Water Quality Monitoring Program Methodology

Post 45 Project, Charleston, SC

US Army Corps of Engineers
Charleston District

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Table of Contents

List of Figures

List of Tables

1 Introduction

The purpose of this report is to document the methodology for the Post 45 project water quality monitoring program. As described in the Environmental Impact Statement (EIS) for the project, numerical modeling analyses indicate that dissolved oxygen (DO) impacts due to the Post 45 project will be *de minimis* as defined in R. 61-68. The modeling analyses also indicate that the project will cause slightly increased salinities in some reaches of the harbor's tributary rivers. The Mitigation Planning and Monitoring and Adaptive Management Plan for the project (Appendix P to the EIS) includes a water quality monitoring program that is intended to document the project effects and to determine if the impacts are consistent with those estimated in the EIS. If the observed project impacts are greater than those estimated in the EIS, then suitable corrective action can be taken, if necessary. Furthermore, if the monitoring data show that the project caused dissolved oxygen impacts greater than the allowable cumulative impact of 0.1 mg/l or salinity impacts greater than those estimated in the EIS or the analysis is inconclusive, then the numerical model will be updated and used to reevaluate the project impacts and mitigation requirements. Because numerical modeling may be required to quantify, identify causes and evaluate the impacts, as well as support analysis of any corrective actions, a secondary goal of the water quality monitoring program is to also collect sufficient data to update the model.

1.1 Study Goals

The goals of the monitoring plan are twofold:

1. Measure changes in environmental variables in the estuary in order to estimate the Post 45 project effects on salinity and DO; and
2. Collect sufficient data to update and refine the numerical water quality model used for EIS analyses, if necessary.

1.2 Report Outline

The following report sections describe the monitoring plan and statistical analysis methodology:

- Section 2, Statistical Design – identifies the methods to be used to process the monitoring data, test hypotheses and estimate levels of project impacts to DO and salinity.
- Section 3, Conceptual Model – describes the Charleston Harbor system dynamics as related to salinity and dissolved oxygen. This conceptual model is used to identify the necessary monitoring components.
- Section 4, Monitoring Plan – describes the locations and variables to be monitored.

2 Statistical Design

Common statistical designs for evaluating project impacts to rivers or streams include analysis of:

- Areas upstream and downstream from the impact area;
- Paired streams (control and impact areas); and
- Before/after project or trend analysis of a single stream.

The best experimental designs incorporate paired observations from both an area potentially affected by the project and a comparison area unaffected by the project that serves as a control. This approach is preferred if a location exists where water quality is both unaffected by the project while being significantly related to the water quality in the project impact area. The paired approach improves upon the before/after approach because it provides data after project construction that can be used to estimate effects of unusual events unrelated to the project (e.g., an extended dry period not observed in the data prior to project construction) that would otherwise confound attempts to isolate the project impacts. Effects of conditions not found in the before period but occurring in the after period will be confused with any effects due to the project, and with the before/after approach it will be impossible to know which of the two types of possible effects is actually the one causing the observed change in water quality.

For DO, a paired design may be used for evaluating potential impacts. The USGS operates a DO monitoring gage at an upriver location on the Cooper River that is outside the influence of the project impacts may serve as the control. This gage (USGS 02172050, COOPER R NR GOOSE CREEK, SC) is located approximately 1.5 miles downstream from the confluence of the West Branch and East Branch of the Cooper River and approximately 18 miles upstream from any dredging associated with the Post 45 project. This area corresponds to model segments C55 & 56 used for the DO TMDL analysis. Based on the EFDC model results presented in the EIS for these segments, the Post 45 project will cause very small DO reductions in this area of the river (-0.008 to -0.009 mg/l change in the 90th percentile "delta DO"). Therefore, this station can serve as a control location with the caveat that up to 0.009 mg/l of change in DO at this location may be attributed to the Post 45 project. Given that this location is not an ideal control station (i.e., with a certainty of zero project effects), the DO should also be analyzed with a before and after design, without a control station.

For salinity, however, a paired design is not feasible because an appropriate control location does not exist. Within the Charleston Harbor estuary, the Post 45 project may affect any area that has measureable salinity concentrations, which precludes use of any area within the estuary as a salinity control location. Also, an appropriate control location in a nearby watershed is not available for use as a control. Nearby estuaries are more sensitive to wet and dry periods than the Cooper River because the freshwater flow into the Cooper is dominated by the regulated Pinopolis dam flow and the daily-averaged flow in the Cooper River remains relatively constant. The flow from the Pinopolis dam is further manipulated to counteract salinity transport into the upper regions of the Cooper River (to avoid salinity reaching the Back River Reservoir). Therefore, salinity in other nearby estuaries will have different responses to weather-related variations and will not be sufficiently related to salinity in the Charleston Harbor estuary. Therefore, the only feasible approach for evaluating salinity impacts is to analyze monitoring of the same locations before and after the project construction.

2.1 Salinity Analysis

Because the monitoring will include collection of continuous data before and after the project dredging, and because the project will cause a physical change to the estuary system at a known point in time, a step-trend analysis is the appropriate statistical test. Figure 2-1 provides an example of a significant

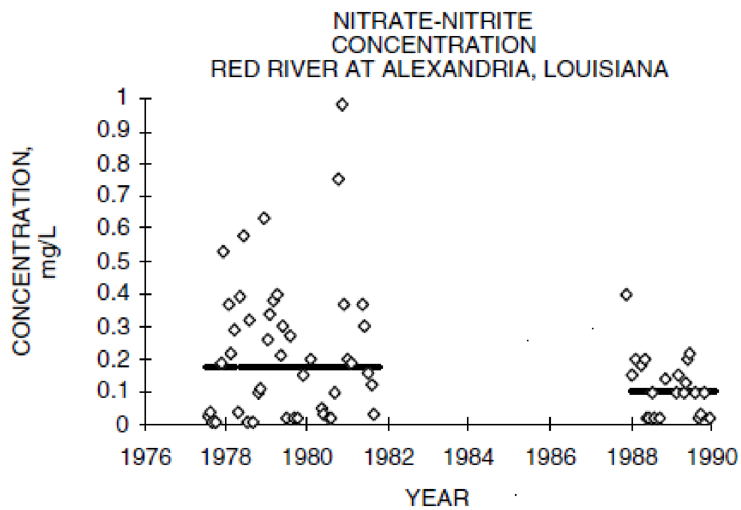

Figure 2-1. Example of significant (*p* = 0.085) step-trend as measured by rank-sum test (Helsel and Hirsch 2002)

step-trend. According to Helsel and Hirsch (2002), step trend procedures should be used in two scenarios: when there is a significant gap in between two distinct time periods being analyzed; or (as in this case) when a specific event is known to have occurred at a specific time that is likely to affect water quality.

Test procedures should be selected based on the data characteristics and study objectives (Helsel and Hirsch 2002). Two important data characteristics to consider are the sampling frequency and the length of the monitoring period. The salinity monitoring data will include measurements every 15 minutes over a time period extending from a minimum of approximately 1 year prior to project dredging through at least 5 years following project completion. For existing long-term gages, the pre-project data will monitoring data extending back to 2006; data prior to 2006 will not be used because of the effects of the previous harbor deepening project, which was completed in 2005. For new monitoring gage locations, a shorter 1-year monitoring period will serve as the pre-project data. Following the 5-year period following construction, continuation of monitoring will be determined by the USACE in collaboration with SCDHEC and other resource agencies as required by the conditions of the project's 401 Water Quality Certification. The objective of the test is to determine if there is a change in the central value of salinity (i.e., the mean) at the gage location that can be attributed to the project, after accounting for other known explanatory variables (i.e., covariates), such as change in offshore salinity or water levels, that could affect salinity.

The traditional default error rate, α, is 5% (0.05). A slightly larger value of 10% will be used for the test in order to increase the power to detect change. The implications of rejecting the null hypothesis (that the Post 45 project did not cause a change) will not in itself result in costly management actions, and therefore selection of a more stringent error rate (e.g., 0.05 or 0.01) is not warranted. Instead, it is the *magnitude* of differences in the average salinities before and after the project that may trigger adaptive management actions (i.e., if the changes in average salinity are greater than those estimated in the EIS, then adaptive management actions may be warranted).

