LAKE TECUMSEH (Brinson Inlet Lake) WEIRS PROJECT

POST WEIR MONITORING REPORT

To the Norfolk District Army Corps of Engineers

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Executive Summary

No undesirable or unanticipated effects have been observed since weir establishment in 2011. Rather, the weirs have effectively met performance goals as indicated by a significant increase in average percent cover of herbaceous vegetation among wetland plots and a significant decrease in average percent open water within the lake, based on pre- and post-weir monitoring. No significant increase has been observed in tree mortality since weir establishment and wetland species richness peaked in 2013. The Service and the CNU team conclude that weir presence has remained favorable on wetland vegetative response and other indicators since establishment at Brinson Inlet Lake.

Introduction

Permit conditions. This report provides the 2013 results for yearly monitoring of the weirs project at Lake Tecumseh located in Virginia Beach, VA required by special permit conditions contained in the Nationwide Permits (2) and (27), application number NAO-2006-0939. Two years prior to weir installation as well as three years post weir installation and monitoring are examined.

History. Brinson Inlet Lake (formerly Lake Tecumseh) is a shallow lake in Virginia Beach within the watershed of Back Bay. The Virginia Beach City Council officially changed the name of the lake from Lake Tecumseh to Brinson Inlet Lake following the appeal of descendants of Thomas Brinson, a 17th century land owner who operated a port when the lake was believed to be an inlet to the Atlantic Ocean.

Goals for the weirs. Hydrological data from 2008, including water quality and water level data, indicated that weirs could reduce the release of a portion of an estimated 2,000 tons of annually discharged silt by inhibiting the lower two-thirds of the wind tidal depth range from draining from the lake. Recreational boating was predicted to benefit from the project through an estimated 193 additional days per year of boating provided by the increased water levels that would result from weir installation. Following this preconstruction analysis, two weirs were constructed across two non-natural drainage canals connecting Brinson Inlet Lake with Asheville Bridge Canal. The goals for the weirs were to reduce turbidity discharge to Back Bay estuary, enhance wildlife habitat, restore wetland hydrology, and increase the number of days per year that recreational boats could utilize the lake.

Monitoring and assessment. The purpose for monitoring the area was to observe and report any undesirable or unanticipated effects on wetlands adjacent to the lake in response to the installation and operation of two weirs beginning in February 2011 by the U.S. Fish and Wildlife Service. The area was monitored for such unanticipated effects as change in vegetative community type, conversion of vegetated wetlands to open water, or the transition from one wetland type to another type. Parameters used to monitor and determine post weir effects within established permanent monitoring wetland plots included tree mortality, average percent herbaceous cover, percent open water, plant species richness, and percent

canopy closure. Data were collected in eight 10-meter square tree plots and 24 1-meter square herbaceous plots on September 4 and 5, 2013. The weirs had been established for a total of 32 months when data were collected in experimental plots and a single control plot. Analysis of data included a Paired T-test to determine significant difference in canopy cover between 2012 and 2013. A single factor analysis of variance (ANOVA) was also conducted to determine significant difference in tree mortality, percent herbaceous cover with and without Duckweed (*Lemna minor*) included, and percent open water between years. Subsequent Tukey Tests were also conducted following results of the single factor ANOVA tests.

Educational and recreational benefits. Christopher Newport University has participated in this both for preliminary analysis (as a part of a class) and in data analysis and reporting performed by Dr. Rob Atkinson and Brittany Bowen, a graduate student. Preliminary water nutrient analysis data were collected on a single day in Fall of 2013 by the class and samples were analyzed by Jennings Lab in Newport News. Fish community composition was sampled by the Virginia Department of Game and Inland Fisheries (VDGIF) and results were analyzed by CNU. Anecdotal evidence suggests that considerable benefits have been enjoyed by boaters in the area.

RESULTS

Hydrology

All elevations in this report are to NAVD88 datum. The invert of the primary weir is at elevation +1.0 feet. The secondary weir is higher than +1.0 feet and permits water to flow around through adjacent wetlands. Prior to weir installation at both sites, average flood elevation in the lake was +1.1 feet and depth ranged from -0.74 to +1.8 feet with an overall mean of +0.5 feet (2008-2009 data).

Tree Mortality

Results thus far from monitoring indicate no significant increase in tree mortality between years and a significant increase in canopy cover within experimental plots.

