

# **HYDROLOGIC & ECOLOGIC DESIGN TOOLS FOR THE PRESERVATION AND MANAGEMENT OF THE SWEETBAY WETLAND, ST. ANDREWS BAY**

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## **ABSTRACT**

The Northwest Florida Water Management District has documented an approach to the preservation of wetland systems as specifically related to the hydrology and ecology of wetland systems and watershed restoration. The analytical techniques and methodology discussed are demonstrated through a pilot study developed for a wetland preservation project in the City of Panama City, Florida. They are particularly useful in urban areas. While hydromodification effects on the wetland studied are severe, the major finding is that the existing wetlands in this community can be restored and maintained in a manner that is consistent with stormwater management objectives. If a comprehensive wetlands preservation/restoration program were undertaken in unison with the development of the City's stormwater management system, a considerable cost savings could be realized. Recommendations and alternatives made by the District are intended to be part of a management plan to preserve and restore the wetland studied. Detailed designs and permits for construction will be required for the City to implement this plan. Monitoring is recommended to evaluate the long term success of the project, and so that management can be better informed to maintain the health of the system. A stormwater management model with long term continuous simulation capabilities was used as the primary analytical tool to consider existing conditions and alternatives. All of the information compiled is typical of that for developing state-of-the-art master plans for stormwater management.

## **INTRODUCTION**

The wetland and watershed area studied for this project are located in Panama City, a coastal community situated on the waters of St. Andrew Bay. The project site, referred to as the Sweetbay Wetlands, receives its water from a small watershed with an area of about 27.4 hectares (69.4 acres). The primary sources of surface inputs are from stormwater runoff, baseflow under saturated soil conditions, and direct precipitation. Drainage to the wetland is almost entirely through man-made conveyances, including an open ditch and storm sewer system. To better delineate these conveyances and the wetland site itself, the watershed was divided into five subwatersheds. The watershed is largely developed with a variety of land uses characteristic of urban areas. The only exception is the undeveloped wetlands area, which is a native forest that has a distinctive cover of Sweetbay trees.

Soils data were obtained from an updated 1984 soil survey for Bay County and digitized into a Geographical Information System (GIS) as a watershed overlay. All the soils in the watershed are sandy and associated with a hydraulic conductivity value of 38.1 cm/hr (15 in/hr). The water table is generally shallow, but for most of the year is greater than 1 meter (3 feet) below land surface. In low areas, including the ditch and wetlands, the water table may be at or near the surface for most of the year. Within the wetlands area, soils are mucky fine sands, exhibiting characteristics of regular inundation. The predominant soil map unit in the wetland is Rutledge sand, recognized as hydric. Land gradients in the study area are flat to moderate (0 to 5 percent slopes), tending to have slow rates of runoff and low erosion potential. Channel cross section and storm pipe invert elevations collected by City surveying crews were used to supplement the topographic survey data.

Land use in the watershed is almost entirely urban, including single-family residential, mixed use, and general commercial categories. The western and northern boundary of the wetland site extends to the back yards of single-family residential housing along Grant and 19th Streets. Commercial development fronting U.S. Highway 98 is located south of the project site. Commercial and multifamily housing are the primary development to the east of the wetland. According to aerial photographs and the City's land use maps, the wetland site is one of the very few non-developed sites left in the watershed. Future land uses fall in the general commercial and mixed use categories. Although much of the remaining undeveloped area has been platted into residential or commercial lots, very few of these lots are considered buildable because of the extent of the jurisdictional wetlands on the project site.

The Sweetbay Wetland is located within a 7.9 hectare (20 acre) block of land on the southwest corner of the intersection between Michigan Avenue and 19th Street. The wetlands on the project site amount to about 1.6 hectares (4 acres). The wetlands are contiguous with North Bay through a ditch that extends east-west across the properties in this block. This ditch continues westward off the project site to the Isabella Avenue right-of-way. From here, the ditch turns northward and continues through a culvert under 19th Street. The ditch continues northward along Isabella Avenue and empties into a large east-west canal, parallel to the Atlanta and St. Andrews Bay Railroad. This canal heads westward across Mound Avenue, where it turns northwest and continues in that direction until it empties into Posten Bayou. Posten Bayou then empties into North Bay, a Class II waterbody. According to jurisdictional determinations, the ditch and the connected wetlands are Waters of the State.

