FINAL REPORT

TIME RATE OF LOCAL SCOUR AT COMPLEX BRIDGE PIERS FIELD AND LABORATORY ANALYSES

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SUBMITTED TO:

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RESEARCH OFFICE

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

SI (MODERN METRIC) CONVERSION FACTORS (from FHWA)

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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16. Abstract

A local scour evolution field study was conducted under this contract. One of the piers on the A1A Bridge over the Intracoastal Waterway (ICCW) in Fort Pierce, Florida was selected for the test site. The existing local scour hole was filled with sand from a nearby channel dredging project and the pier instrumented and monitored for a period of 164 days (November 5, 2008 to April 17, 2009). The instrumentation consisted of three acoustic scour depth meters, a bottom mounted, upward looking ADCP for measuring the flow velocity profile, a bottom mounted pressure transducer for measuring water depths and wave parameters and a temperature gauge for measuring water temperatures. The installation was operational and collected data for 164 days. Unfortunately, there were no significant flow events during this time period and therefore the local scour was minimal. There is, however, an effort underway to obtain the necessary funding to extend the deployment period.

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The authors would also like to express their appreciation to those in FDOT D4 that were so helpful in locating a test site, locating a source of fill sediment, obtaining the necessary permits, etc. In particular a big thanks to Jose Quintana, John Danielsen, Brian O'Donoghue, Alberto Sardinas and their staff for their untiring support throughout this project.

Executive Summary

A local scour evolution field study was conducted under this contract. One of the piers on the A1A Bridge over the Intracoastal Waterway (ICCW) in Fort Pierce, Florida was selected for the test site. The existing local scour hole was filled with sand from a nearby channel dredging project and the pier instrumented and monitored for a period of 164 days (November 5, 2008 to April 17, 2009). The instrumentation consisted of three acoustic scour depth meters, a bottom mounted, upward looking ADCP for measuring the flow velocity profile, a bottom mounted pressure transducer for measuring water depths and wave parameters and a temperature gauge for measuring water temperatures. The installation was operational and collected data for 164 days. Unfortunately, there were no significant flow events during this time period and therefore the local scour was minimal. There is, however, an effort underway to obtain the necessary funding to extend the deployment period.

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Introduction

As a result of bridge scour research over the past two decades there have been significant advances in the ability to predict design scour depths at bridge piers. There are, however, locations (such as tidal waters along the US coastline) where the design storm event is intense but of short duration. Hurricane storm surges produce the design flow event in most coastal locations in the Gulf of Mexico and along the east coast of the United States. The storm surge induced flow velocities can be large, but in the vast majority of cases the duration of the peak flows is only a few hours. The bridge scour that occurs during one of these events will only reach an equilibrium value for extremely small structures on the order of a few feet in diameter. The author of this proposal and one of his Ph.D. students have developed a computer model for predicting the rate of scour for simple structures subjected to unsteady (varying water depths and flow velocities) flows such as those produced by hurricane storm surges. The model is based on data from steady flow local scour experiments conducted by the author and his students. This model has not been verified, but predicts that the scour depths at structures with diameters on the order of 10 to 15 ft only reach 40% to 60% of their equilibrium values during a typical 100 year storm surge event. For larger structures the scour reductions are even larger. There are other rate-of-scour evolution models in the literature as well that need to be tested.

To improve and verify these models two types of data are needed: 1) data from controlled laboratory experiments with large structures and unsteady flows that cover the clearwater and live bed scour regimes, and 2) field experiments with large prototype piers. The quantities that must be measured in both the laboratory and the field experiments are water depth, upstream flow velocity, water temperature, water salinity (field only), sediment properties and scour depth most of which can vary with time. Two practical ways to obtain the needed scour data in the field are: 1) install instrumentation near a new structure that has not yet experienced scour or 2) instrument an existing structure, fill the scour hole and monitor the scour hole redevelopment. The duration of the monitoring should be sufficient to capture at least a minor storm event.

The objective of this research was to obtain scour evolution rate data at a relatively large bridge pier that is subjected to unsteady flows that produce frequent live bed scour conditions. The information produced by such a study will be of significant value in testing and improving the empirical, semi-empirical and numerical time dependent local scour models. Once the models are verified they can be used to more accurately predict design local scour depths for bridge foundations and other structures located in coastal environments. This has the potential of saving large sums of money in bridge foundation costs.

Methodology

The approach taken is discussed in this section. The first step in this research effort was to specify the desired and sufficient conditions for the study site. This turned out to be much more difficult than anticipated. Letters were sent to all FDOT District Drainage Engineers with a description of the project and a request for potential site recommendations (Appendix A). The recommended sites were analyzed and in some cases visited (see Appendix B) but none met the required conditions. The criteria were modified and letters sent to a number of bridge engineers in Florida and the surrounding states. Finally a site was located on the east coast of Florida near Fort Pierce, Florida in St. Lucie County. The bridge, known as "South Bridge", is on Seaway Drive (A1A) and spans the Intracoastal Waterway (ICCW) just south of Fort Pierce Inlet. A location map is shown in Figure 1. An aerial photograph of the bridge and its location relative to Fort Pierce Inlet is shown in Figure 2. The piers on this bridge are much more complex than desired for this study but met the minimal requirements.