The analysis will include the following steps:

1) Exploratory data analysis – The sample data will be screened to identify potential errors and analyzed to determine data gaps. The sample data will be processed to have consistent frequencies to minimize variances across the data set due to sampling frequency. Although the US Geological Survey (USGS) gages will collect data at a high frequency (e.g., 15 minute intervals), some explanatory variables will only be available at daily intervals. Furthermore, daily values are sufficient to meet the objectives of the study. Therefore, daily values for all variables will be generated. This step will also include generation of summary statistics for each variable. Daily averaging of tidally influenced variables can result in a phenomenon known as tidal aliasing (Godin 1972 *in* USGS 2011), which results in a low frequency variation on the order of 3 to 4 percent of the tidal component of the signal. Tidal aliasing is an artifact of the averaging process and it does not represent actual low frequency variation in the signal. Therefore, for explanatory variables that are tidally influenced, the data will first be low-pass filtered to remove the effects of semi-diurnal tides prior to calculating daily averaged values.

2) Model effects from explanatory variables – Multiple linear regression models will be used to separate out the effects of known covariates (e.g., offshore boundary [water level, salinity], upstream boundary [flow], watershed flows [based on rainfall data]).

3) Address serial correlation[1] – If serial correlation is not removed by adding new variables, then additional steps will be taken to address serial correlation. The sample data will be time-averaged (e.g., daily, weekly or monthly averaged) such that each result is an independent observation and the time series is not correlated with itself. Sufficiently long time-averaging periods will be used to avoid the necessity of time series methods to account for serial correlation. The residuals from the regression models will be tested to determine if any adjustment is required.

[1] Serial correlation (also known as autocorrelation) is the correlation between consecutive observations. According to Helsel and Hirsch (2002), the most common kind of serial correlation in water resources is positive serial correlation, where high values tend to follow high values and low values tend to follow low values. Statistical tests assume independent observations, and therefore serial correlation must be removed prior to conducting statistical tests.

4) Test hypothesis - Test for step change with analysis of covariance (ANCOVA) methods to determine if there is sufficient evidence to reject the null hypothesis (that the Post 45 project did not cause a change) in favor of the alternate hypothesis that the Post 45 project caused a change in the mean salinity at the monitoring locations in the harbor. The ANCOVA will include a binary explanatory variable indicating the time before (0) versus after (1) the project. A shift in the relationship between the two time periods (as shown by a significant test for the slope of the binary variable) will determine the magnitude of the shift that can be attributed to the project, as long as values for all the other regression explanatory variables remain within the range of values previously observed for the "before" time period.

2.2 Dissolved Oxygen Analysis

The analysis of the DO sample data will use a paired design analysis (control/impact - before/after), with an upstream area of the Cooper River serving as a control station. If locations in the impact area (e.g., in the Ashley River or Wando River) are not found to have significant relationships to the control station, then the before/after analyses will be conducted at these locations, similar to the methods proposed for the salinity analysis. For the paired design analysis, similar methods as those described for salinity above would be used, except the ANCOVA would also include DO at the upstream control location as an explanatory variable.

In addition to evaluating the change in the median value, the analysis will also evaluate the change in the 10^{th} percentile DO. These two quantiles will be evaluated for the March through October time period. Evaluation of the change in the 10^{th} percentile DO for the March through October time period is consistent with the goal of the TMDL methodology, which is to evaluate impacts during warm water low DO conditions. The evaluation will use a variation of regression called quantile regression. It is analogous to the aforementioned regression procedure except that instead of estimating the mean of the response variable Y, a percentile (quantile) of the Y variable is estimated.

3 Conceptual Model

A conceptual model is presented in this section to describe the general Charleston Harbor system dynamics and project impacts as related to salinity and DO. The conceptual model is not intended to provide exhaustive descriptions of the estuary and project impacts (this information is provided in detail in the EIS). Instead, the purpose of the conceptual model is simply to assist identification of the necessary monitoring components, particularly the explanatory variables that should be monitored and accounted for in the analysis of the salinity and DO impacts. Accounting for the major sources of variability in the salinity and DO data increases the likelihood of isolating the water quality impacts caused by the proposed Post 45 project. In statistical terms, accounting for variability in water quality due to these other factors decreases “unexplained” variation in data (Spooner et al. 2014).

Detailed three-dimensional (3D) numerical models have been developed for the Charleston Harbor estuary, both for the DO Total Maximum Daily Load (TMDL) study (Tetra Tech and Jordan, Jones, and Goulding 2008; Cantrell 2013) and for the EIS (USACE 2015). These numerical models used the Environmental Fluid Dynamics Code (EFDC) and have been calibrated to extensive measured data sets. These model studies as well as other available monitoring data provide ample information for the development of the conceptual model discussed below.

3.1 Salinity

The salinity distribution in the Charleston Harbor estuary is essentially a result of the balance between the salinity intruding from the ocean and the freshwater flowing into the estuary from the Pinopolis dam and the local watershed areas. Saline ocean water is denser than fresh water, which generally causes higher salinity concentrations near the estuary bottom and lower salinity concentrations near the surface. The degree of this vertical salinity variation is a function of both fresh water river flow and tidal energy in the estuary. Higher river flow and lower tidal energy increase the degree of vertical salinity stratification. In the Charleston Harbor estuary, the estuary is considered partially-mixed (Tetra Tech and Jordan, Jones, and Goulding 2008), which means that there is some vertical variation in salinity, but it does not exhibit highly-stratified conditions.

The Post 45 project will deepen and widen the federal navigation channel, which will allow more of the denser, more saline ocean water to be transported up the river system. As described in the EIS, this will result in an upriver shift in the salinity distribution in the estuary.

The primary salinity impact concerns are related to wetland vegetation impacts and the effects on DO. For wetland impacts, the evaluation in the EIS used the change in average annual salinity to estimate changes in wetland vegetation. As described in the EIS, the most significant wetland impacts are expected to be limited to the upper Ashley and Cooper Rivers in the vicinity of the 0.5 ppt salinity contour, which generally indicates the transition between brackish and fresh water marsh vegetation. Therefore, monitoring the average or median annual salinity values in these areas are of the greatest interest. Salinity-related effects on DO are discussed in detail in the following section, but for the purposes of the salinity conceptual model, the daily-averaged salinity is of interest for evaluating the potential impacts on DO concentrations.

Primary factors affecting the average salinity in the rivers are shown in Figure 3-1. Based on sensitivity testing of the 3D numerical models, the primary variables affecting average salinity in the estuary include:

1) Upstream (Pinopolis dam) fresh water flows;
2) Local watershed flows;
3) Ocean salinity; and
4) Ocean water level.

The upstream flows to the Cooper River are controlled at the Pinopolis dam. In general, increasing freshwater releases from the dam causes lower salinity in the estuary, particularly in the Cooper River. However, on average, the dam flows are maintained at a relatively constant daily flow rate due to contractual agreements between the USACE and South Carolina Public Service Authority. Although the salinity in the Cooper River is sensitive to dam flows, the fact that the daily flow is held relatively constant means that it is unlikely to be a significant source of variation in annual average salinity in the river. The variations in flow may, however, affect daily-averaged salinity in the Cooper River, and to a lesser extent, it may affect the Wando and Ashley Rivers.

In general, increasing freshwater inflows from the local watershed cause lower salinity in the estuary. Based on the model results, these flows have only very small effects on salinity in the Cooper and Wando Rivers. However, the Ashley River is sensitive to freshwater inflows from the local watershed. Therefore, rainfall should be included in monitoring program in order to account for the local watershed inflow effects on the Ashley River.

Increasing ocean salinity causes higher salinities in the estuary. Offshore salinity is measured at a buoy located about 5 miles offshore from Capers Island (Station 41029 - Capers Nearshore [CAP2]). This buoy is part of the Carolinas Regional Coastal Ocean Observing System, and it is owned and maintained by the University of North Carolina Wilmington's Coastal Ocean Research and Monitoring Program. As shown by salinity measured offshore at the CAP2 buoy (Figure 3-2), there are significant low frequency salinity variations 5 miles offshore from Charleston Harbor. The 5^{th} and 95^{th} percentile salinities are 31.7 and 35.7 ppt, respectively. Based on the 3D model sensitivity, this range of salinity variation on the offshore boundary can affect median salinity on the Cooper River at the I-526 bridge by roughly ± 1 ppt. This is a similar order of magnitude as the estimated effects for the Post 45 project, and therefore the offshore salinity variation should be included in the monitoring program and statistical analyses.