The site is predominately native forest communities including floodplain swamp, upland mixed forest, wet flatwoods, and xeric hammock. As a forested wetland, it is intermittently flooded from stormwater runoff. The inner and lowermost portions are seasonally flooded due to high rainfall amounts and a high water table. The wetland falls within an ecoregion classified as a subtropical coastal plain forest and is a Palustrine system dominated with Sweetbay. Although its water level has been artificially lowered, the area is still classified as a wetland because soil moisture is sufficient to support

hydrophytes. The ditch which runs through the wetland is a natural stream which was widened and deepened by the Bay County Mosquito Control District in the late 1930's. The spoil from this excavation was placed on the north side of the ditch. This creates a berm which isolates portions of a bottomland forest from waters of the state. At two areas, there are breaks in the spoil which allow surface water flow between portions of the forest and the ditch. The area to the south of the ditch appears to be relatively undisturbed. The trees in this area form a closed canopy and are approximately 24.4 to 30.5 meters (80 to 100 feet) tall with diameters at breast height ranging between 20 cm. (8 inches) and 30 cm. (12 inches).

Historically, much of the present day wetland system was part of a larger drainage system that consisted of an additional upland wetlands area of about 15.8 hectares (40 acres) and natural watershed area of about 39.5 hectares (100 acres). The stream which flowed from the historical upland and wetland areas to the present day wetland was identified on a 1943 edition of US Geological Survey Panama City Quadrangle (7.5 minute topographic map). According to later maps (USGS, 1956), the larger system had been dissected through construction of a roadway and development. These development activities, as well as ditch excavations, have altered the hydrology of the remaining wetland area.

The conveyance system for the Sweetbay wetland consists of a combination of storm sewers, culverts, and open channels, with the main drainage feature being an open channel that runs generally east to west over the entire length of the watershed. The channel is relatively flat with less than 0.3 meters (1 foot) of grade change for its entire length. This flat slope condition results in low channel velocities that allow sedimentation to take place in the channel, observed at several of the culverts crossing this channel. The southwest corner of the watershed, bounded by Highway 98 to the north and Michigan Avenue to the east, is collected in a storm sewer system along Highway 98 and discharged through a 61 cm. (24 inch) concrete pipe directly into the Sweetbay wetland. In the southeast corner of the basin, runoff originating from an area bounded by Highway 98 to the north and Michigan Avenue to the west is collected in a storm sewer system along Highway 98 and piped through a 107 cm. (42 inch) concrete pipe to a point of discharge into the main open channel. This open channel starts on the west side of Deer Avenue, midway between Highway 98 and 19th Street, and flows west toward Michigan Avenue. The channel also intercepts and conveys runoff from the area of the watershed that is bounded by Highway 98 to the south, Michigan Avenue to the west, and 19th Street to the north. Two roads, one paved and one dirt, both with sets of triple 76 cm. (30 inch) concrete culverts, cross the open channel upstream of Michigan Avenue. The open channel crosses under Michigan Avenue through a 0.9 by 1.8 meter (3 feet by 6 feet), 22.3 meter (73 feet) long concrete box culvert and enters the wetland area. The channel continues to the northwest corner the wetland to a point of ultimate discharge through a 1.2 meter by 2.1 meter (4 feet by 7 feet), 24.4 meter (80 feet) long concrete box culvert. The box culvert was found to contain approximately 0.5 meters (1.6 feet) of sediment throughout its length. This sedimentation and corresponding loss of flow area was taken into consideration as part of hydraulic analysis of the drainage system.

The upstream opening of the box culvert at 19th Street is the point at which all flow and rainfall data was collected for this study. Rainfall over the study area was collected in an automated tipping bucket, and 10-minute continuous water surface elevations in the culvert were recorded using a Handar stage recorder. The only area noted within the watershed that is subject to flooding is a low area located in the southeastern portion of the study area. The area is located in a depression on the south side of Highway 98 where Deer Avenue intersects the highway. Street and lawn flooding are the primary problems at this intersection; no structures appear impacted. The cause of the flooding appears to be the capacity of the drop inlets located in the depression.