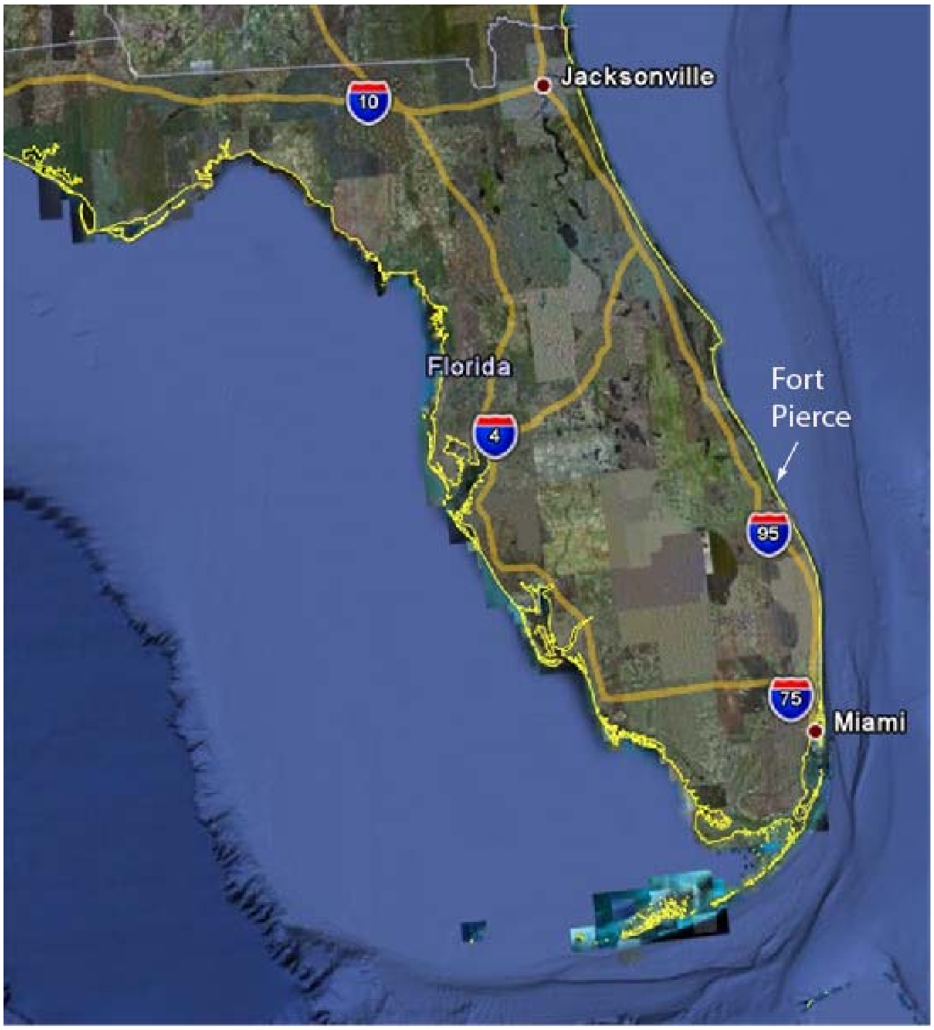


Figure 1 Location map for test pier.

Figure 2 Aerial photograph showing test pier location relative to Fort Pierce Inlet.

The instrumentation and data acquisition system used on the project were designed/constructed/purchased and tested in the Coastal Engineering Laboratory.

The next challenge was to fill the existing scour hole with sediment similar to that in the area of the pier. This process was also more difficult and costly than anticipated. FDOT District 4 engineers located a planned marina channel dredging project just to the north of the study area. After numerous communications between the P.I. of this study, the marina owner, dredge company, permitting agencies, and FDOT D4 staff an agreement was reached and a contract signed. The scour hole fill process, which could not be started until all (dredge and fill) permits were in place, required approximately two and one-half months to complete. The sand had to be dredged from the channel, placed on a barge, transported to the site and deposited. To optimize the sand deposition process a sand chute was constructed, transported to the site and attached to the pier. The chute extended from above the water surface to just above the unscoured bed elevation as shown in Figure 3.

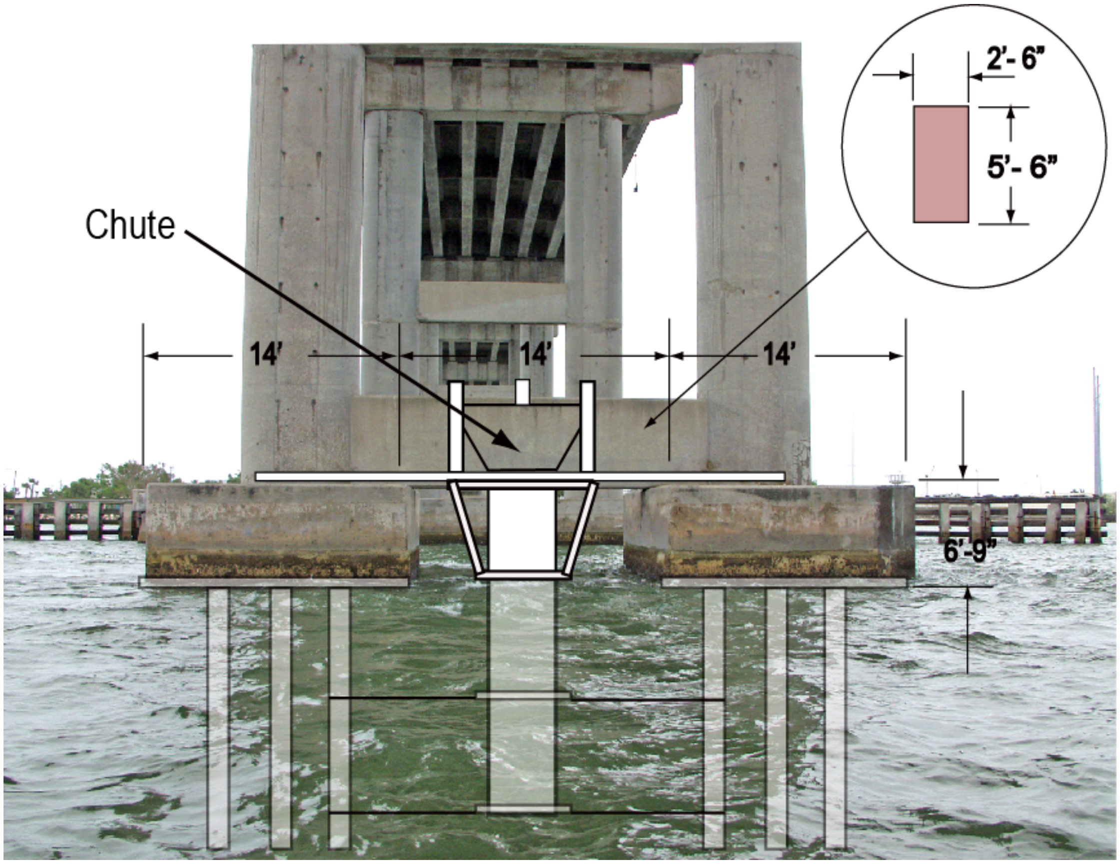
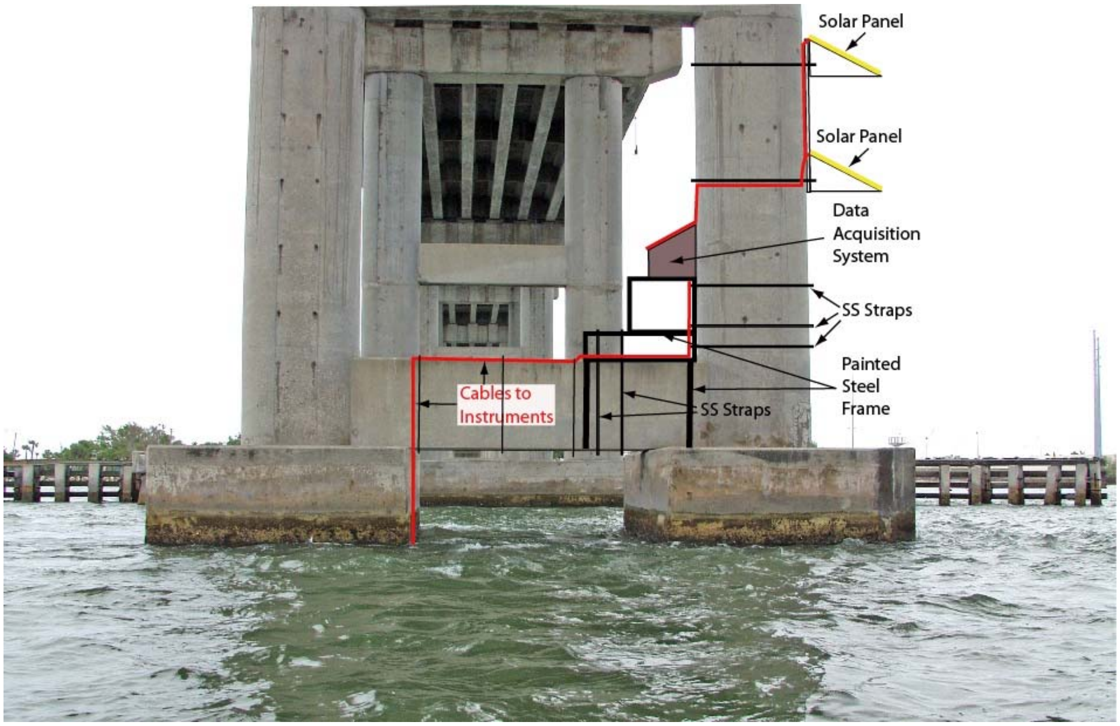
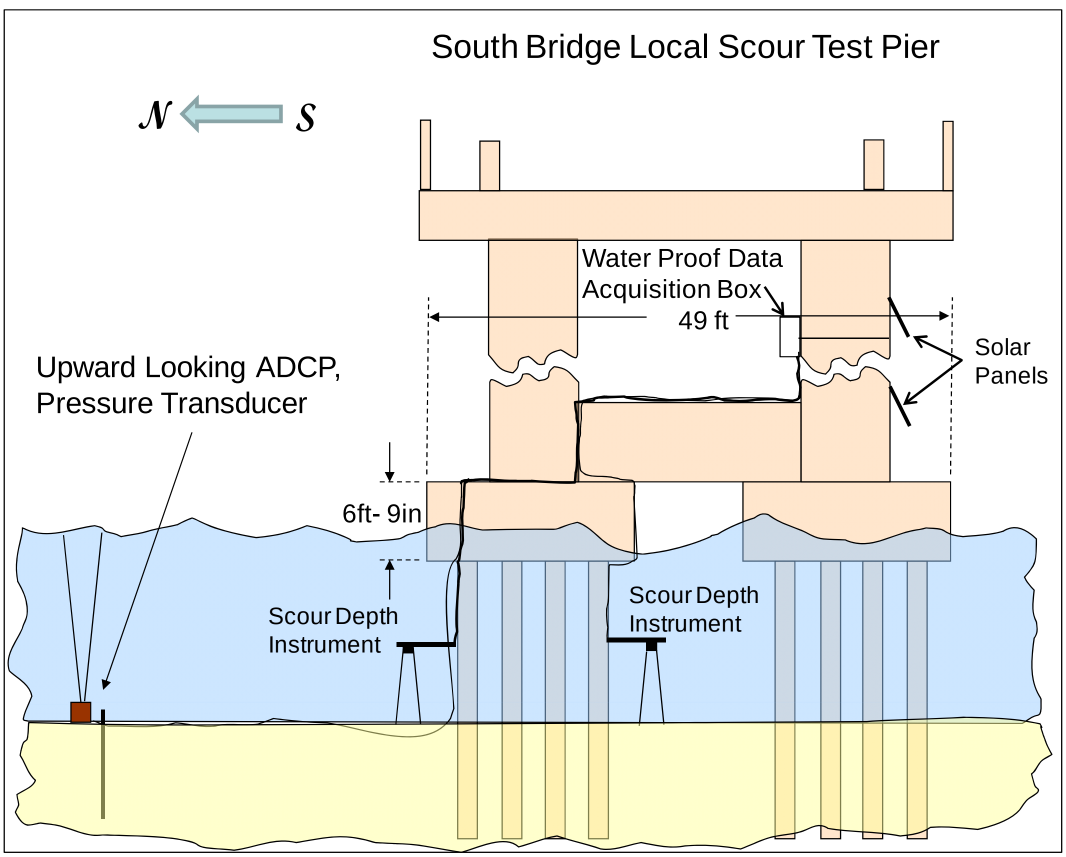


