Effects of water control structures on sediment characteristics and channel morphology in estuarine systems in Southwest Florida

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ABSTRACT

Water control structures are used to prevent salt-water intrusion and control flooding. They frequently result in pulsing of fresh water into estuarine systems. The purpose of this study is to determine if water control structures influence channel morphology and sediment characteristics. Channel morphologies have been measured along cross-channel transects in four estuaries in the southwest Florida area (Figure 1): Henderson Creek, Faka-Union Canal, Blackwater River, and Cocohatchee Canal. Henderson, Faka-Union, and Cocahatchee are each controlled by a different type of water control structure. Blackwater River has no water control structure and has been used as a control for comparison. In addition to testing the effect of water control structure versus no water control structure, channel morphology has been compared above and below each water control structure during the dry season in June and wet season in November. Sediment characteristics have been determined for each of the areas along transects and through time. These data are being used to determine how each type of water control structure affects the sedimentology within the channel, as well as how channel morphology responds to the presence of a structure.

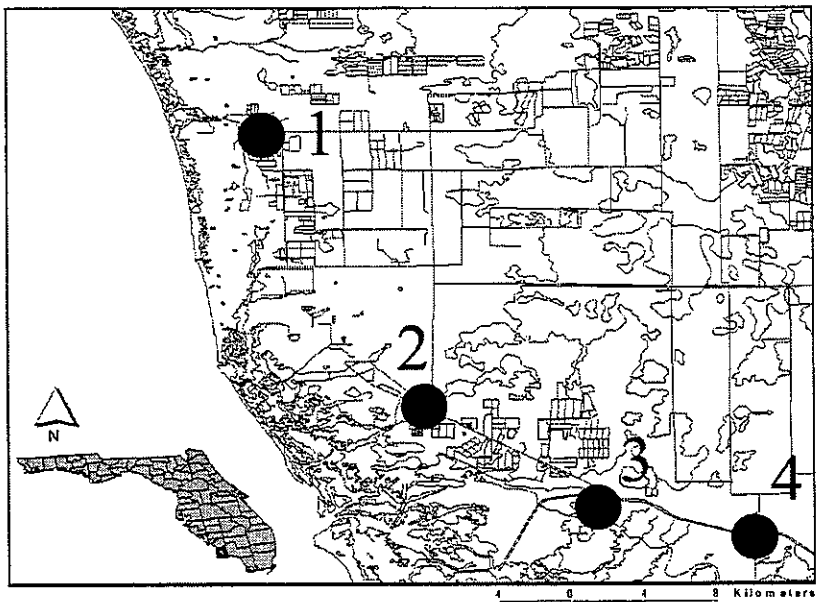


Figure 1: Map showing locations of 1) Cocohatchee Canal, 2) Henderson Creek, 3) Blackwater River, 4) Faka-Union Canal.

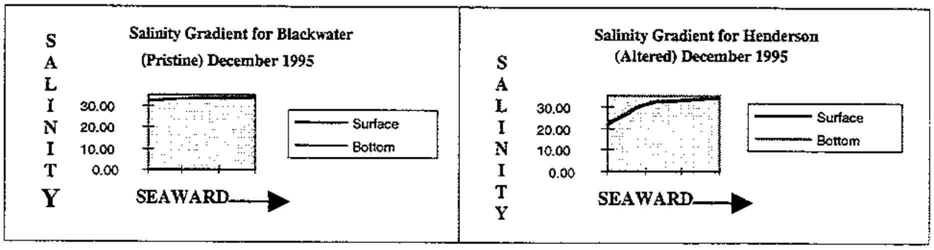
INTRODUCTION

The Southwest Florida estuarine system is the subject of this study. Freshwater is delivered to this estuarine system through a series of natural rivers and man-made channels. Many of these channels have a water control structure in place to prevent salt-water intrusion, control flooding and promote aquifer recharge. Freshwater release from these structures results in pulses of fresh water into the estuarine system. Henderson Creek, Faka-Union Canal, and Cocohatchee Canal are three such channels under study. Blackwater River has no water control and has been used as a control for comparison.