Increasing ocean water levels cause higher salinities in the estuary. The low-frequency (i.e., sub-tidal) ocean water level variation can be estimated based on the water levels recorded by the NOAA gage installed at Custom House on the Cooper River (Station ID 8665530) in the lower harbor. This gage location is close enough to the harbor inlet that the mean water levels are similar to those that occur in the ocean. Figure 3-3 plots the monthly and 5-month running average mean sea levels with the average

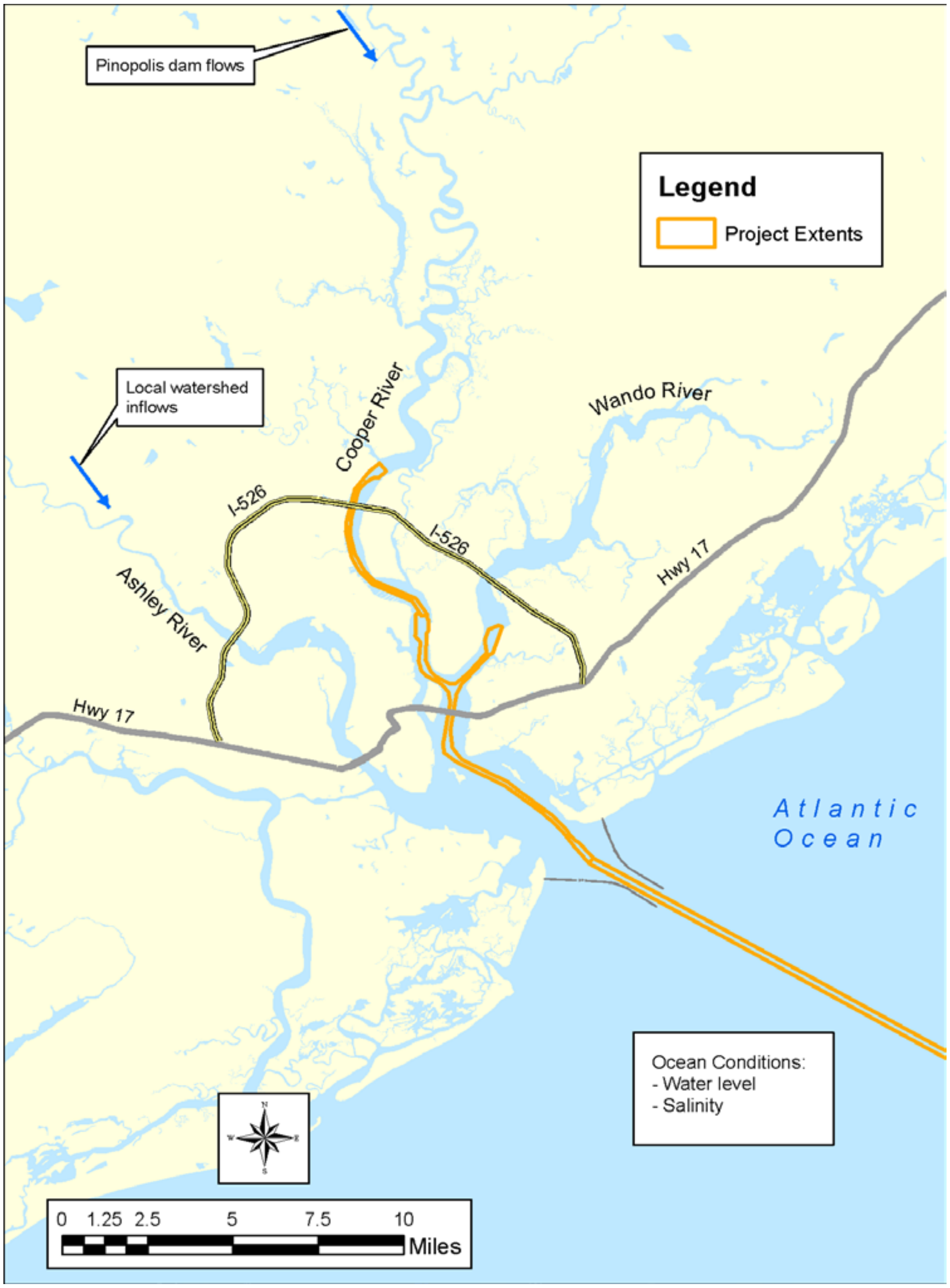

Figure 3-1. Primary factors affecting long-term average salinity in the Charleston Harbor estuary

seasonal cycle and linear sea level trend removed, as calculated by NOAA for the Customs House gage. As explained by NOAA (2015), the interannual variations are caused by irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. Based on the 3D model results, the low-frequency variation in water levels can have an effect on the average salinity in the estuary of a similar order of magnitude as the estimated effects for the Post 45 project. Therefore, the low-frequency ocean water level variation should be included in the monitoring program and statistical analyses.

