency (>90%); High Production of oxygen per horse power hour (>10 lbs O2/hp-hr); High Sidestream O2 concentration (>50 mg/L); and Low Capital Cost.
Fair / Moderate = 2 — 2 – Moderate Maintenance; Medium Oxygen Transfer Efficiency (60-90%); Medium Production of oxygen per horse power hour (6-9 lbs O2/hp-hr); Medium Sidestream O2 concentration (10-50 mg/L); and Medium Capital Cost.
Poor / Low = 1 — 1 – High Maintenance; Low Oxygen Transfer Efficiency (<60%); Low Production of oxygen per horse power hour (<6 lbs O2/hp-hr); Low Sidestream O2 concentration (<10 mg/L); and High Capital Cost

Harbor Improvements Physical Performance/Effectiveness
Good / High = 3 — 3 – Most applicable to DO improvement goals; Low Maintenance; and Low Capital Cost.

Table 3.3

Level II Assessment of Limitations - Point Sources
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

	Evaluation Criteria						Score
Alternatives	**Performance/Effectiveness**	**Reliability**	**BOD Reduction (lbs/day)**	**Capital Cost**	**Constraints**	**Seasonal Application**	
ADVANCED TREATMENT			**(lbs/day)**				
Membrane Filtration	Tertiary treatment system	Medium Maintenance	Particulate organics (does not remove dissolved organics)	High	Wastewater treatment system reconfiguration and site land availability	Annual	
	1	2	1	1	2	3	10
MANAGEMENT							
Rolling Maintenance Shutdown during Critical Months	Maintenance shutdown at a facility producing 50% reduction in that dischargers effluent flow	Low Maintenance	0 - 134,000	Low	No area required. Requires coordination and agreement among dischargers along the river/harbor. Maintenance may not be required by a facility during the applicable season. Contingencies for emergency shutdowns and completing other maintenance activities during this period (thereby eliminating a need for another shutdown) requires consideration. Actual BOD load during shutdowns in not known and would require further investigation	Summer	
	3	3	2	3	3	2	16
PHYSICAL MODIFICATIONS							
Urban Water Reuse Plan	Reuse of treated wastewater for irrigation during summer period	Medium Maintenance	0 - 30,000	High	Construction of a distribution network and an increase in consumer demand	Summer	
	2	2	1	1	2	2	10
Seaward Pipeline with Timed Tidal Discharge	Reduces BOD loadings by collecting discharge and piping seaward to be discharged with tidal cycle	Medium Maintenance	0 -500,000	High	Available land and right of ways for pipeline construction	Annual	
	3	3	3	3	3	3	18
Discharge Collection Network with Supplemental Oxygen Injection (Venturi Nozzle)	Reduces BOD loadings by collecting discharge.	Medium Maintenance	~80,000	Medium	Available land area and need for right of ways for pipeline	Annual	
	3	3	1	2	2	3	14
Constructed Wetlands	Treatment system with increased residence time for polishing of BOD in treated wastewater	Medium Maintenance	0 - 500,000	High	Large land requirement also availability of suitable land and need for right of ways for pipeline construction	Annual	
	2	2	3	3	1	3	14
Storage and Controlled Discharge Pond	Storage of discharge reduces BOD loadings in the Harbor segment during critical period	Low Maintenance	0 - 500,000	Medium	Large land requirement also availability of suitable land and need for right of ways for pipeline construction	Annual	
	3	3	3	2	3	3	17

Notes:
BOD - Biochemical Oxygen Demand

Ranking Summary:
Seaward pipeline with timed tidal discharge 18
Storage and controlled discharge pond 17
Rolling maintenance shutdown during critical months 16

Prepared By: ____________
Checked By: ____________

Ranking Scale:
Good / High = 3
Fair / Moderate = 2
Poor / Low = 1

Point Source Performance/Effectiveness
3 – Most benefit to DO improvement goals; low maintenance; high BOD reduction (250,000 to 500,000 lbs/day); low capital costs; no area constraints; and most effective during summer season..
2 – Moderate benefit to DO improvement goals; moderate maintenance; and medium BOD reduction (100,000 to 250,000 lbs/day); medium capital costs; some area constraints; and most effective during summer season.
1 – Further research needed to assess DO improvement goals; high maintenance; and low BOD reduction (<100,000 lbs/day); high capital costs; area constraints; and limited seasonal application.