The purpose of this study is to determine if the presence of water control structures affects the sediment characteristics and channel morphology. This study compares the sediment characteristics and channel morphology above and below the water control structures of three channels with a river with no water control structure. A comparison is also made between the dry season in June and the wet season in November.

METHODS

Field Methods. Blackwater River was selected as a control as it has no water control structures. Cocohatchee Canal, Henderson Creek, and Faka-Union Canal each have a water control structure controlling the amount and timing of freshwater delivered to the estuarine system. Three transect stations were set across the channel both above and below each water control structure. For Blackwater River, four transect stations were set. Each transect



Figures 8-9 – Lack of salinity stratification during January 1995

DISCUSSION AND CONCLUSIONS

The difference in the gradients in communities along dimension 3 in the MDS plot suggests that molluscan communities are responding to the alteration of the Henderson estuary. Although it is common for communities to pattern themselves relating to substrate because species distributions are strongly influenced by sediment composition (Lyons, 1989), these samples are structured differently, suggesting that another condition is producing a more powerful signal than substrate. The data suggest that sample structure resulting from MDS is responding to the stratification and range of salinity present in the estuaries. The Henderson samples are widely distributed along the z-axis, which has a negative correlation in salinity. Blackwater samples are also distributed along this axis, but they are more clumped. The stratification and salinity range signals in these estuaries may be responsible for producing these different patterns. Stratification in the Henderson estuary is extreme during the wet season, suggesting the pulsed release of freshwater from the weir is a factor. The freshwater forms a lens over the tidal prism, which not only increases stratification, but also the salinity range from up- to down-estuary. These two factors appear to be present in the MDS plot of Henderson samples along dimension 3, depicting a headwaters to mouth gradient in the composition of the samples. Blackwater estuary lacks stratification during the wet season and has a narrow range of salinity. The Blackwater communities have only a slight gradient along dimension 3, responding to the lack of stratification and also narrower range of salinity, producing the clumping of communities. Further cluster analysis of the estuaries suggested substrate may be a secondary condition in community structure, especially in Blackwater. Also, the composition of the organisms producing a change in community structure is different between the estuaries, although species richness is the same.

The results of this study can be used to establish baseline data for estuary restoration and management. In this case, mollusk communities are responding to the presence or absence of salinity stratification and the breadth of the salinity range in the estuary.

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station was located with a differential GPS. Channel morphology was determined by measuring water depths across the channels and tying water depth to South Florida Water Management District gauging stations. The water level was measured after each transect was measured to minimize for water level changes related to tides. Water depths were tied to water stages relative to NGVD elevation for each station to remove changes in depth due to fluctuating water levels from station to station and through time. In Blackwater River, there are no gauging stations so a metal conduit was driven into the river bottom and marked at the mangrove leaf-line, a biological marker, which is approximately equivalent to the high tide level. After each transect was measured, water depth was measured relative to the biological marker. When possible, three surfical sediment samples were taken along each transect. At some transect stations, three samples were unobtainable. Most stations had at least two sediment samples.

Laboratory Methods. Sediment grain size was measured by settling analysis. The surficial sediments were wet sieved to separate the coarser than one millimeter-sized particles from the finer than 1 millimeter- sized particles. Grain size of the finer than 1 millimeter grains were determined using a visual-accumulation tube (Subcommittee on Sedimentation, 1957). The settling method uses a quartz grain as a standard and the settling size is the equivalent diameter of a quartz grain with the same velocity (Tedesco, 1991). For example, a shell fragment with a large diameter might settle at the same rate as a quartz grain that is one half the diameter of the shell fragment.

The coarser than one-millimeter particles were settled in a large plastic tube in room temperature tap water. Settling velocity was measured and the settling grain size was determined using standardized tables for equivalent sphere sizes (Gibbs *et al.,* 1971). Settling analysis provides information about the hydraulic behavior of the particles to provide information on probable grain transport mechanism (true bedload, intermittent bedload, intermittent suspension, or true suspension).

RESULTS

Sediment Grain Size. Grains sizes greater than 700 μm tend to be transported as true bedload; grains sizes between 175 and 700 μm tend to be transported as intermittent bedload; grain sizes between 40 and 175 μm tend to be transported as intermittent suspension; and grain sizes less than 40 μm tend to be transported as true suspension (Boggs, 1995). For comparative purposes, grain-size fractions were averaged for each of the samples above verses below the water control structure (Table 1).