A single factor ANOVA indicated no significant difference in average number of dead trees between years, ($F=0.110$, $p=0.978$) (Table 1). The percentage of dead trees has ranged between and 9% and 12% for every year sampled thus far (Table 1). A Paired T-test, excluding plot D1 that had missing 2012 percent canopy cover data, did indicate that average percent canopy cover within experimental plots experienced a significant increase of 9 points between 2012 and 2013 ($p=0.017$)(Table 1)(Figure 1). Average percent canopy cover also increased a total of 15 points between 2012 and 2013 for the control plot (Table 1).

Table 1. Average number and percent dead trees and canopy cover within 10-meter square tree plots for years 2009-2013 (n=8) in Brinson Inlet Lake, Virginia Beach, Virginia. Results from control plot (n=1) appear in parentheses. ND = Not Determined.

Tree Plots	Pre-Weir		Post-Weir		
	2009	2010	2011	2012	2013
Average Number Dead Trees	3.1	2.4	2.4	2.3	3.1
Percent Dead Trees	12.3 (3.2)	9.9 (9.1)	9.2 (9.1)	9.8 (10.3)	12.63 (10)
Percent Canopy Cover	ND	69 (85)	ND	66 (80)	75 (95)

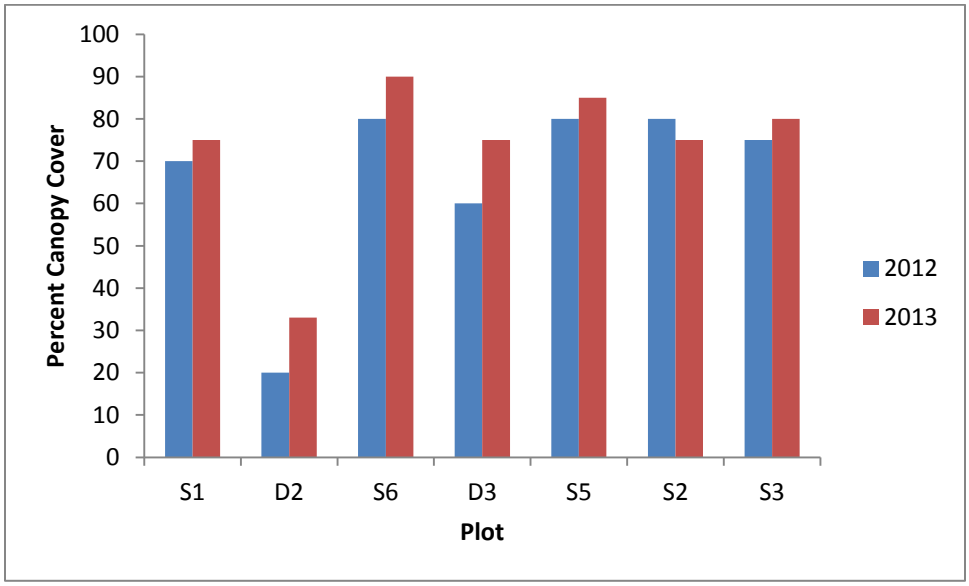


Figure 1. Percent Canopy Cover within 10-meter square tree plots (n=7), excluding Plot D1, in 2012 and 2013, for Brinson Inlet Lake, Virginia Beach, Virginia.

Herbaceous Plant Cover

A single factor ANOVA was conducted between years to determine significance in average percent cover of herbaceous vegetation in experimental plots (Table 2). Results of the ANOVA indicated a significant difference in average percent cover of herbaceous vegetation in experimental plots ($F=19.9$, $p=1.88E-12$). A Tukey Test was conducted to determine what years had significantly different average percent cover of herbaceous vegetation. Results of the Tukey Test indicated a significant increase ($p<0.05$) in average percent cover of herbaceous vegetation between all post-weir years (2011-2013) and all pre-weir years (2009-2010).

A second single factor ANOVA was conducted to determine if a significant difference was present in average percent cover of herbaceous vegetation excluding Duckweed (*Lemna minor*) between years (Table 2). Results of the ANOVA also indicated a significant difference in average percent cover of herbaceous vegetation excluding Duckweed in plots ($F=6.70$, $p=6.94E-05$). A Tukey Test was conducted to determine what years had significantly different average percent cover of herbaceous vegetation excluding Duckweed. Results of the Tukey Test indicated a significant increase ($p<0.05$) in herbaceous percent cover excluding Duckweed between 2013 and pre-weir years 2009 and 2010.