Figure 3 Drawing showing sand chute used in placing sediment in local scour hole.

Once the sand was in place the instrumentation and data acquisition system was installed and the monitoring initiated. Data from the site were downloaded to computers at the Coastal Laboratory at the University of Florida daily. Data reduction and analysis was the final step in the study.


Solar Panel
Solar Panel
Data Acquisition System
SS Straps
Painted Steel Frame
SS Straps
Cables to Instruments

a.


South Bridge Local Scour Test Pier
N
S
Water Proof Data Acquisition Box
49 ft
Solar Panels
Upward Looking ADCP, Pressure Transducer
6ft- 9in
Scour Depth Instrument
Scour Depth Instrument

b.

Figure 4 Photograph (a) and drawing (b) showing the locations of the instrumentation.

Instrumentation and Data Acquisition

The instrumentation used in this study is listed below.

Instrumentation

The quantities measured were:

1. Water velocities throughout the water column seaward of the test pier
2. Water depth
3. Wave heights and periods
4. Bed elevation at three locations in the scour hole

The instrumentation used was:

Water velocities, water depths and wave parameters

An RDI Model WHMZW1200-I-UG18 Acoustic Doppler Current Profiler (ADCP)

Bed elevation in the scour hole

Three Tritech Altimeters Model PA50016 acoustic depth meters

Two of the scour depth measuring instruments (altimeters) were attached to the outside of the seaward piles. The third altimeter was mounted to one of the interior piles as shown in Figure 4. The ADCP and pressure transducer were attached to the bed seaward of the pier as shown in Figure 4.

Data Acquisition

The data acquisition system was mounted on a platform of the bridge column as shown in Figure 4. Data from the instruments were sent to the data acquisition system where it was recorded. The data was downloaded twice daily to computers at the Coastal Laboratory at the University of Florida in Gainesville, Florida via a cell phone modem in the data acquisition system. Electrical power to operate the instruments and data acquisition system was provided by two solar panels mounted to the pier (see Figure 4).

Data

Data collection began November 5, 2008 and for the purposes of this report ended April 17, 2009, a total of 164 days. Plots of the data are presented in Figures 5-9. Note that the water depth and flow velocity measurements did not experience any problems over the duration of the study (Figure 5). The scour depth instruments provided good data for the majority of this period, but altimeter 2 started having problems around January 21, 2009 and altimeter 3 around February 8, 2009. Altimeter 1 provided good data until March 14, 2009. The dive crew has been waiting until the decision was made regarding the extension of the measurement period to repair/removed the instruments.