At the Blackwater River control site, differences were apparent between wet and dry seasons. During the dry season, the dominant mode of transport was intermittent suspension (71.31%). In the wet season, grains were transported as intermittent bedload (29.4%), intermittent suspension (39.5%) and true suspension (31.8%)(Table 1). The river had less than 2% of grains moving as true bedload in both seasons.

Each of the other sites shows a difference in the grain size distribution above and below the water control structure. Henderson Creek is an exception in the dry season when water does not flow through the structure. During the dry season, Henderson Creek is dominated by intermittent suspension-sized grains (49.5% above; 54.9% below). During the wet season, water flows over and through the structure and causes a coarsening in grain size from intermittent suspension (50.4%) above the structure to intermittent bedload (46.1%) and intermittent suspension (44.4%) below the structure. Also apparent is a loss of true suspension from above the structure (21.6%) to below (7.8%) the structure.

In each of the other channels, there is continuous to intermittent flow through the water control structures year round. During the dry season, sediments above the structure in Cocohatchee Canal are dominated by fine-grained sediments that move as both intermittent and true suspension (96%). Below the structure, 84% of the sediments are intermittent bedload and intermittent suspension, perhaps reflecting the design of the structure. During the wet season, sediments above the structure are coarser than the dry season and have very low percentages of true suspension-sized grains (8.5% vs. 58.3%)(Table 1). The water control structure at Cocohatchee Canal appears to effectively trap fine-grained sediments above the structure in the dry season and release them during the wet season.

Faka-Union Canal has a nearly continuous source of fresh water flowing over the structure year round. Despite this continuous flow, true suspension-sized grains are still trapped above the structure (64.5%) during the dry season, whereas intermittent bedload dominates the grain size (52.8%) below the structure. During the wet season above the water control structure, grains move as both intermittent and true suspension (86.4%). Below the water control structure, grains are somewhat coarser with grains moving as intermittent bedload and intermittent suspension (82%) (Table 1).

The effect of water control structures appears to be a trapping of true suspension-sized grains above the water control structure. While the relative difference in grain size above verses below the water control structure varies from structural to structure, all show a release of these suspension-sized grains during the wet season.

Blackwater River—6/1999 (n=12)			**Faka-Union Canal—6/1999 (n=18)**	Above WCS	Below WCS
True Bedload	1.87	N/A	True Bedload	0.98	7.06
Intermittent Bedload	24.48	N/A	Intermittent Bedload	5.61	52.77
Intermittent Suspension	71.31	N/A	Intermittent Suspension	28.90	29.16
True Suspension	2.34	N/A	True Suspension	64.51	11.01
Blackwater River—11/1999 (n=12)			**Faka-Union Canal—11/1999 (n=17)**	Above WCS	Below WCS
True Bedload	0.00	N/A	True Bedload	0.95	7.31
Intermittent Bedload	29.38	N/A	Intermittent Bedload	12.7	60.64
Intermittent Suspension	39.45	N/A	Intermittent Suspension	41.28	23.92
True Suspension	31.77	N/A	True Suspension	45.07	8.13
Henderson Creek—6/1999 (n=18)	Above WCS	Below WCS	**Cocohatchee Canal—6/1999 (n=17)**	Above WCS	Below WCS
True Bedload	3.05	0.36	True Bedload	2.11	8.50
Intermittent Bedload	22.02	28.67	Intermittent Bedload	1.97	34.38
Intermittent Suspension	49.54	54.86	Intermittent Suspension	37.69	49.53
True Suspension	25.39	16.11	True Suspension	58.23	7.59
Henderson Creek—11/1999 (n=14)	Above WCS	Below WCS	**Cocohatchee Canal—11/1999 (n=12)**	Above WCS	Below WCS
True Bedload	0.78	1.69	True Bedload	4.26	0.64
Intermittent Bedload	27.30	46.13	Intermittent Bedload	24.20	77.27
Intermittent Suspension	50.37	44.40	Intermittent Suspension	63.02	20.82
True Suspension	21.55	7.78	True Suspension	8.52	1.27

Table 1. Average Sediment Grain Size For Dry Season (June) and Wet Season (November)

Channel Morphology. Blackwater River is a very shallow, mangrove-lined channel with an organic and fine mud bottom. It contains very little rock or shell debris. From transect to transect, there is very little change in the channel morphology. Each of the remaining channels, with the exception of Blackwater River, are straight, man-made canals that have been dredged.