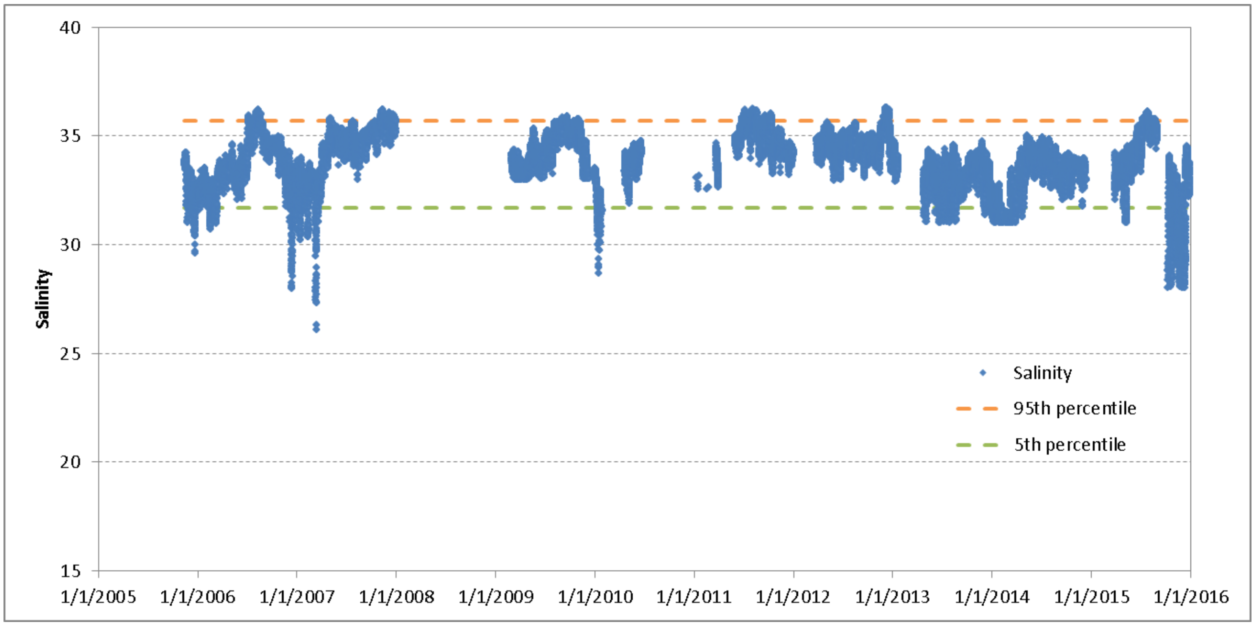

Figure 3-2. Historical offshore salinity variation at CAP2

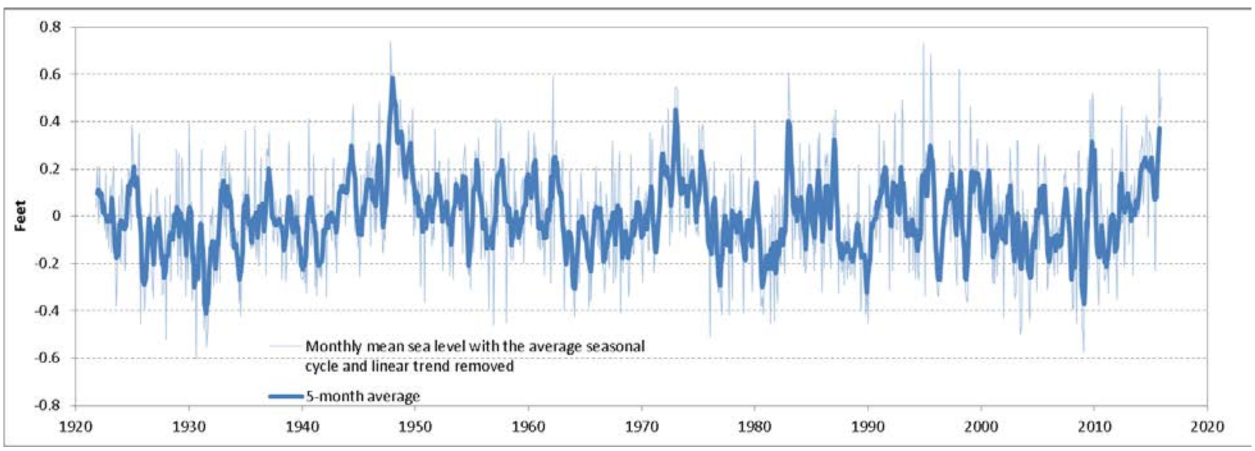

Figure 3-3. Interannual variation of monthly mean sea level and the 5-month running average

Astronomical tidal water levels also affect the daily-average salinity in the estuary. In estuaries with significant vertical salinity stratification (such as the Lower Savannah River), larger tide ranges (e.g., spring tides) enhance vertical mixing, decrease vertical salinity stratification and thereby reduce salinity intrusion into the estuary. However, Charleston Harbor has relatively low vertical salinity stratification. In Charleston Harbor, salinity intrusion increases with increasing tide range, decreasing freshwater flow and increasing daily mean water level.

3.2 Dissolved Oxygen

In general, DO concentrations in estuaries are essentially a function of:

- Addition of DO at the water surface (reaeration);
- Loss of DO to oxidation of substances in the water column and bottom sediments (from both natural sources and anthropogenic sources [which may include point source discharges and non-point source pollution]);
- Incoming and outgoing DO concentrations at the boundaries (i.e., watershed tributaries and the ocean); and
- Changes in DO saturation concentration (a function of temperature and salinity).

As explained by Cantrell (2013), natural factors such as organic loading and reduced oxygen levels from wetlands and marshes and estuarine dynamics in the mixing zone where freshwater and saltwater come together can create naturally low DO conditions in South Carolina estuaries. The waters in and around Charleston Harbor are considered to be both naturally low in DO and further impacted by wastewater dischargers. However, the Total Maximum Daily Load (TMDL) for oxygen demanding substances limits the maximum impact of point source discharges to 0.1 mg/l; and anthropogenic non-point sources of pollution do not contribute to reductions in DO in the harbor (Cantrell 2013).

As described in the EIS, the Post 45 project is expected to cause small reductions in the DO in the estuary. The processes through which a navigation channel expansion will affect dissolved oxygen include:

- Changes in reaeration, as a result of changes in water depth and current speed;
- Changes in dissolved oxygen saturation concentration, as a result of changes in salinity or temperature; and
- Changes in residence time of oxygen demanding substances, as a result of changes in the tributary hydrodynamics.

The primary concern related to project DO impacts is compliance with state water quality standards for protection of aquatic life. The South Carolina Department of Health and Environmental Control (DHEC) developed a Total Maximum Daily Load (TMDL) to determine the maximum amount of oxygen demanding load from point source discharges (industries and municipal wastewater treatment plants) that Charleston Harbor can assimilate while still meeting the water quality standards for DO. In addition, the cumulative effect of the Post 45 project plus the point source dischargers must not cause a reduction greater than 0.149 mg/l in the river.

The TMDL was calculated based on the changes to daily-averaged DO concentrations caused by the point source discharges. The DO concentrations were also volume-averaged within river segments (river segments are one river-width wide and roughly two river-widths in length). The impacts to dissolved oxygen from the Post 45 project were calculated using the same averaging method. The cumulative impacts (i.e., the discharges and the Post 45 project) were estimated by adding the daily-average DO impacts together. The 90th percentile of these daily cumulative DO impacts calculated over the March through October time period (referred to as the “delta DO”) was determined not to exceed the 0.149

mg/l allowable impact. The DO impacts from the point sources and the Post 45 project are shown in Figure 3-4 through 3-6 for the three rivers. Based on the expected areas of the greatest potential project impacts, the spatial area of interest for monitoring and evaluating the project effects is primarily the

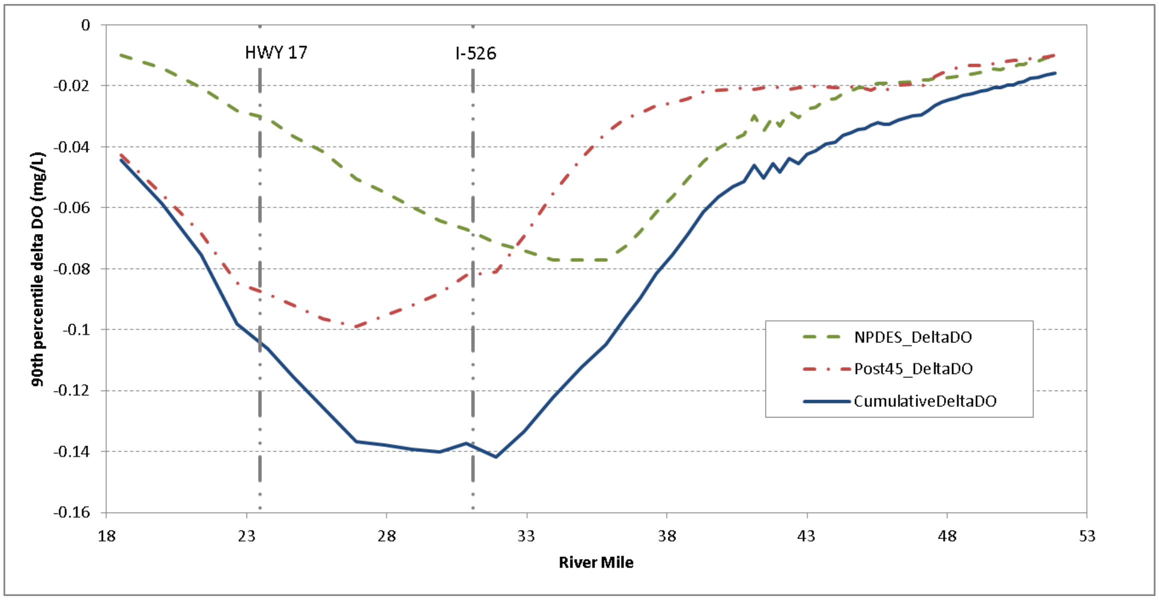

Figure 3-4. Longitudinal plot of 90th percentile impact to DO along the Cooper River

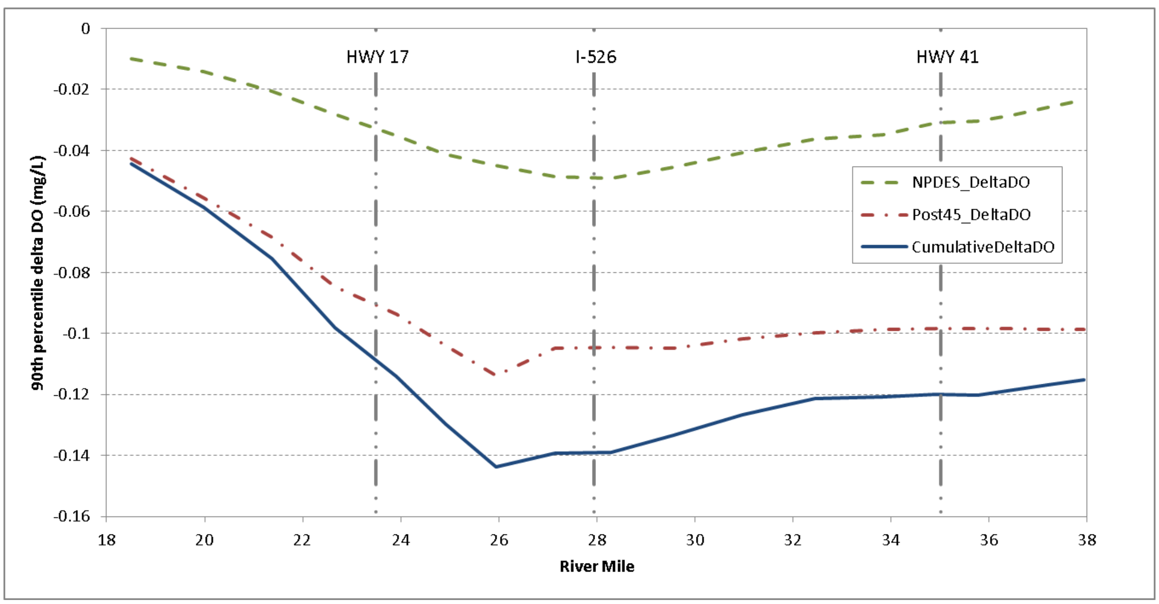

Figure 3-5. Longitudinal plot of 90th percentile impact to DO along the Wando River