## MATERIALS AND METHODS

The basic analytical or analysis tool used for this study is the U.S. EPA Stormwater Management Model (SWMM). SWMM is a comprehensive mathematical model that simulates urban runoff quantity and quality in stormwater management systems by simulating transport through the drainage network and storage areas. The model has the capability of performing detailed hydraulic flow routing for the purpose of evaluating flooding through an extended transport block. The model can simulate individual events such as critical design storms or continuous long-term hydrologic series of any period of time. Through the simulation of long-term hydrologic series from historic records of rainfall, the model is capable of evaluating peak discharge conditions associated with extreme flooding events.

Although the model did not automatically interface with the GIS database system, it was very easy to manually input all of the data developed through the GIS in an interactive format. The model data assigned to each subcatchment and used for calibration is provided in Table 1. Observed runoff and rainfall data used for calibration were obtained from the stream flow monitoring station installed for this study at the wetland outlet on 19th Street. The model was calibrated for three storm events in March and April. As a model verification step, Hurricane Erin (1995) was simulated and compared to observed data. Both flows and water levels reproduced by the calibrated model indicated that it was quite capable of reproducing stormwater runoff from the urban areas in the watershed. A summary of model calibration and verification results are provided in Table 2.

**Table 1. Calibrated Model Parameters.**

Subwatershed	Width	Area	%Imp	Slope	ImpN	PerN	IDS	PDS	Su	Ks	IMD
5	550.0	20.79	27.70	0.00430	0.015	0.30	0.05	0.30	4.0	15.0	0.30
3	650.0	13.18	22.02	0.00698	0.015	0.30	0.05	0.30	4.0	15.0	0.30
2	565.0	5.31	28.46	0.00117	0.015	0.30	0.05	0.30	4.0	15.0	0.30
1	650.0	21.17	19.18	0.01298	0.015	0.30	0.05	0.30	4.0	15.0	0.30

4	300.0	8.91	30.32	0.01307	0.015	0.30	0.05	0.30	4.0	15.0	0.30
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%Imp: Percentage Imperviousness  
 Slope: Average slope of the subwatershed  
 ImpN: Roughness Coefficient for Impervious Area  
 PerN: Roughness Coefficient for Pervious Area  
 IDS: Depression Storage for Impervious Area.(In)  
 PDS: Depression Storage for Pervious Area.(In)  
 Su: Suction Coefficient(ft)  
 Ks: Coefficient of Permeability(ft/sec)  
 IMD: Initial Moisture Deficit (ft/ft)

**Table 2. Model Calibration Results**

	Rain Intensity (in/hr)	Total Rain (In)	Volume (acre-ft)			Peak Flow (cfs)		
			Simulated	Observed	%Error	Simulated	Observed	%Error
<b>Storm 1</b>	0.35	0.84	7.79	8.03	-3.08	1.79	1.66	7.26
<b>Storm 2</b>	0.46	0.42	6.48	7.13	-10.03	1.16	1.17	-0.86
<b>Storm 3</b>	0.39	0.43	9.73	9.48	2.57	1.21	1.14	5.79
<b>Verification Storm</b>	0.49	1.72	38.49	42.15	-9.51	1.36	1.57	-15.44

To evaluate the current hydrologic conditions in the watershed, the validated model was run in a continuous manner using long term records of hourly rainfall available from the National Weather Service records. Missing data in the long term rainfall records were supplemented with nearby weather station data at Apalachicola and Niceville stations when necessary. A total of 44 years of rainfall record was used. Average annual rainfall from this record was 140.9 cm. (55.48 inches). Over the same record, the maximum one-hour rainfall amount was 9.1 cm. (3.6 inches), and the maximum single storm amount was 39.3 cm. (15.48 inches). The model results for the existing condition are summarized in Table 3. The maximum discharge and water level elevations provide baseline values. In general, none of the alternatives should exceed these values as this could cause upstream flood damage liability.