Above the water control structure at Henderson Creek, the channel is lined with a thick plant covering that exists in both the wet and the dry seasons. From the wet to the dry season, the most significant change in channel morphology is seen below the water control structure. The channel has a mud and sand bottom with small amount of shell and rock debris and a few large boulders. During the wet season, when the sluice gates of the water control structure are open, the water is directed from the east to the west side of the channel. This directed flow causes an erosional cut along the west bank.

In Cocohatchee Canal, there is minimal change in the channel morphologies from the wet season to the dry season. Above the water control structure, there was a thick green beard algae covering on the bottom during the dry season. This plant covering was largely absent during the wet season and may have been removed by accelerated flow through the gates caused by a tropical storm event. Below the water control structure at Cocohatchee, the channel is lined with a large boulder riprap field.

Faka-Union Canal is a wide canal with a mud, shell, and sand bottom above the water control structure. There are several large tree stumps that line the bottom of the channel. There were very minimal changes in the channel morphology from the dry season to the wet season for the area above the water control structure (Figure 2- transect 3). Immediately below the water control structure, is a deep pool lined with cobble and boulder sized granite rocks that were placed in a systematic manner to control water flow patterns. The channel bottom beyond the granite rocks is mainly sand with a small amount of mud. The transect immediately below the water control structure (transect 4) shows deepening of the channel between the dry and wet season (Figure 2).

A surprising result of this study was the overall minimal change in channel morphologies between the dry and wet seasons. The lack of change is particularly evident above the water control structures. Engineering designs including concrete aprons, riprap, and plunge pools have effectively decoupled flows from the channel bottoms potentially preventing more obvious changes in channel morphology.

SUMMARY

The results of this study indicate that water control structures play a significant role in controlling the dominant grain size found in the channels. The effect of water control structures appears to be a trapping of true suspension-sized grains above the water control structure. While the relative difference in grain size above verses below the water control structure varies from structure to structure, all show a release of these suspension-sized grains during the wet season. This is a significant finding in that environmental contaminants (pesticides and heavy metals) tend to be concentrated in the fine-grained fraction (Salomons and Forstner, 1984). Thus, water control structures may result in point-source discharges.

The study also concludes that water control structures are not as influential to the channel morphology as they are to grain size. Engineering designs including concrete aprons, riprap, and plunge pools have effectively decoupled flows from the channel bottoms potentially preventing more obvious changes in channel morphology. The type of water control structure however, also influences the channel morphologies. In a channel such as Henderson Creek, that allows water to flow only during the wet season, the channel appears to undergo more erosion than a channel such as Cocohatchee Canal or Faka-Union Canal that allow water to flow year round. The Blackwater River control appears to have undergone minimal changes in channel morphology.

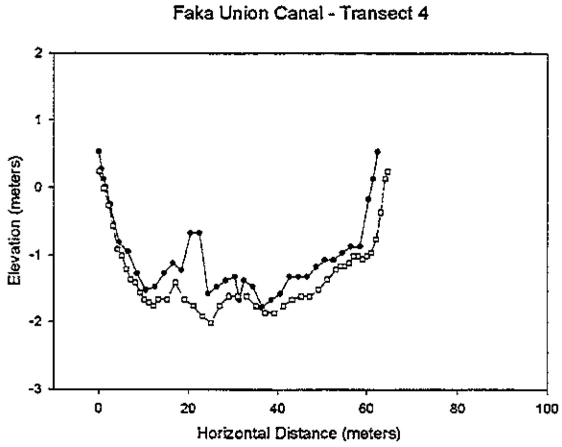

Figure 2: Channel morphology above (top) and below (bottom) Faka-Union Canal.

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