A final single factor ANOVA test was conducted to determine the presence of a significant difference in average percent open water in plots between years (Table 2). Results of the ANOVA indicated a significant difference in percent open water between years ($F=20.37$, $p=1.05E-12$). A Tukey Test was conducted to determine what years differed significantly from one another. Results of the Tukey Test indicated a significant decrease ($p<0.05$) in percent open water in plots between pre- and post-weir years, although percent open water was also found to be significantly lower in 2012 and 2013 when compared to percent open water in 2011.

All statistical results indicate a significant increase in herbaceous vegetation with a corresponding significant decrease in percent open water after the establishment of the weirs. The weirs have not resulted in undesirable effects such as decreased herbaceous vegetation or an increase in open water since establishment. Qualitative photos of the 1-meter square plots for 2013 are in Appendix C (attached CD).

Table 2. Average Percent Cover (APC) of herbaceous vegetation, duckweed, and open water within 1-meter subplots (n=24) for 2009-2013 in Brinson Inlet Lake, Virginia Beach, Virginia. Percentages from the control plot appear in parentheses. ND = Not Determined.

Herbaceous Plots	Pre-Weir		Post-Weir		
	2009	2010	2011	2012	2013
Average Percent Cover	32	36	65	103	87.7
APC Excluding Duckweed	32 (ND)	36 (31)	52 (ND)	51 (20)	77(22)
Average Percent Open Water	69 (ND)	56 (15)	38 (ND)	14 (77)	16(72)

Plant Species Richness and Persistence

Total species richness present at all plots during the four-year monitoring period (2009-2013) was 31 species (Table 3). Highest species richness was recorded post weir installation, in 2013 (Table 3). Four species were solely present prior to weir installation with ten species solely present in plots after weir installation (Table 3). The control plot had approximately half the number of species as all other plots in most years; though in 2013, the control plot had less than half the number of species present in all other plots (Table 3).

Two species, Tearthumb (*Polygonum arifolium*) and Duckweed (*Lemna minor*), were found to dominate herbaceous cover in plots and exhibited average percent cover >10% (Figure 2). The top five species most abundant in plots also included *Poaceae* sp., Common Reed (*Phragmites australis*), and Lizard's Tail (*Saururus cernuus*)(Figure 2).

Table 3. Species presence and total number of species in experimental plots pre- and post-weir installation and control plot, by year, for Brinson Inlet Lake, Virginia Beach, Virginia.

Species Presence/Persistence	All	Pre-Weir		Post-Weir		
	Control	2009	2010	2011	2012	2013
Bald Cypress (*Taxodium distichum*)	X	X	X	X	X	X
Swamp Tupelo (*Nyssa sylvatica*)	X	X	X	X	X	X
Red Maple (*Acer rubrum*)	X	X	X	X	X	X
Sweet Gum (*Liquidambar styraciflua*)		X	X	X	X	X
Swamp Cottonwood (*Populus heterophyla*)		X	X	X	X	X
Wax Myrtle (*Myrica cerifera*)	X	X	X	X	X	X
Baccharis (*Baccharis halimifolia*)		X	X	X	X	X
Loblolly Pine (*Pinus taeda*)		X	X	X		
Tearthumb (*Polygonum arifolium*)		X	X	X	X	X
Rice Cutgrass (*Leersia oryzoides*)		X	X	X	X	X
Sedge (*Carex* sp.)	X	X	X	X	X	X
Lizard's Tail (*Saururus cernuus*)	X	X	X	X	X	X

Arrow Arum (*Peltandra virginica*)	X	X	X	X	X	X
Swamp Loosestrife (*Decodon verticilliatus*)		X	X	X	X	X
Marsh Fleabane (*Pluchea foetida*)		X	X	X	X	
False Nettle (*Boehmeria cylindrica*)		X	X	X	X	X
Soft Rush (*Juncus effusus*)		X	X	X	X	X
Royal Fern (*Osmunda regalis*)	X	X	X	X	X	X
Spongeplant (*Limnobium spongia*)		X	X	X	X	X
Common Reed (*Phragmites australis*)	X	X	X	X	X	X
Pennywort (*Hydrocotyle* sp.)	X	X	X	X	X	X
Cattail (*Typha* sp.)		X		X	X	X
Smartweed (*Polygonum* sp.)		X		X	X	X
Virginia Day-flower (*Commelina virginica*)		X		X	X	
Water Hemlock (*Cicuta maculata*)		X	X	X		
Mallow (*Malva* sp.)	X		X		X	X
Goldenclub (*Orontium aquaticum*)		X	X			
Primrose Willow (*Ludwigia* sp.)		X	X			
Pickerelweed (*Pontederia cordata*)				X	X	X
Big Cordgrass (*Spartina cynosuroides*)		X				
Three Way Sedge (*Dulichium arundinaceum*)			X			X
Catbrier (*Smilax* sp.)	X					X
Wild Rose (*Rosa* sp.)	X					
Poison Ivy (*Rhus toxicodendron*)		X				
Bedstraw (*Galium* sp.)				X		X
Buttercup (*Rununculus* sp.)				X		
Eurasian Milfoil (*Myriophyllum spicatum*)				X		
Sagitarria sp.						X
Murdannia keisak						X
Duckweed (*Lemna minor*)				X	X	X
Wild Rice (*Zizania* sp.)						X
Wild Celery (*Angelica* sp.)						X
TOTAL NUMBER SPECIES	13	29	26	30	26	31