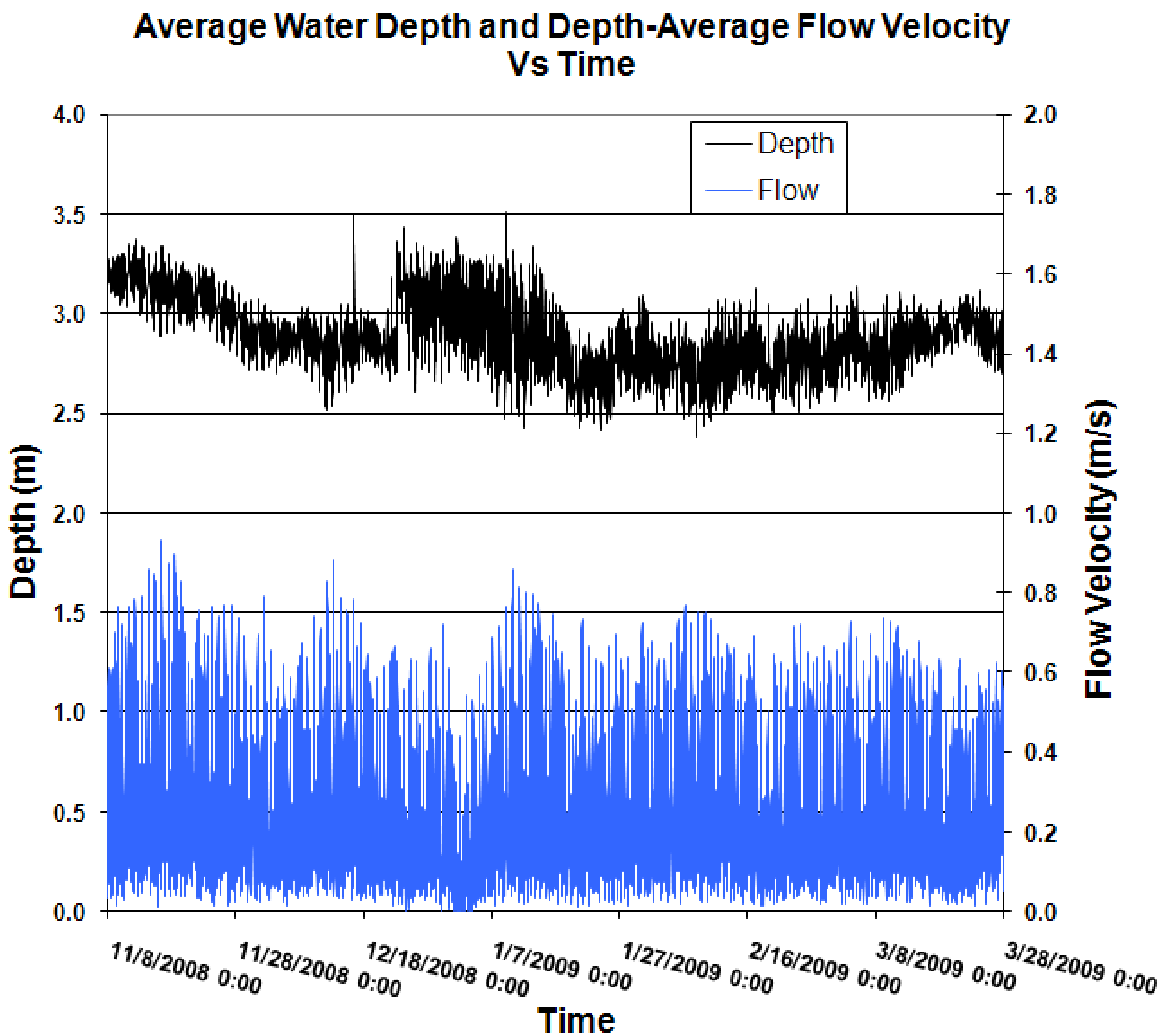

Average Water Depth and Depth-Average Flow Velocity Vs Time
Depth
Flow
Depth (m)
Flow Velocity (m/s)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
11/8/2008 0:00
11/28/2008 0:00
12/18/2008 0:00
1/7/2009 0:00
1/27/2009 0:00
2/16/2009 0:00
3/8/2009 0:00
3/28/2009 0:00
Time

Figure 5 Water depth and depth-average flow velocity versus time just seaward of the test pier.

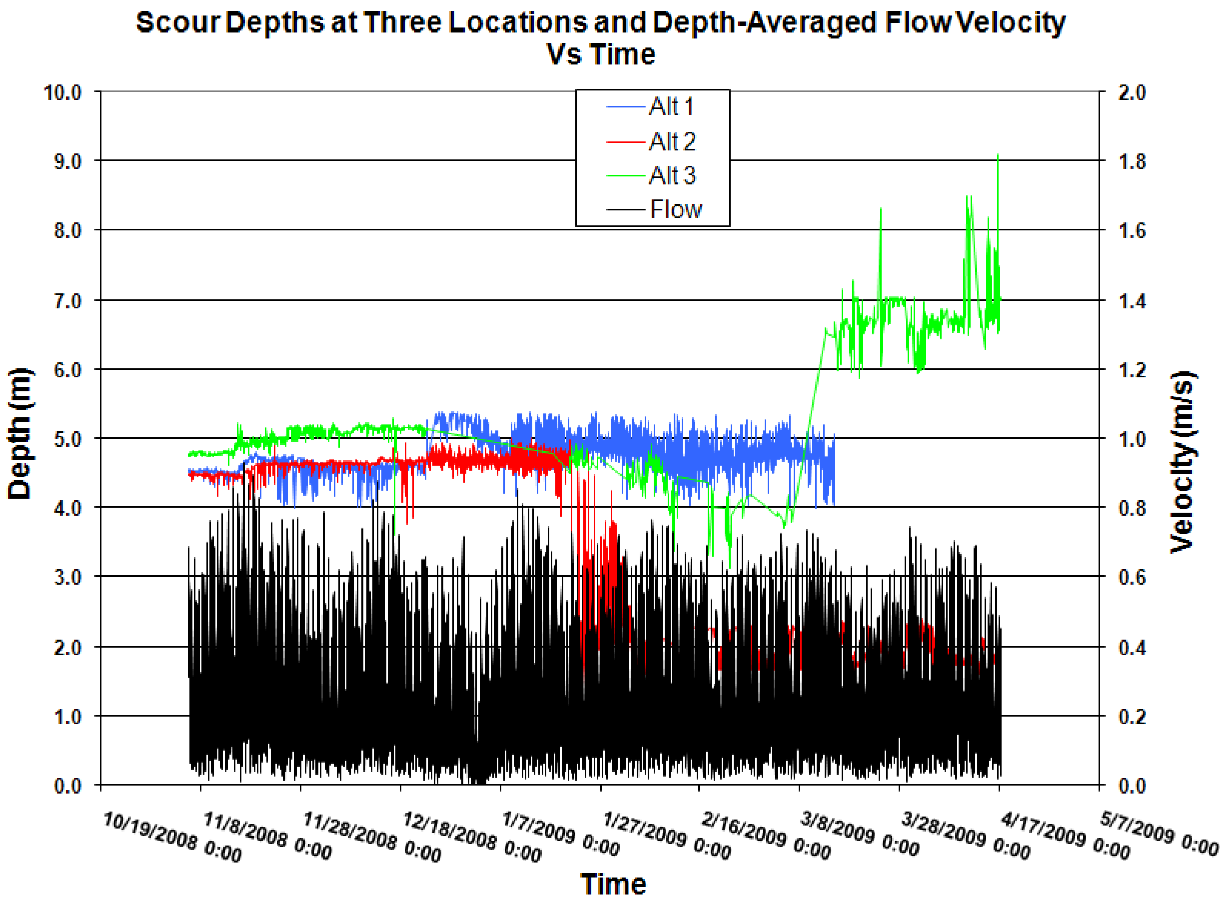


Figure 6 Scour depth and depth-averaged flow velocity versus time.