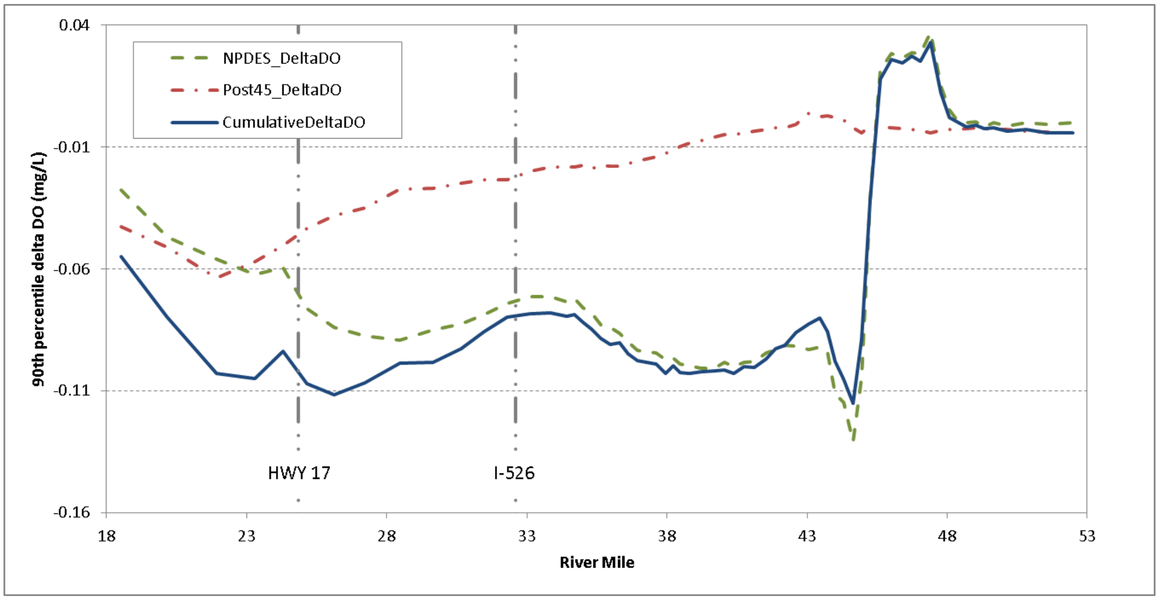

Figure 3-6. Longitudinal plot of 90th percentile impact to DO along the Ashley River

segment of the Cooper River between Hwy 17 and I-526 and the entrance to the Wando River between Hwy 17 and I-526.

The primary factors affecting the DO in the rivers are shown in Figure 3-7. DO saturation is a function of salinity and temperature, and therefore all of the variables factors affecting salinity discussed in the previous section also apply to DO. The primary variables affecting DO in the estuary include:

1) Upstream (Pinopolis dam) boundary
    a) Flow
    b) DO concentration
    c) Loads
    d) Temperature
2) Local watershed flows and loads (rainfall)
3) Ocean boundary
    a) Salinity
    b) Water level
    c) DO concentration
    d) Temperature
4) Meteorological conditions
    a) Air temperature
    b) Wind speed

In general, the DO is very sensitive to changes in temperature and salinity. As water temperature and salinity increase, the DO saturation (and therefore DO) decreases. Additionally, as water temperature increases, the oxidation rate of oxygen demanding substances also increases (both in the water column

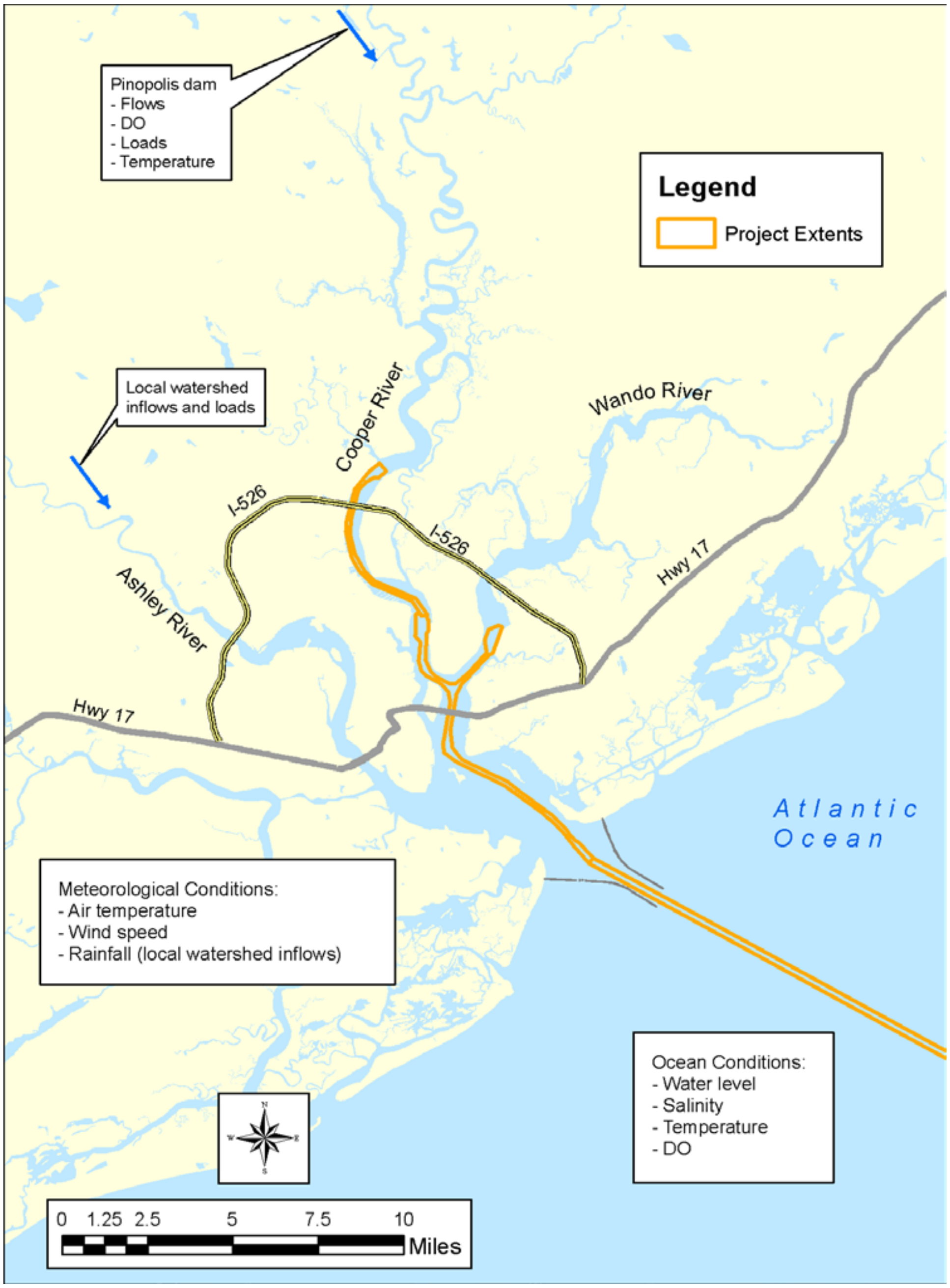

Figure 3-7. Primary factors affecting average DO in the Charleston Harbor estuary

and in the bottom sediments), which decreases water column DO concentrations. Therefore, salinity and temperature are the most important explanatory variables that must be included in the monitoring plan.