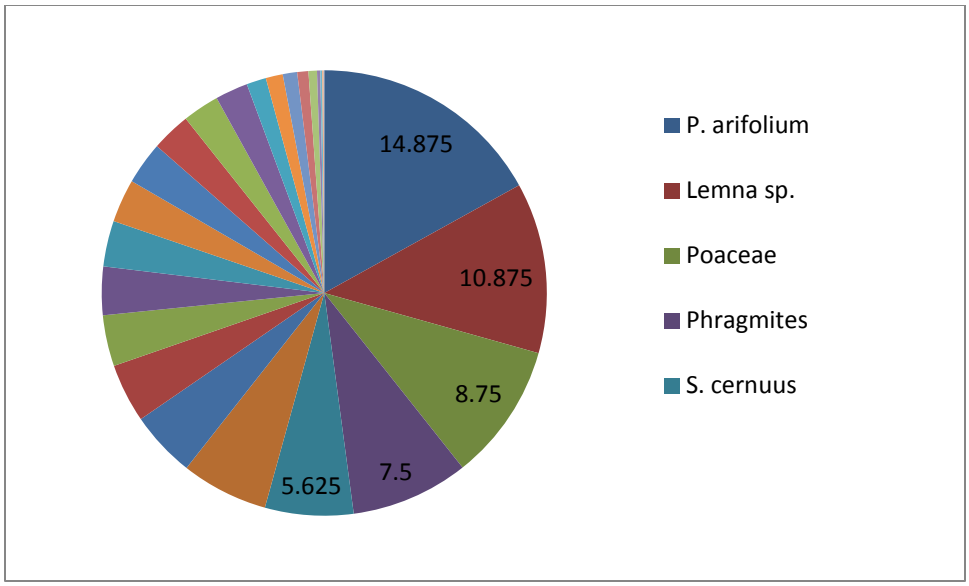


Figure 2. Species abundance (average percent cover) and top five most abundant species present in experimental 1-meter subplots (n=24) in 2013 in Brinson Inlet Lake, Virginia Beach, Virginia.

Preliminary Water Nutrient and Oxygen Analyses

Phosphorus levels and Total Kjeldahl Nitrogen were sampled at Brinson Inlet Lake on a single day in Fall of 2013. Results yielded phosphorus levels at or above the 0.02 mg/L threshold defined by Gibson et al. (2000) for lake conditions, suggesting mesotrophic conditions at two sampling sites and marginally-eutrophic conditions at two sampling sites (Table 4), which could increase growth of algae such as *Cladophora* sp. which is present in the lake. Dissolved oxygen levels were only sampled on one occasion in fall 2013 and were much higher than the 5.0 mg/L threshold discussed by Walker et al. (2007) for aquatic life in two sampled locations in the lake (Figure 3).

Table 4. Total Kjeldahl Nitrogen and Total Phosphorus concentrations at two sampling locations in 2013 in Brinson Inlet Lake, Virginia Beach, Virginia.