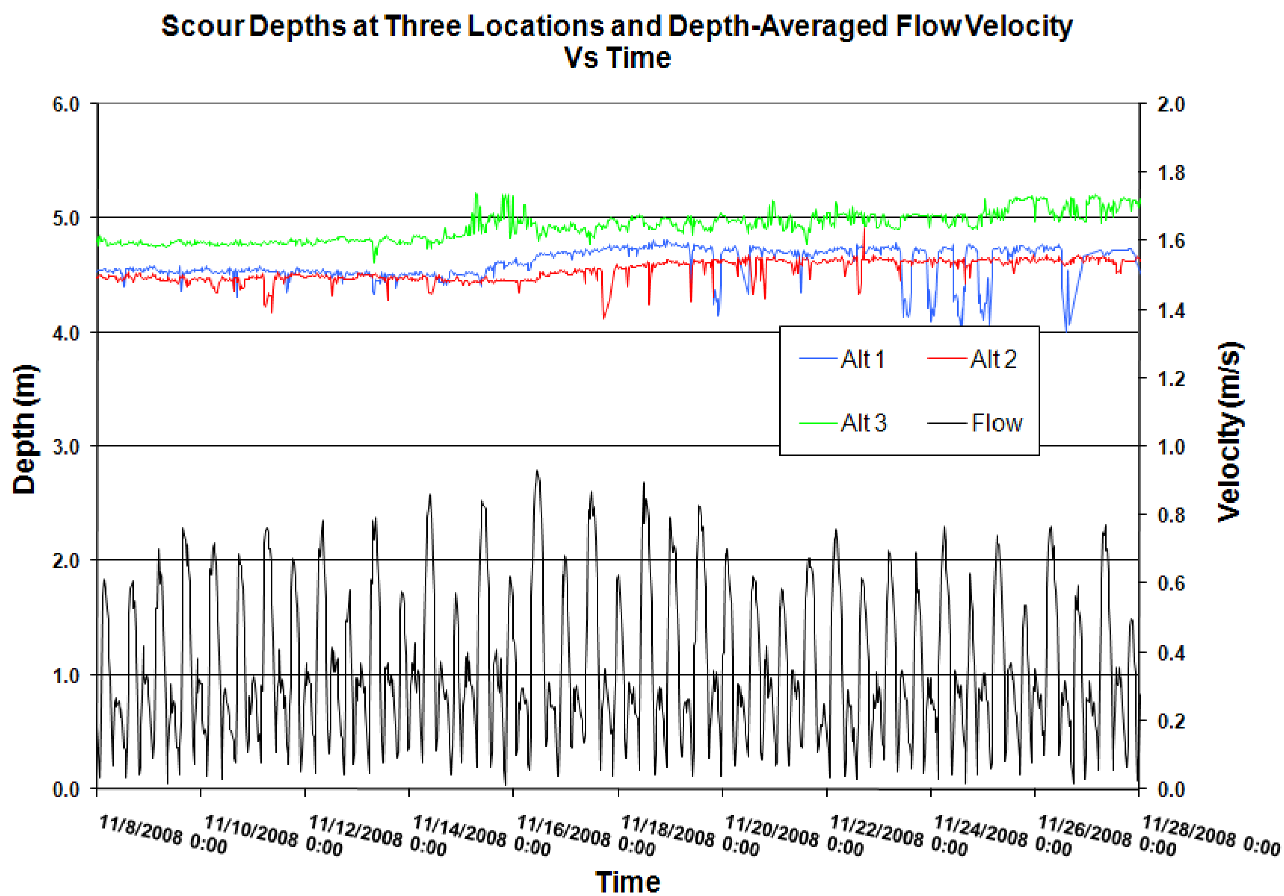


Figure 7 Scour depth and depth averaged flow velocity versus time for a 20 day interval.