**Table 3 . Daily Flows Statistics for Existing Condition Simulation**

	Flow (cfs)	Elevation (ft)
<b>Min. Value</b>	0.238	4.08
<b>Max. Value</b>	26.8	6.26
<b>Average</b>	0.353	4.12
<b>Std. Deviation</b>	0.366	0.147

To evaluate natural hydrologic conditions, the long-term rainfall record was used but the watershed area was increased to 68.3 hectares (173 acres) and model parameters were adjusted to reflect a historic condition where most of the watershed was undeveloped. This resulted in a model with greater watershed area and an increase in depression storage based on sandy soil and shallow water table conditions, to simulate the soil moisture storage capacity and high infiltration rates of the native soils in the

watershed. The baseflow component was also adjusted to reflect the increased groundwater contribution that would have occurred due to the increase in stream channel length. The baseflow per channel length computed from a baseflow separation of the observed streamflow records was used to extrapolate the natural condition baseflow, which amounted to 0.012 m<sup>3</sup>/s (0.42 cfs). To reflect the natural topography of the wetland, the excavated portion of the existing channel was reduced by an average depth of 0.3 meters (1 foot).

The natural condition model results are provided as summary statistics in Table 4. As expected, these results reflect more attenuated flood flows and a larger total volume contribution to the wetland than the existing condition. Mean and minimum water levels are also higher due to the larger baseflow contribution under natural conditions. Due to a lack of data, the model does not reflect conditions in which baseflow would cease as result of varying water table depth. In reality, the wetland would occasionally dry out due to a varying watertable condition.

**Table 4. Daily Flows Statistics for Natural Conditions Model**

	<b>Flow (cfs)</b>	<b>Elevation (ft)</b>
<b>Min. Value</b>	0.393	5.38
<b>Max. Value</b>	16.72	6.16
<b>Average</b>	0.500	5.45
<b>Std. Deviation</b>	0.4428	0.0977

Alternative analysis was primarily directed at modifying the 19th Street outlet so that future flows to wetland would emulate the historical natural condition. The basic water level control strategy was to try different types of outlets and to simulate these outlets with SWMM until the desired condition was met. Plants in the wetland were considered to represent a long-term history of inundation on the site. Although not a direct measure of water elevations, the coverage of submerged and transitional plant species and the jurisdictional areas of the wetland provided an indication of the historical area of inundation. The dominance of submerged species generally fall at or below the 1.5 meter (5 foot) contour, whereas the transitional wetland species are dominant above the 1.5 meter elevation to a maximum elevation of about 1.8 meters (6 feet), msl. The outer fringe of the wetlands jurisdictional boundaries are also predominantly at or below the 1.8 meter elevation. In addition, the hydric soils fall at or below the 1.8 meter contour. Thus, a mean water elevation of 1.5 meters, msl with periodic flooding above this elevation appeared to be a suitable target.

Several alternatives were considered to see if the basic water level and flood control strategy would be met and to determine the benefits of each. This analysis included the existing condition, the “no action” alternative, because it was thought that one of the feasible alternatives was to simply not clean out the sediments in the box culvert under 19th Street. Maintaining the existing grade in the culvert results in outflows from the wetland that are lower than that which would occur if the ditch were more frequently maintained. A second alternative was to restrict the channel as much as possible by allowing an increase in water depth in the wetland to as much as 0.6 meters

(2 feet). The outlet configuration for this scenario was a weir set at elevation of 0.8 meters (2.5 feet) above the current bottom of the channel with a very steep v-notch to allow the wetland to completely drain between storms. Due to high flow and flood level conditions during low frequency storms, this alternative was not recommended. The third alternative was to develop a design that would have an increased storage capacity but allow extreme high flows to pass the weir in excess of the capacity of the existing box culvert under 19th Street. This took the form of a v-notch weir at 0.5 meters (1.5 feet) above the current channel bottom.