Nutrient Analysis	Location 1		Location 2	
	Subsite a	Subsite b	Subsite a	Subsite b
Total Kjeldahl Nitrogen	1.18 mg/L	1.18 mg/L	1.15 mg/L	2.39 mg/L
Total Phosphorus	0.02 mg/L	0.02 mg/L	0.05 mg/L	0.12 mg/L

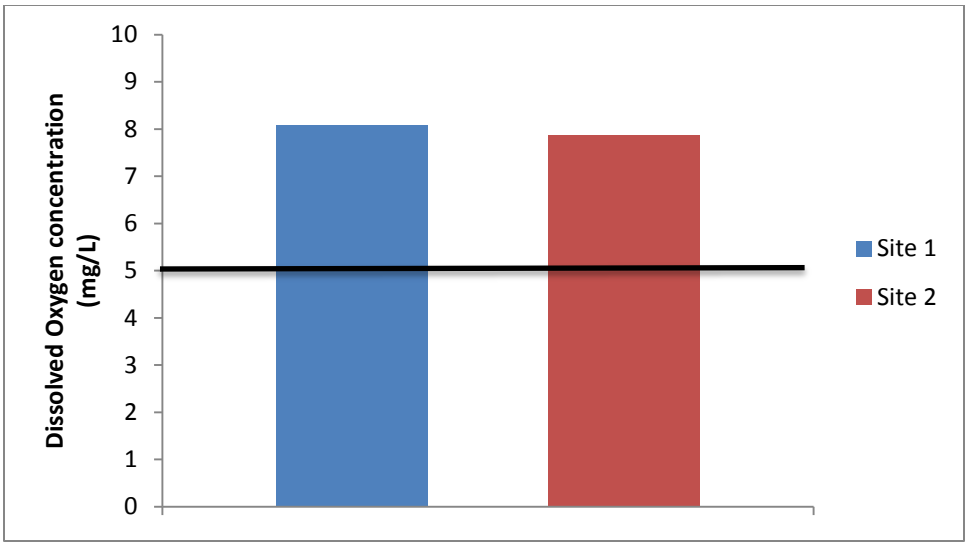


Figure 3. Dissolved Oxygen concentrations for two sampled sites in the lake in 2013. Brinson Inlet Lake, Virginia Beach, Virginia. Threshold of 5.0 mg/L is indicated by the black, horizontal line.

An electroshock census of fish in the lake showed an increase in fish commonly found in eutrophic aquatic systems, including Redear Sunfish (*Lepomis microlophus*) and Golden Shiner (*Notemigonus crysoleucas*)(Bachmann et al., 1996)(Table 5).

Table 5. Frequency of occurrence (% of samples in which a species occurs) of five most frequently encountered species of fish during electroshock sampling in 2013 in Brinson Inlet Lake, Virginia Beach, Virginia.

Species	Percent Occurrence
Bluegill (*Lepomis macrochirus*)	20.1
Redear Sunfish (*Lepomis microlophus*)	19.2
Yellow Perch (*Perca flavescens*)	14.5
Golden Shiner (*Notemigonus crysoleucas*)	9.7
Pumpkinseed (*Lepomis gibbosus*)	8.7

Conclusion

No undesirable or unanticipated effects have been observed since weir establishment in 2011. Rather, the weirs have effectively met performance goals as indicated by a significant increase in average percent cover of herbaceous vegetation among wetland plots and a significant decrease in average percent open water within the lake, based on pre- and post-weir monitoring. No significant increase has been observed in tree mortality since weir establishment and wetland species richness peaked in 2013. Preliminary water nutrient levels, including Total Phosphorus and Total Kjeldahl Nitrogen, and an abundance of specific fish species in the lake signal the presence of mesotrophic to marginally-eutrophic conditions. Unlike deeper lakes which may exhibit diminished ecosystem health and eutrophication effects associated with hypoxia, dissolved oxygen concentrations remain high in Brinson Inlet Lake, probably as a result of the naturally shallow depth; therefore aquatic life is thriving in the lake. Based on our review of yearly monitoring results, the Service and the CNU team conclude that weir presence at Brinson Inlet Lake has remained favorable on wetland vegetative response and other indicators.

Works Cited

Bachmann, R. W., B. L. Jones, D. D. Fox, M. Hoyer, L. A. Bull, and D. E. Canfield, Jr. 1996. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Canadian Journal of Fisheries and Aquatic Sciences 53:842-855.

Gibson, G., R. Carlson, J. Simpson, E. Smeltzer, J. Gerritson, S. Chapra, S. Heiskary, J. Jones, and R. Kennedy. 2000. Nutrient Criteria Technical Guidance Manual Lakes and Reservoirs. United States Environmental Protection Agency, Washington D.C., USA.

Walker, J. L., T. Younos, and C. E. Zipper. 2007. Nutrients in lakes and reservoirs – a literature review for use in nutrient criteria development. Virginia Water Resources Research Center: 1-100.