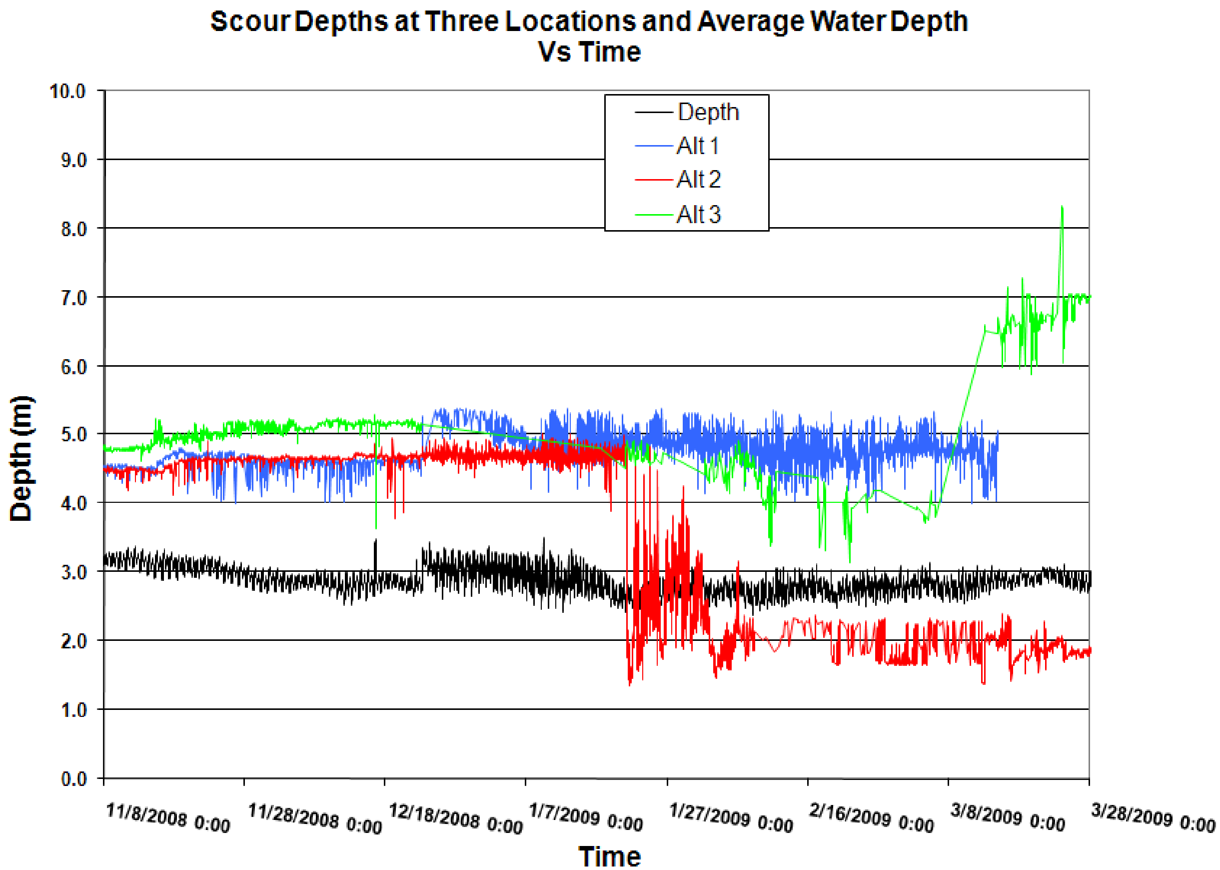


Figure 8 Scour depth at three locations and water depth seaward of the pier versus time.

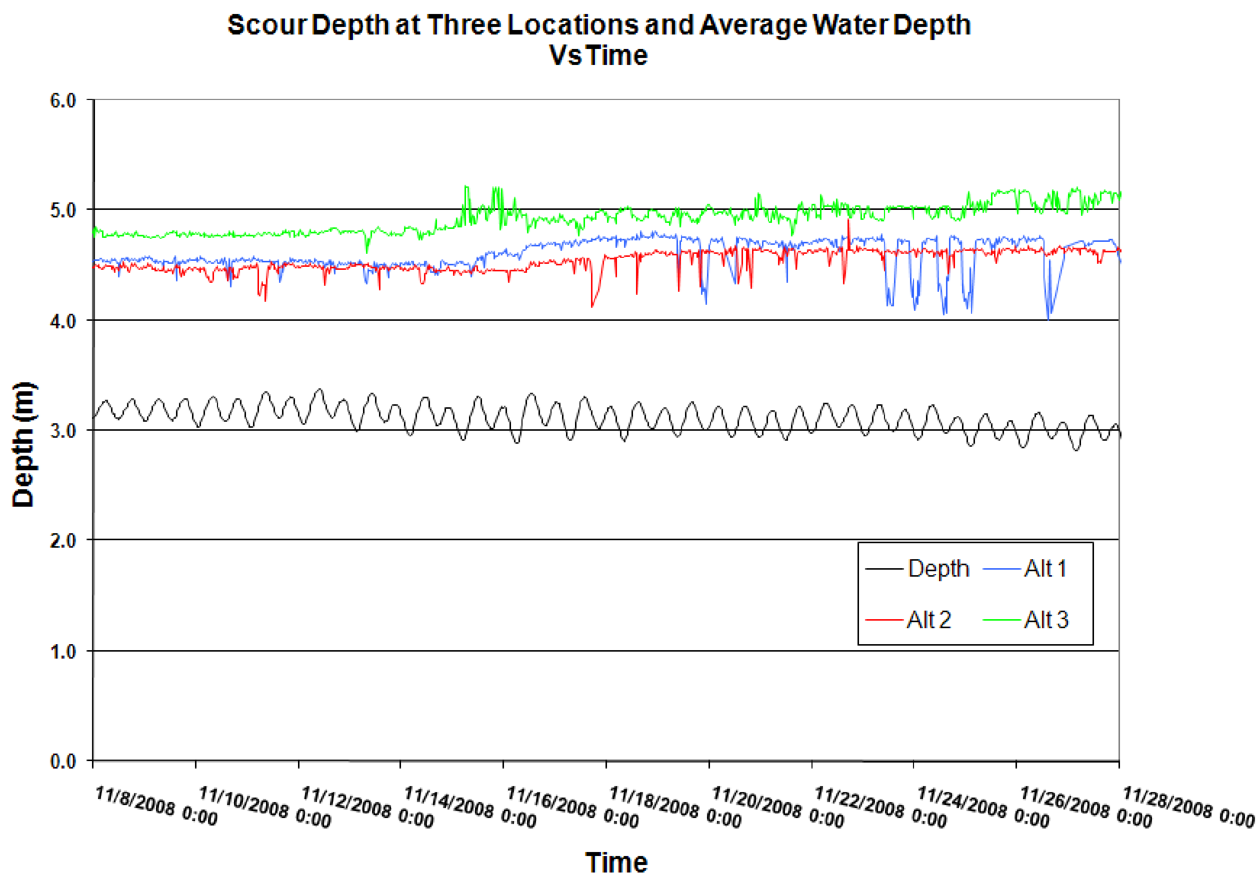


Figure 9 Scour depth at three locations and water depth seaward of the pier versus time for a 20 day time interval.

Analysis

The sediment was placed at the pier through a chute located between the two pile groups as shown in Figure 3. The bottom of the chute was located just above the unscoured bed. Even though the sediment was distributed in the scour hole by the flood and ebb tidal flows during the fill process the bed in the scour hole was a bit uneven at the start of the measurements. For this reason it was anticipated that the scour rates at the locations of the three depth meters would be different initially. Also due to the time dependence of the reversing flows it was anticipated that there would be both scour and accretion with a net reduction in bed elevation with time. Note the erosion and deposition during a tidal cycle. Unfortunately, there were no significant flow events during this initial time interval of deployment and thus the scour during this time was minimal.

The Principal Investigator (P.I.) of this study is also the P.I. on an NCHRP project (24-32) entitled “Scour at Wide Piers and Long Skewed Piers”. Included in the scope of the NCHRP project is an evaluation of existing predictive scour evolution equations/methods using laboratory data. All of the existing scour evolution data is for steady, constant velocity flows. Under these conditions there is a steady increase in local scour depth, with no deposition. The equation developed by Bruce Melville at the University of Auckland in Auckland, New Zealand performed the best of those examined when the equilibrium scour depth equation in his formulation was replaced by that due to Sheppard. The method developed by Miller and Sheppard performed well in the clear-water range but had some difficulties for some situations in the live-bed range.

Unfortunately, there was insufficient scour at the test site during the short duration of the measurements to test the scour evolution equations. It appears, however, that the FHWA might fund an extension of this measurement program through the upcoming hurricane season. If funded, this will allow scour monitoring through the time of year with the highest probability of storm activity. The site need not experience a direct hit in order to obtain valuable scour evolution data even a minor storm would suffice.

Summary

In summary, it was very difficult and time consuming to locate a suitable test pier at which to conduct the study. It was also difficult and time consuming to locate a source of fill sand that was within the budget of the project. Design and construction of the instrumentation and data acquisition system was straight forward and was completed and tested long before the site was ready for installation. The scour hole fill process was aided by the chute that was designed and constructed for this purpose.