Based on sensitivity testing of the 3D model, changes in local watershed flows and loads cause significant DO impacts in the Ashley River. Conrads et al. (2002) found that rainfall and the resulting local watershed flows and loads caused DO reductions in the east branch of the upper Cooper River.

Monitoring of rainfall should be included in order to evaluate the effects of this explanatory variable on the DO in the estuary.

The DO is not very sensitive to ±20 percent variations in constant point source discharge loads at the maximum permitted rate (changes are on the order of ±0.01 mg/l). Nonetheless, this variable can be also evaluated in the statistical analysis because the daily discharge report data can be obtained from dischargers.

4 Monitoring Plan

As stated in the introduction, there are two goals of the monitoring plan: to measure changes in environmental variables in the estuary in order to estimate the Post 45 project effects on salinity and DO; and to collect sufficient data to update and refine the numerical water quality model used for EIS analyses, if necessary.

To meet the first goal, the monitoring will include measurement of both the salinity and DO in the areas to be affected by the project. It will also include monitoring of other important explanatory variables that must be included in the statistical analyses.

To meet the second goal, the monitoring will include measurement of variables needed for the model boundaries (offshore, upstream, point source, nonpoint source and meteorological boundaries). The monitoring will require water chemistry data for comparison to model predictions and confirmation of the model calibration.

4.1 Monitoring Period

New monitoring gages will be installed approximately 1-year prior to project construction. The project construction will be completed over a period of approximately 3-4 years. Following completion of project dredging, the monitoring data collection will continue for an additional 5 years. Although this defines the period of active data collection for this project, the statistical analysis may also include a longer time period extending more than 1-year prior to project construction for analysis of existing USGS gages where a longer pre-project data record is available.

4.2 Monitoring Variables

Table 4-1 summarizes the variables of interest, the monitoring sources and the need for monitoring each of these variables. These are each described in greater detail in the following sections.

4.3 Offshore Monitoring

As mentioned previously, offshore salinity and temperature is measured at a buoy located about 5 miles offshore from Capers Island (Station 41029 - Capers Nearshore [CAP2]). This buoy is part of the Carolinas Regional Coastal Ocean Observing System, and it is owned and maintained by the University of North Carolina Wilmington's (UNCW) Coastal Ocean Research and Monitoring Program. Although the plot in Section 3 (Figure 3-2) shows substantial gaps in real-time data reported to the web that occur when there are communications outages or power outages, the CTD still collects and internally logs data. This archived data will be made available from UNCW when they swap the CTD at the buoy. This data is anticipated to be available throughout the monitoring project.

Table 4-1 Summary of variables of interest, monitoring data sources and the need for each variable

Variable	Monitoring Source	Need			
		Impact Observation	Explanatory Variable	Model Boundary	Model Calibration
Offshore:					
Offshore salinity and temperature	Buoy at Station 41029 - Capers Nearshore (CAP 2) - Continuous data		X	X	
Offshore DO	Assume constant % saturation (calculate % saturation based on measured salinity and temperature)		X	X	
Offshore mean water level	NOAA Customs House gage		X	X	
Upstream Cooper River:					
Upstream DO and temperature	New USGS DO sensor at existing Tailrace Canal gage		X	X	
Upstream loads	Santee Cooper monthly water chemistry monitoring (SC-033) and USGS flow rates at existing Tailrace Canal gage		X	X	
Watershed:					
Local watershed flows and loads	Rainfall gaging stations throughout watershed		X	X	
Impact Areas:					
Wando River DO	USGS continuous monitoring stations - Existing mid-depth at I-526 - New bottom gage at I-526 - New mid-depth gage near Hwy 41	X			X
Cooper River DO	USGS continuous monitoring stations - Existing mid-depth at Hwy 17, I-526 and near Goose Cr. - New bottom gage at I-526 - New mid-depth gage between Hwy 17 and I-526 (at Navy Base)	X			X
Ashley River DO and salinity	USGS continuous monitoring station - Existing mid-depth at I-526 - New mid-depth downstream of Jessen Landing	X			X
Cooper River Salinity	Above listed USGS continuous monitoring stations for DO, plus - Existing mid-depth gage at Mobay - Existing mid-depth gage at Pimlico - New mid-depth gage between Mobay and Goose Cr. gages	X			X
Other variables:					
Point source discharges	Daily monitoring reports (maintained by individual dischargers) for flow, BOD, NH3		X		X
Estuary water chemistry	DHEC fixed water quality monitoring stations		X		X
Meteorological conditions	Airport and other monitoring stations		X		X

This data will be used in the statistical analysis as explanatory variables. It will also be used as ocean boundary information to support the numerical model, if necessary.

4.4 USGS Gages

The USACE, USGS, BCDCOG and other cooperators currently operate a system of water quality data collection stations within the Charleston Harbor system using 15-minute data collection at mid-depth (Figure 4-1). Data collected include temperature, water level, specific conductance (SC) and DO. The SC data is used to calculate salinity at each gage location.

New monitoring gages are shown in Figure 4-2. Additional gages will be placed to monitor changes in the anticipated impact areas, including:

- Two bottom DO gages added at the existing mid-depth gage locations on the Cooper and Wando Rivers at the I-526 highway crossings;
- A new SC, temperature and water level gage on the upper Cooper River in the vicinity of the existing 0.5 ppt contour (to be installed approx. 1 mile upstream from the Williams Station Steam Plant discharge);
- A new DO, SC, temperature and water level gage on the upper Ashley River in the vicinity of the existing 0.5 ppt contour (to be installed on a boardwalk downstream of the Herbert Jessen boat landing); and
- A new DO, SC, temperature and water level gage on the lower Cooper River in the vicinity of where the maximum project impacts to DO are anticipated to occur;
- A new DO, SC, temperature and water level gage on the Wando River and the State Highway 41 crossing.

In addition, the monitoring will include a new DO sensor at the existing gage at the tailrace canal to monitor DO concentrations just downstream from the dam. This data will be used to monitor the DO concentrations entering the estuary from the upstream boundary.

As mentioned previously, the new gages will be installed approximately 1-year prior to project construction. The project construction will be completed over a period of approximately 3-4 years. Following completion of project dredging, the monitoring data collection will continue for an additional 5 years.

4.5 Upstream Cooper River

The Biological Services group at Santee Cooper collects monitoring data at Station SC-033 (located on the Tailrace canal just below Highway 52) on a monthly basis. They collect the following *in situ* data: DO, pH, temperature and conductivity. They also collect samples analyzed by their in-house laboratory for: turbidity, color, alkalinity, bacteria, NH3, TKN, TP (total phosphorus), chlorides, fluorides, bromide, sulfate, nitrate, nitrite, solids data (TSS & TS), and various metals.