TABLE 5.1 Concept 1 Alternative 1A – Harbor Injection Technology (29 Speece Cones)

Cost Assessment for Design Phase I Step 1
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS
Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings
Required point source BOD reduction is 200,250 lbs/day
(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)
Required nonpoint source BOD reduction is 90,000 lbs/day
Total Oxygen Requirements = 290,250 lbs/day
Supplemental DO needed during summer months
Harbor injection technology capable of 290,000 lbs O_2/day
Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M
50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))
Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	29	cone	$ 425,000	$ 12,325,000
Harbor injection technology (PSA O2 plant)	29	cone	$ 325,000	$ 9,425,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	$ -	$ -
			Subtotal	$ 21,750,000
			Oversight (15%)	$ 3,262,500
			Contingency (50%)	$ 10,875,000
			TOTAL CAPITAL COSTS	**$ 35,887,500**
ANNUAL COSTS				
Speece Cone O&M plus O2 generation energy	90	day	$ 13,920	$ 1,252,800
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	0	day	$ 10,560	$ -
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	0	day	$ 12,960	$ -
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	0	day	$ 13,440	$ -
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	0	day	$ 7,680	$ -
				$ -
			Subtotal	$ 1,252,800
			Oversight & Reporting (30%)	$ 375,840
			TOTAL ANNUAL COSTS	**$ 1,628,640**

DO - dissolved oxygen
BOD - biochemical oxygen demand
O&M - Operations and Maintenance

CAPITAL COSTS	$ 35,887,500
ANNUAL COSTS	$ 1,628,640
TOTAL OPINION OF PROBABLE COSTS	**$ 37,516,140**
TOTAL OPINION OF PROBABLE COSTS OVER 20 YEARS	**$ 68,460,300**

Prepared By:
Checked By:

TABLE 5.1 Concept 1 Alternative 1B – Harbor Injection Technology (29 Speece Cones with scheduled maintenance shut downs)

Cost Assessment for Design Phase I Step 1
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS
Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings
Required point source BOD reduction is 200,250 lbs/day
(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)
Required nonpoint source BOD reduction is 90,000 lbs/day
Total Oxygen Requirements = 290,250 lbs/day
Supplemental DO needed during summer months
Harbor injection technology capable of 290,000 lbs O_2/day
Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M
50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))
Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	29	cone	$ 425,000	$ 12,325,000
Harbor injection technology (PSA O2 plant)	29	cone	$ 325,000	$ 9,425,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	$ -	$ -
			Subtotal	$ 21,750,000
			Oversight (15%)	$ 3,262,500
			Contingency (50%)	$ 10,875,000
			TOTAL CAPITAL COSTS	**$ 35,887,500**
ANNUAL COSTS				
Speece Cone O&M plus O2 generation energy	34	day	$ 13,920	$ 473,280
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	14	day	$ 10,560	$ 147,840
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	14	day	$ 12,960	$ 181,440
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	14	day	$ 13,440	$ 188,160
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	14	day	$ 7,680	$ 107,520
				$ -
			Subtotal	$ 1,098,240
			Oversight & Reporting (30%)	$ 329,472
			TOTAL ANNUAL COSTS	**$ 1,427,712**

DO - dissolved oxygen
BOD - biochemical oxygen demand
O&M - Operations and Maintenance

CAPITAL COSTS	$ 35,887,500
ANNUAL COSTS	$ 1,427,712
TOTAL OPINION OF PROBABLE COSTS	**$ 37,315,212**
TOTAL OPINION OF PROBABLE COSTS OVER 20 YEARS	**$ 64,441,740**

Prepared By:
Checked By:

TABLE 5.1 Concept 1 Alternative 1C - Disharge Collection Network 60-day retention

Cost Assessment for Design Phase I Step 2
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS
Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings
Required point source BOD reduction is 200,250 lbs/day
(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)
Required nonpoint source BOD reduction is 90,000 lbs/day
Total Oxygen Requirements = 290,250 lbs/day
Supplemental DO needed during summer months
Harbor injection technology capable of 290,000 lbs O_2/day
Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M
50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))
Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	0	cone	$ 425,000	$ -
Harbor injection technology (PSA O2 plant)	0	cone	$ 325,000	$ -
Discharge Collection Network 60-day HRT Pond (Option II-C-1)	1	network	$ 42,902,991	$ 42,902,991
Supplemental Oxygen Injection	10	mile	$ 40,500	$ 405,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	$ -	$ -
				$ -
			Subtotal	$ 43,307,991
			Oversight (15%)	$ 6,496,199
			Contingency (50%)	$ 21,653,996
			TOTAL CAPITAL COSTS	**$ 71,458,185**
ANNUAL COSTS				
Speece Cone O&M plus O2 generation energy	0	day	$ 19,200	$ -
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	0	day	$ 15,840	$ -
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	0	day	$ 18,240	$ -
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	0	day	$ 18,720	$ -
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	0	day	$ 12,960	$ -
Supplemental Oxygen Injection (energy required)	90	day	$ 1,780	$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		$ 40,500	$ 4,050
				$ -
			Subtotal	$ 164,250
			Oversight & Reporting (30%)	$ 49,275
			TOTAL ANNUAL COSTS	**$ 213,525**