Once a measurement program, such as this one, is in place and operating properly it should be operated for a sufficient period of time to meet the objectives of the study. In this case the objective was to obtain scour evolution data at a large, complex bridge pier with measurements of all the necessary parameters impacting the scour (water depth, flow velocity, and structure and sediment properties). Such information is essential for testing scour rate mathematical/computer models that are based on smaller scale laboratory data.

APPENDIX A - SITE REQUIREMENTS

TIME RATE OF LOCAL SCOUR MODEL

FIELD VERIFICATION

FIELD STUDY REQUIREMENTS

Background:

A mathematical/computer model has been developed to compute local scour depths at single pile structures in cohesionless sediments as a function of time. This semi-empirical model has been verified on circular pile structures up to 3 ft in diameter in steady flows. Since the rate of local scour is dependent on structure size and the unsteadiness of the flow data is needed for larger structures subjected to unsteady flows.

The plan is to 1) instrument the structure and surrounding area (water depth, temperature and turbidity, flow velocity and scour depths at several locations), 2) fill the existing scour hole with sand from near the structure and 3) monitor the flow and scour at the site for an extended period of time (~ 1 year).

Information regarding the location of a potential structure for use in this study is being sought by the FDOT Central office and researchers at the University of Florida. Any and all suggestions will be appreciated. The structure, sediment and flow requirements are given below.

Requirements:

<u>Ideal Situation</u>

1. Recently installed circular structure 5 ft -15 ft in diameter that is at least 8 to 10 diameters from other structures.
2. Cohesionless sediment (sand) with a D_{50} between 0.15 mm and 0.4 mm.
3. Mean water depth between 15 ft and 30 ft.
4. Subjected to tidal flows with a spring tidal range greater than 4 ft that produce peak velocities in the live bed scour range for the sediment ($V \approx 1$ ft/s for $D_{50} = 0.2$ mm, $V \approx 1.1$ ft/s for

   $D_{50} = 0.4$ mm, etc.).

<u>Acceptable Situation</u>

1. Existing circular or square structure 5 ft -15 ft in diameter/width that is at least 8 to 10 diameters from other structures in line with the flow.
2. Cohesionless sediment (sand) with a D_{50} between 0.15 mm and 1.0 mm.
3. Mean water depth between 8 ft and 30 ft.
4. Subjected to tidal flows with a spring tidal range greater than 2.5 ft that produce peak velocities in the live bed scour range for the sediment ($V \approx 1$ ft/s for $D_{50} = 0.2$ mm,

$V \approx 1.1$ ft/s for $D_{50} = 0.4$ mm, $V \approx 1.5$ ft/s for $D_{50} = 1.0$ mm etc.).

Less Desirable but Acceptable Situation

1. Single structure 5 ft -15 ft in diameter/width that is at least 8 to 10 diameters from other structures in line with the flow.
2. Cohesionless sediment (sand) with a D_{50} between 0.15 mm and 3.0 mm.
3. Mean water depth between 8 ft and 30 ft.
4. Subjected to unidirectional, time varying flows that produce peak velocities in the live bed scour range for the sediment ($V \approx 1$ ft/s for $D_{50} = 0.2$ mm, $V \approx 1.1$ ft/s for $D_{50} = 0.4$ mm, $V \approx 2.7$ ft/s for $D_{50} = 3.0$ mm etc.).

While the above stated conditions would best suit the purposes of this study we have not been able to locate a situation that falls within these constraints. We must therefore broaden our search and loosen the requirements. Some of the parameters cannot be changed while others are either less important or can be accounted for in the analysis of the data. The modified requirements are as follows:

1. Single structure 5 to 60 ft in diameter/width that is at least 8 to 10 diameters away from another structure. While a simple shaped structure is more desirable it can be a complex bridge pier composed of a pile group, pile cap and column (or any combination of the three). We will consider any single structure that is not located near another structure and meets the following conditions.
2. The sediment at the site **MUST BE COHESIONLESS** (sand, shell, etc.). It is also essential that the site be **VOID OF ANY SCOUR PROTECTION** in the form of rip-rap, mats, etc.
3. Mean water depths between 6 ft and 75 ft.
4. The flow can be riverine (one directional flow) or tidal (multi-directional flow) as long as flow velocities at the structure exceed approximately 1 ft/s (0.6 knots, 0.7 miles/hr) on a daily basis.

If you think you have a structure that meets these requirements please contact me at the following numbers/email address and we will check it out. If you have drawings of the structure and boring logs from the site this would be very helpful.

Thank you

Max Sheppard

(352) 392-1436 ext. 1428

(352) 377-9524 ext. 22

Sheppard@ufl.edu

APPENDIX B - EXAMPLE STUDY SITES CONSIDERED

EXAMPLE STUDY SITES CONSIDERED

A major effort was expended trying to locate an adequate site for the study. Many bridge locations were investigated on paper and several visited and the substructure and bed conditions investigated. An example site visit trip report is presented below:

Haulover Bridge

Trip Report

Site: Bakers-Haulover Inlet

Location: Miami, FL

Structure: Herman B. Fultz Bridge

Date: July 15, 16 2004

Purpose: Visual and Physical Inspection of Inlet to determine possibility of use in field scour project for the University of Florida Department of Civil & Coastal Engineering

Dive Master: Vic Adams

Divers: Sidney Schofield, Justin Marin

Original Site Data

Authorizing Act 1960 River and Harbor Act

Cost Federal $243,235 Non-Federal $243,235

Federal O&M cost to Sept. 1995 $185,688

Total authorized project length 1.02 miles

Channel Feature Depth(ft) Width(ft) Entrance 11 200 Inner Channel 8 100 Marina Basin 8 200

Improvements to Site

North & South Jetties for channel control and easy maintenance

PURPOSE

The purpose of the trip was to determine if the Bakers-Haulover Inlet was suitable for use in a field scour project proposed by D. Max Sheppard with the University of Florida Department of Civil & Coastal Engineering. Requirements needed to be met for project viability are as follows:

- Large rounded pier supports
- Sandy bed layer extending down past the point of equilibrium scour
- Sand source to fill existing scour layer
- Significant flow velocities to obtain live bed scour conditions
- Accessibility for monitoring equipment and maintenance

The Bakers-Haulover inlet was recommended by FDOT District 6. A visual inspection was conducted and physical measurements were recorded of the site both above and below the water.

DATA & OBSERVATIONS

Fully dimensioned pier profiles and a site layout are provided in the following figures.

Flow velocities in the channel are quite high for the inlet, so the dive time was slated for 8:45 AM on July 16 at the high tide mark for ease of mobility. Lag time on the tide was between 10-20 minutes. High tide provided 45 minutes of dive time before tidal flows increased to a point of significant difficulty in work.

Upon initially arriving at the sight it was discovered that all eight of the piers supporting the bridge were placed on top of pile caps. Sand probes revealed that the sand layer thickness varied from more than 2' to exposed rock.