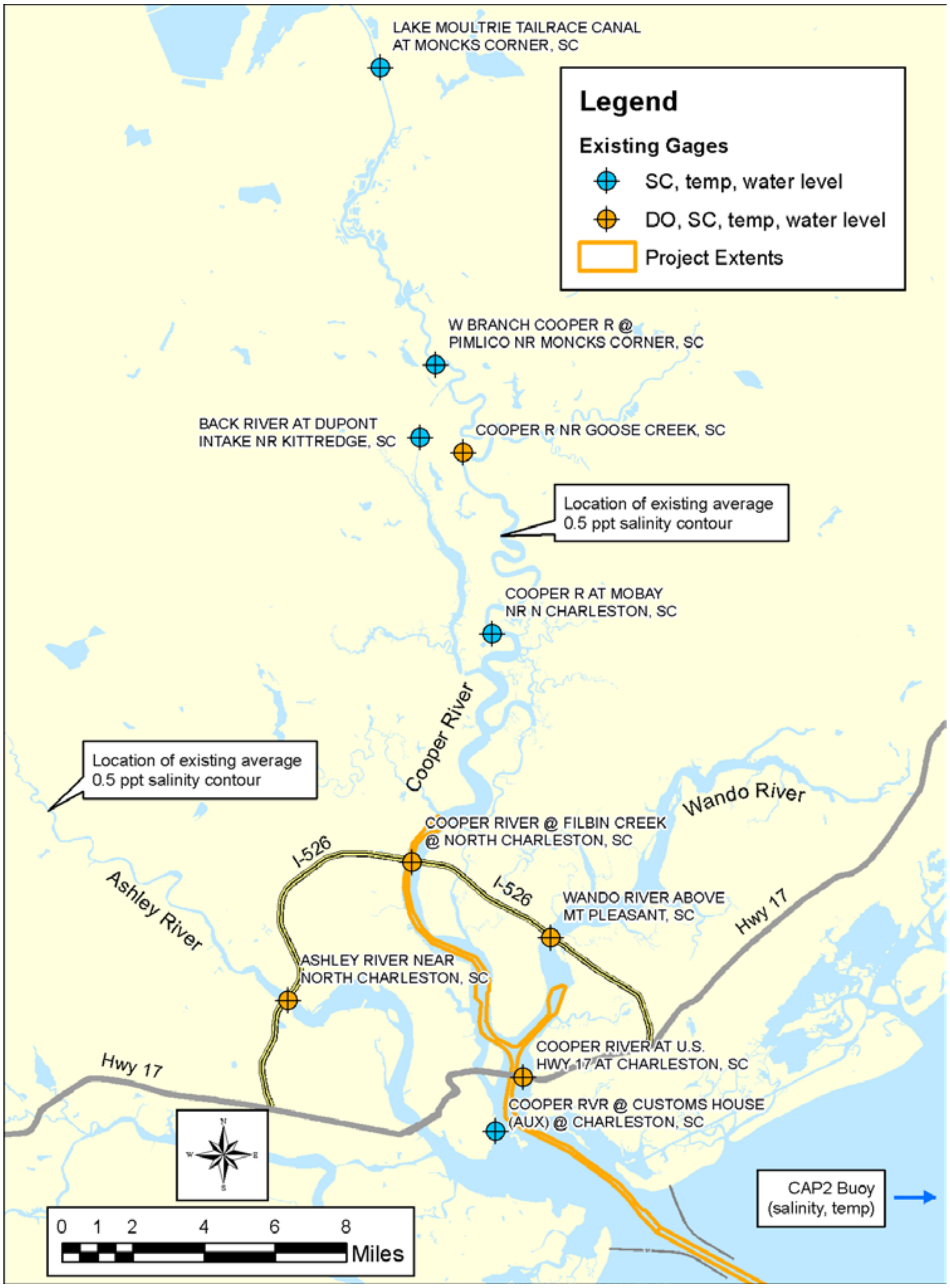

Figure 4-1. Existing monitoring gages

Flow rates near the upstream boundary are monitored by a USGS continuous gage (02172002 LAKE MOULTRIE TAILRACE CANAL AT MONCKS CORNER, SC). Loading rates can be estimated based on the measured daily flow rates, daily DO measured by the new USGS gage sensor, and the monthly water chemistry data collected by Santee Cooper.

4.6 Watershed Flows and Loads

Watershed loads can be estimated using monitored rainfall data and the LSPC watershed model developed as part of the TMDL model. The monitoring program will rely on daily rainfall data collected

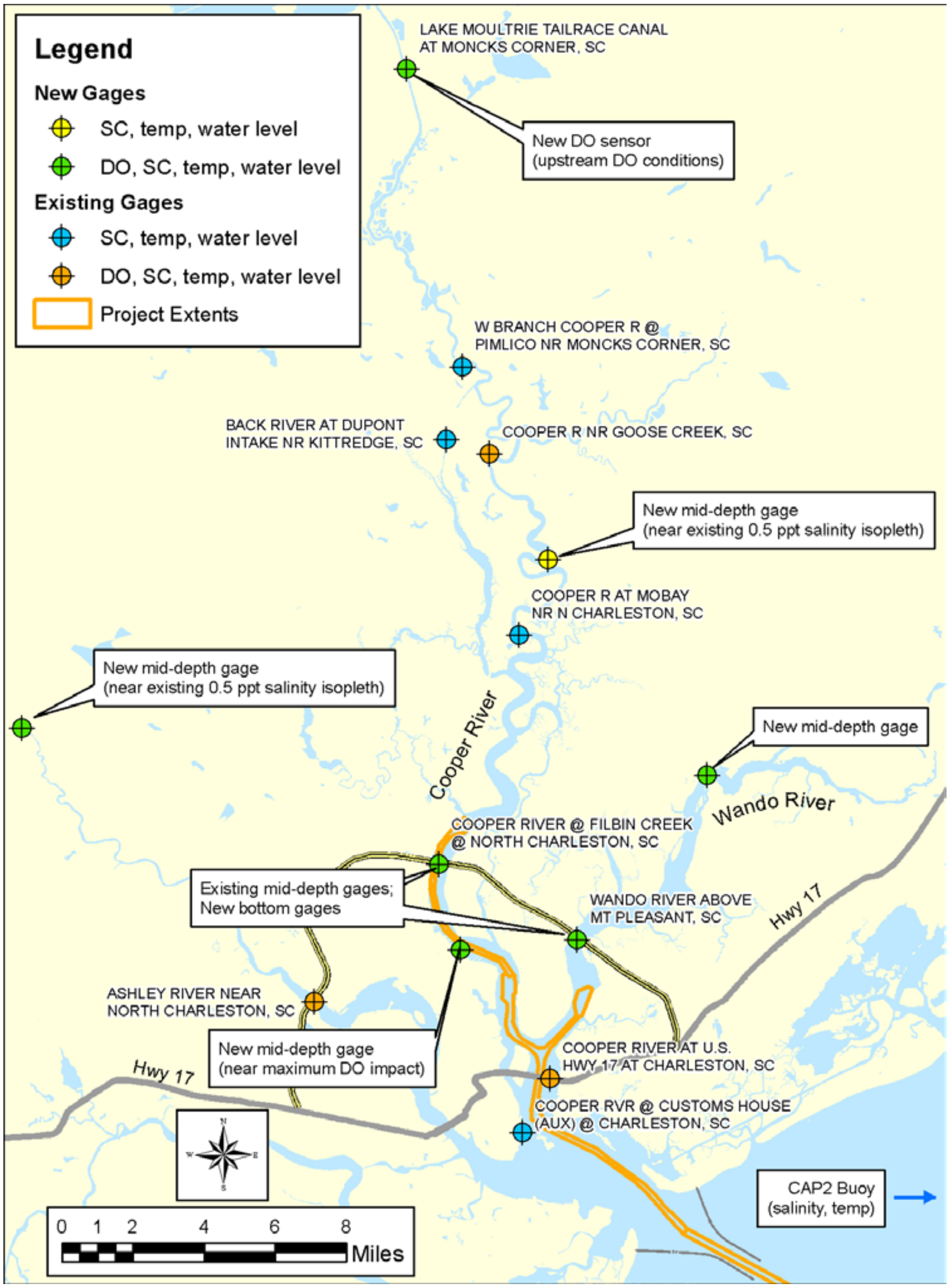

Figure 4-2. New monitoring gages

by the National Weather Service, USGS, the Community Collaborative Rain, Hail and Snow network (CoCoRaHS) and Remote Automatic Weather Stations (RAWS). Rainfall monitoring gages in the study area are shown in Figure 4-3.