Based on the model results, the third alternative was the selected alternative. In order to evaluate potential upstream flooding problems with and without outlet modifications, the 25-year and 100-year return period design storms were simulated for the existing condition and Alternative 3. Rainfall input to the model for these analyses were critical period design storms. The model results indicated there would be no increase in flooding in upstream locations when compared to the existing conditions simulations. The flooding problems diagnosed in the watershed are primarily due to tailwater conditions in the culverts at upstream locations in the channel. When the capacity of the box culvert under 19th Street was increased (cross sectional area enlarged), the Alternative 3 outlet modifications were actually an improvement over the existing condition.

## **DISCUSSION AND CONCLUSIONS**

The Sweetbay Wetlands in the City of Panama City were an ideally suited test site for demonstrating the concept of using a state of the art hydrologic model and analysis techniques to plan for the preservation and management of wetlands systems. The major finding of the analysis is that the wetland studied can be restored and maintained in a manner that is consistent with stormwater management objectives. The primary functional values identified for the wetlands studied were nutrient removal and transformation, sediment and chemical contaminants retention, and attenuation of flood waters. All of these attributes are due to the size and storage capacity of the wetland relative to the size of watershed. The artificial creation of a system of similar capacity, such as a wet detention pond, would be considerably more expensive, even cost prohibitive. Like most flood control systems, the selected alternative for modifying the outlet of the wetland will attenuate moderate storm events to reduce downstream flooding problems. The outlet was designed to pass the more extreme storm events associated with a 25-year or greater return period. This was to prevent any increase in upstream flooding liabilities. When the selected alternative is undertaken in conjunction with the City's overall stormwater management plan, a considerable cost savings, as well as the benefits of a healthy, green, passive recreational area should be realized.

The tasks to protect and restore the health of the wetland are to return the site to a more natural state, before the stream was dredged in the 1930's, by increasing inundation and removing exotics. These tasks can be achieved by efforts to re-establish the original inundation cycle of the wetlands which existed prior to the channelization of the stream.

To accomplish this task, a weir will need to be constructed at the wetland outlet. This structure will also increase water treatment and exhibit the natural role of wetlands for supplying a freshwater supply to the downstream estuarine system. Stress on the climax swamp overstory, dominated by Sweet Bay, will be reduced by increasing the flooding frequency and holding more water in the wetland for saturating soils and increasing the water table. The Chain Fern which is more prolific now than prior to channelization will diminish and the environment will be less hospitable to exotics when the area is more frequently inundated. A small number of exotics which have invaded this area may need to be removed by hand to re-establish the integrity of the native plant community. There are three main components of the hydrologic restoration plan for the project site as follows:

1. Adjustment of site hydrology to a more natural condition;
2. Adjustment of hydroperiod to sustain the growth of desirable wetland plant species and habitat; and
3. Increased detention time to increase water quality function and avoidance of flooding problems.

Completion of the hydrologic restoration plan is contingent upon the completion detailed design work and material specifications. The v-notch area of the weir should be designed with maximum flexibility so that if needed, the wetland can be completely drained or a different orifice installed. Additional surveying work is recommended to set the weir at the proper elevation. As part of this plan, it is critical when installing the weir, that the culvert under 19th Street be dredged and later maintained in a clean condition. However, in the interim period prior to construction of the weir, it is not recommended to lower the existing bottom channel through the box since this would only result in increased channelization and possibly increased stress on the wetland. The inlet box culvert on Michigan Avenue should be routinely cleaned to avoid upstream flooding problems.

As an enhancement to the project, a small presettling basin or sediment sump could be created with a trash rack just east of Michigan Avenue at the inflow culvert. This forbay or sediment trapping area would be beneficial once the ditch within the wetland area has naturally filled in and stabilized with vegetation. The sump would allow for removal of excessive sediments and provide for better litter control. An alternative to the sump is to deepen the existing inflow channel to elevations slightly below the inverts of the existing culverts. Routine maintenance of the inflow channel involving sediment removal would still be required. The trash rack would help with the maintenance of the wetland property. Another consideration is to limit the extent of boardwalks into the wetland to areas of previous soil disturbance and higher elevations such as the old spoil bank.

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