Piers 1 & 2

Piers 1 & 2 were located in a bedding environment that consisted of mostly sand with few breaches of bedrock and several larger detached rock pieces which appear to have been exposed in the scour hole and provided a very small amount of non-uniform armoring. Due to the local scour within the channel, the pile caps of both piers were exposed. The existing scour conditions of Pier 2 were that of a width of up to 16' on either side of the pile cap and 12' forward of the oncoming flow. The scour depth at Pier 2 was found to be 9' below the existing bed level. Due to the close proximity of the two piers, their individual scour holes overlapped to a great extent creating a fairly large scoured area encompassing both piers. In many place around the Pier 2 pile cap (mainly the leading and side edges) the scour depth has reached a depth in excess of 6"-10" beyond the pile cap.

Piers 3, 4, 5, & 6

Piers 3, 4, 5, & 6 are located adjacent to the channel fenders protecting the main portion of the channel. Previous literature and experiments have shown that these fenders often reduce the equilibrium scour depth at the piers. However, these piers in some places (to a much less degree) were scoured to a depth where the lower edge of the pile cap was visible. The scour hole from each pier also overlapped with the scour hole of the pier in line with it. In the holes for these four piers, a much larger quantity of bed rock was noticed. A possible explanation for the almost negligible difference in scour hole size is that the pile cap lessens the protective effect of the fender. Exact physical measurements were not taken of Piers 3, 4, 5, & 6 due to lack of safe dive time.

Piers 7 & 8

Piers 7 & 8 contained the largest amount of exposed bed rock, covering roughly 50% of the scoured area. However, Piers 7 & 8 also showed the deepest scour hole, with Pier 7 having scour more than 1’ below the pile cap on its leading edge (scour depth being further punctuated by a dozen lobster living beneath the edge). As before, the two scour holes of Piers 7 & 8 overlapped into each other.

CONCLUSIONS

The main obstacle is the existence of the pile caps on all of the piers. The scour field project is aimed toward data collection and comparison with the time-rate scour model created by Sheppard & Miller which was designed for use with circular pilings. After refilling of the scour hole, the pier system would have to be treated as a Case 3 Complex Pier for comparison with normal single circular piling data and predictions.

Also, the extremely narrow dive windows would make installation and maintenance of the equipment difficult.

The large presence of rock would also affect the scour process in that some areas of the scour hole would not be scoured away and instead change the flow dynamic in the hole. The overlap of the scoured hole would also make monitoring the depth of a single scour hole difficult.

A suitable sand source for filling the hole could have been found just inside the inlet in Biscayne Bay.

The results of the Field Trip have shown that the Bakers-Haulover Inlet is probably unsuited for the scour field project proposed by the University of Florida.

(Images of the site can be seen on the following pages

(a)

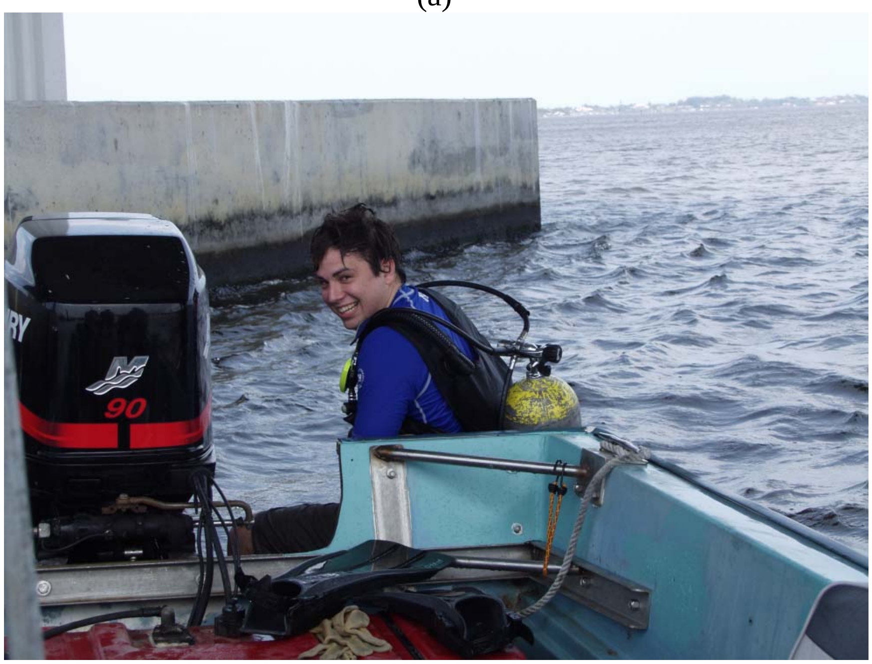
(b)

Figure B 1 Photographs of Bakers-Haulover Bridge piers.

Other sites visited include:

Roosevelt Bridge
US 1 over St. Lucie River in Stuart, Florida (FDOT District 4)

(a)

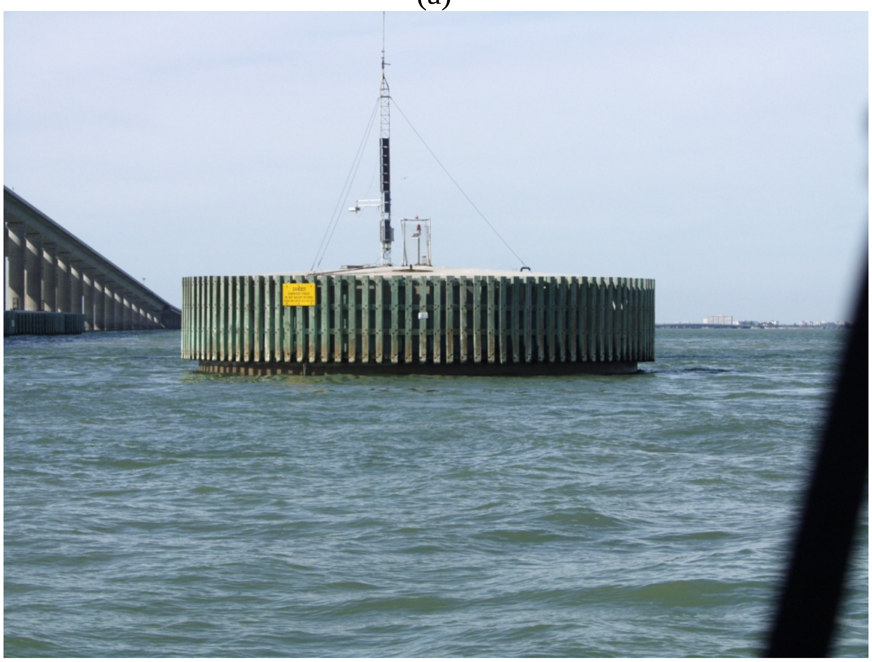


(b)

Figure B 2 Photographs of Roosevelt Bridge piers.

Sunshine Skyway Bridge
I-275 over the entrance to Tampa Bay, Florida (FDOT District 7)

(a)



(b)

(c)

Figure B 3 Photographs of Sunshine Skyway Bridge piers.