List of Appendices

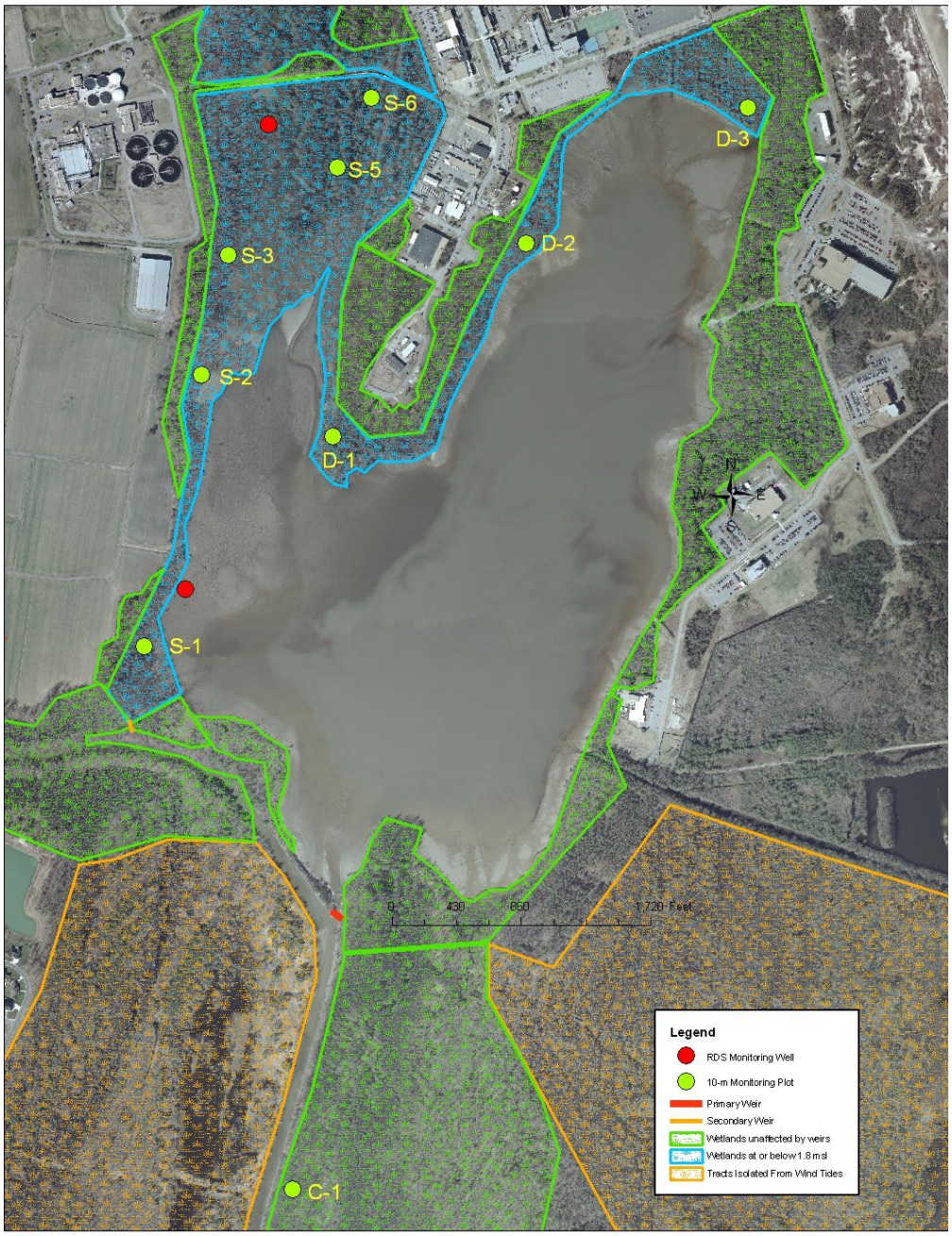
Appendix A: Monitoring Plot Location Map

Appendix B: Nationwide Permit certification with special conditions dated March 11, 2010.

Appendix C: 2013 qualitative photographs of monitoring plots on CD

Appendix A: Monitoring Plot Location Map for Brinson Inlet Lake, Virginia Beach, Virginia. Hydrology area within blue polygon is monitored area for effects by installed weirs.

Wetlands Associated With Proposed Weirs
Lake Tecumseh, Virginia Beach, Virginia
Total Wetlands = 104 acres
Total Forested Wetlands = 66 acres



Appendix B: Nationwide Permit Certification

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