4.7 Point Source Discharges

Dischargers to the estuary are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. To comply with the permit, the discharge flows and loads are monitored by the permitted dischargers and reported to DHEC on a monthly basis as Discharge Monitoring Reports

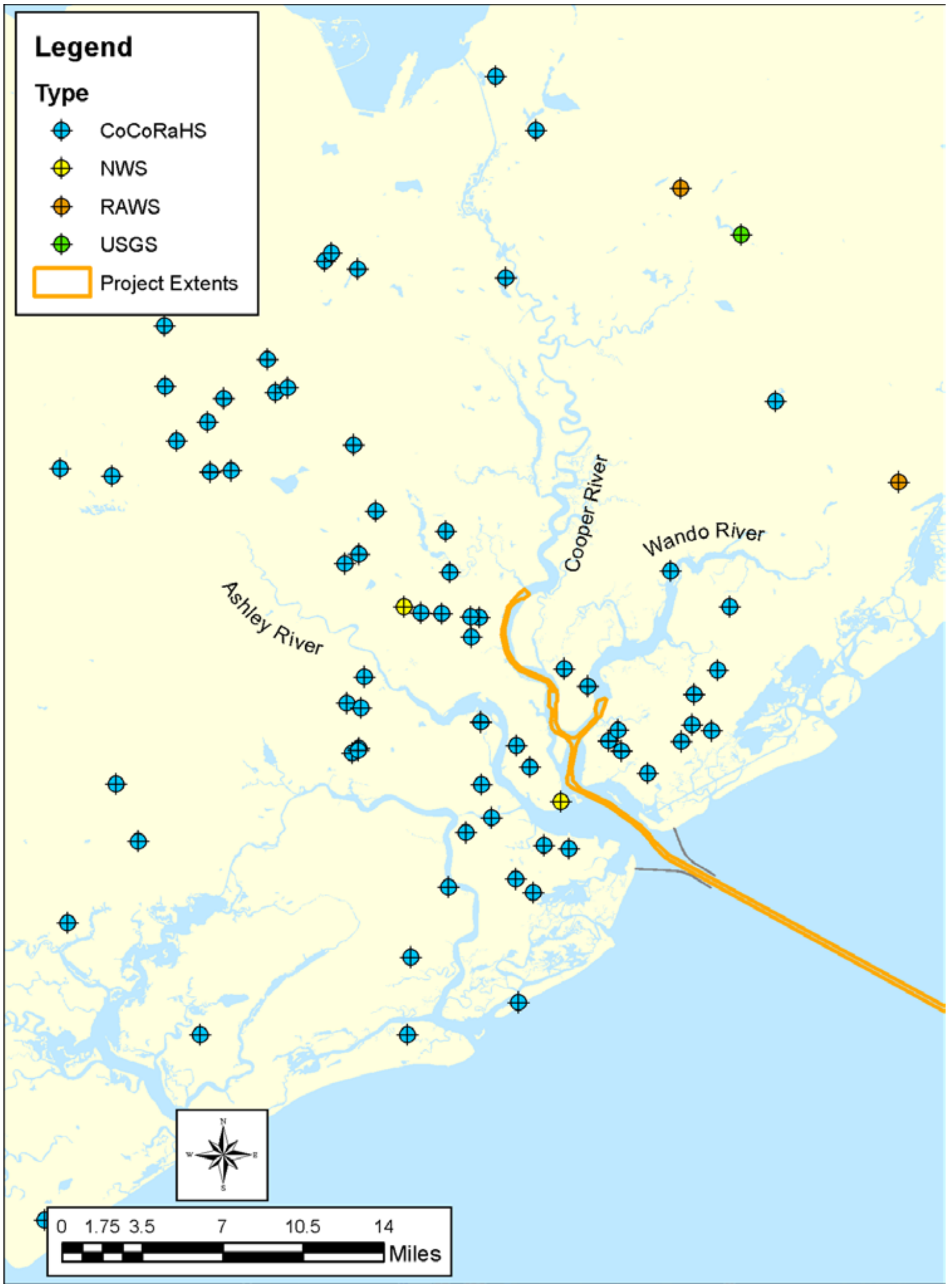

Figure 4-3. Rainfall monitoring gages

(DMR). The DMRs do not include daily monitoring data, but this data is collected by the major point source discharge permittees and can be obtained upon request to the permittees.

4.8 Estuary Water Chemistry

DHEC's Ambient Surface Water Physical & Chemical Monitoring Program includes ongoing fixed-location monitoring and statewide statistical survey monitoring. The fixed-location component of the monitoring network is comprised of Base Sites that are generally sampled every other month, year round. Statistical Survey Monitoring Sites are typically sampled once per month for one year and moved from year to

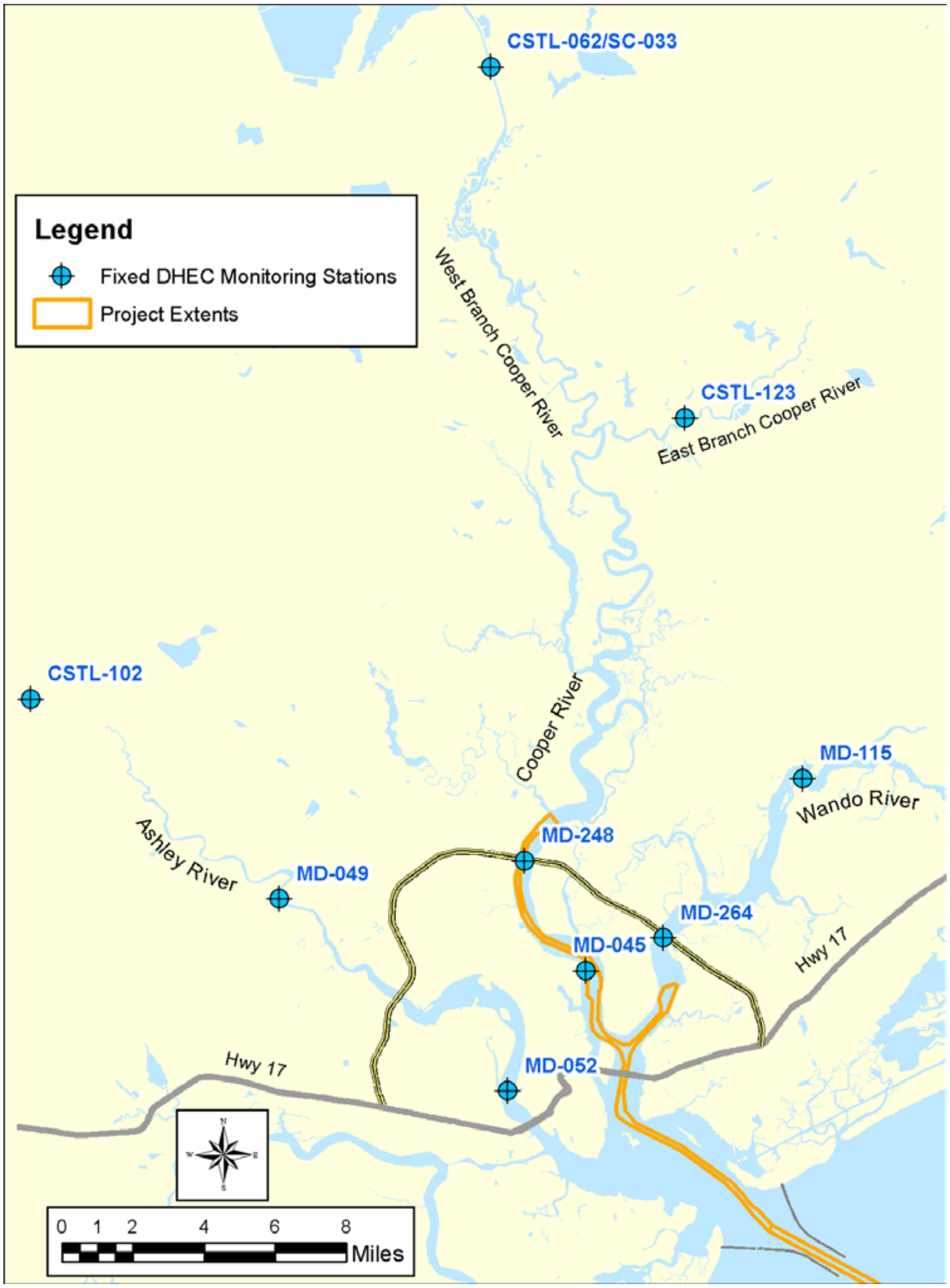

Figure 4-4. DHEC fixed water quality monitoring stations

year. The nine Base Sites in the estuary are shown in Figure 4-4. The bi-monthly parameters analyzed include DO, pH, water temperature, air temperature, specific conductance, salinity, turbidity, BOD5, nitrate/nitrite nitrogen, total phosphorus, alkalinity, ammonia nitrogen and total kjeldahl nitrogen.

4.9 Meteorological Monitoring

In addition to rainfall monitoring, discussed previously, monitoring of other meteorological variables (including wind speed, wind direction and air temperature) is available at the two NWS monitoring stations shown in Figure 4-3, which includes the Charleston International Airport and downtown Charleston.

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