DO - dissolved oxygen
BOD - biochemical oxygen demand
O&M - Operations and Maintenance

CAPITAL COSTS	$ 71,458,185
ANNUAL COSTS	$ 213,525
TOTAL OPINION OF PROBABLE COSTS	**$ 71,671,710**
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	**$ 75,728,685**

Prepared By:
Checked By:

TABLE 5.1 Concept 1 Alternative 1C - Disharge Collection Network 30-day retention

Cost Assessment for Design Phase I Step 2
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS
Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings
Required point source BOD reduction is 200,250 lbs/day
(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)
Required nonpoint source BOD reduction is 90,000 lbs/day
Total Oxygen Requirements = 290,250 lbs/day
Supplemental DO needed during summer months
Harbor injection technology capable of 290,000 lbs O_2/day
Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M
50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))
Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	0	cone	$ 425,000	$ -
Harbor injection technology (PSA O2 plant)	0	cone	$ 325,000	$ -
Discharge Collection Network 30-day HRT Pond (Option II-B-1)	1	network	$ 37,471,338	$ 37,471,338
Supplemental Oxygen Injection	10	mile	$ 40,500	$ 405,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	$ -	$ -
				$ -
			Subtotal	$ 37,876,338
			Oversight (15%)	$ 5,681,451
			Contingency (50%)	$ 18,938,169
			TOTAL CAPITAL COSTS	**$ 62,495,958**
ANNUAL COSTS				
Speece Cone O&M plus O2 generation energy	0	day	$ 19,200	$ -
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	0	day	$ 15,840	$ -
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	0	day	$ 18,240	$ -
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	0	day	$ 18,720	$ -
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	0	day	$ 12,960	$ -
Supplemental Oxygen Injection (energy required)	90	day	$ 1,780	$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		$ 40,500	$ 4,050
				$ -
			Subtotal	$ 164,250
			Oversight & Reporting (30%)	$ 49,275
			TOTAL ANNUAL COSTS	**$ 213,525**

DO - dissolved oxygen
BOD - biochemical oxygen demand
O&M - Operations and Maintenance

CAPITAL COSTS	$ 62,495,958
ANNUAL COSTS	$ 213,525
TOTAL OPINION OF PROBABLE COSTS	**$ 62,709,483**
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	**$ 66,766,458**

Prepared By:
Checked By:

TABLE 5.2 Concept 1 Alternative 2A – Harbor Injection Technology (73 Speece Cones)

Cost Assessment for Design Phase I Step 2
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS
Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings
Required Point Source BOD reduction is 635,500 lbs/day
Required Nonpoint Source BOD reduction is 90,000 lbs/day
Total Oxygen Requirements = 725,500 lbs/day
Supplemental DO needed during summer months
Harbor injection technology capable of 730,000 lbs O_2/day
Inject harbor near midpoint of Hutchinson Island and via mobile barge
Barge available for use and no storage expense
Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M
50 % BOD loading reduction from an individual discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers)
Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	73	cone	$ 425,000	$ 31,025,000
Harbor injection technology (PSA O2 plant)	73	cone	$ 325,000	$ 23,725,000
Discharge Collection Network 30-day HRT Pond	0	network	$ 39,556,271	$ -
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	$ -	$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	$ -	$ -
				$ -
			Subtotal	$ 54,750,000
			Oversight (15%)	$ 8,212,500
			Contingency (50%)	$ 27,375,000
			TOTAL CAPITAL COSTS	**$ 90,337,500**
ANNUAL COSTS				
Speece Cone O&M plus O2 generation energy	90	day	$ 35,040	$ 3,153,600
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	0	day	$ 31,680	$ -
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	0	day	$ 34,080	$ -
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	0	day	$ 34,560	$ -
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	0	day	$ 28,800	$ -
Supplemental Oxygen Injection (energy required)	0	day	$ 1,780	$ -
Supplemental Oxygen Injection (O&M)	0		$ 40,500	$ -
				$ -
			Subtotal	$ 3,153,600
			Oversight & Reporting (30%)	$ 946,080
			TOTAL ANNUAL COSTS	**$ 4,099,680**

DO - dissolved oxygen
BOD - biochemical oxygen demand
O&M - Operations and Maintenance

CAPITAL COSTS	$ 90,337,500
ANNUAL COSTS	$ 4,099,680
TOTAL OPINION OF PROBABLE COSTS	**$ 94,437,180**
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	**$ 172,331,100**

Prepared By:
Checked By: