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Waterway Expert Traffic System

Final Report, Documents Development of a Tool for Coastal Zone Management

Submitted to

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Section I

Introduction

A new tool for Coastal Zone Management

Knowledge about canal sea state and of how and when watercraft are being operated was, until now, not available from an automated source.

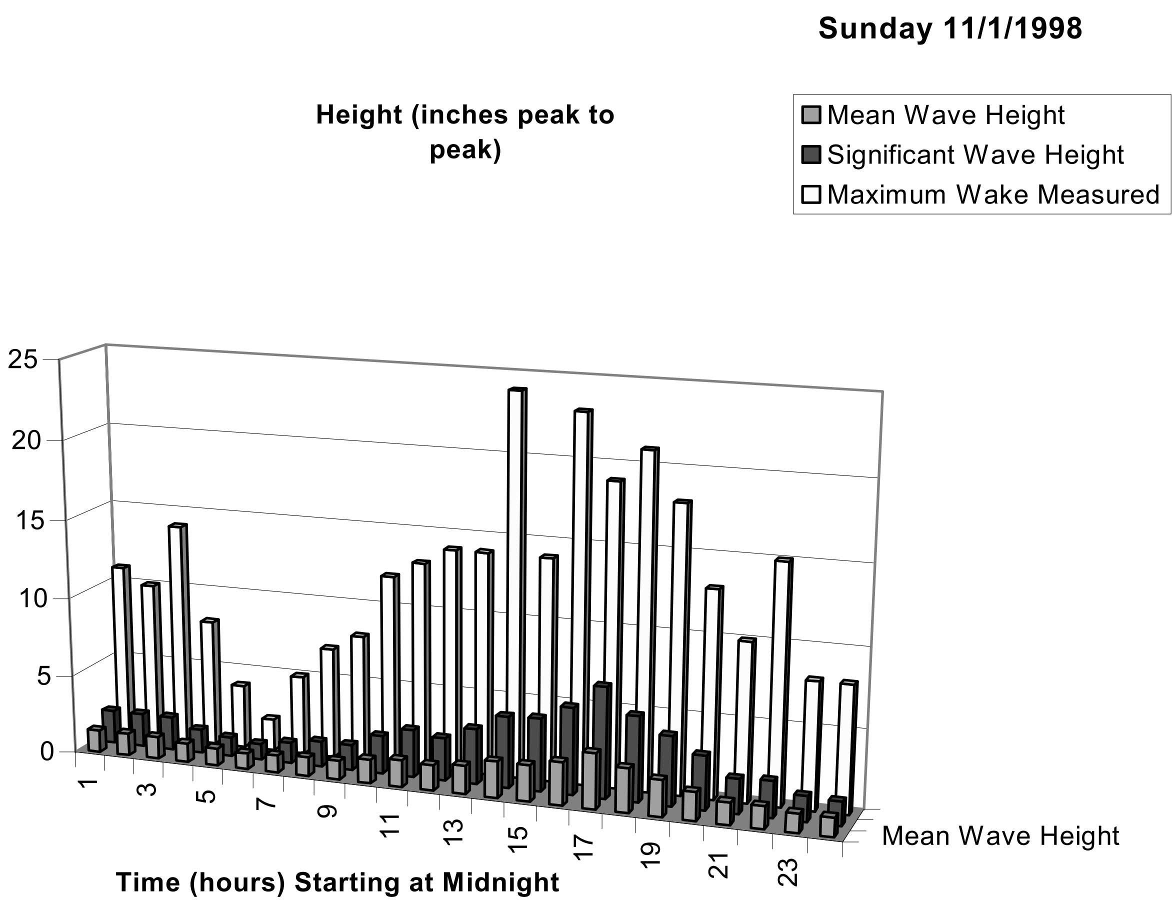
Figure 1. Special scientific equipment to monitor watercraft usage in an urban canal is shown deployed in the ICW (Inter Coastal Waterway) at a site located within the Fort Lauderdale, Florida city limits.

This is a second year study, conducted in an urban canal, of wakes and waves made by boats and weather. The study is funded through a grant provided to the NOVA Southeastern University (NSU) Oceanographic Center by the Florida Department of Environmental Protection. The study reveals interesting facts about waterway use and sea state. Enabling environmental measurement technology is developed in this study to cope with the problem of sampling a canal sufficiently to draw quantifiable, sustainable conclusions about sea state and vessel traffic.

Maintenance of the Nations navigational waterways is an ongoing necessity. Dealing with the shoreline is one of the most important considerations to a waterfront property owner. Information and regulatory signs, waves, and the shoreline, are among the most important considerations in maintaining a safe navigational waterway. Detailed information about waterway use is necessary for planning, education, regulation, maintenance and enforcement. Competition for a limited resource makes urban canals of particular importance for research and knowledge base development.

Boat wakes contribute to shoreline erosion, especially in unprotected smaller creeks and coves. They can also stir up bottom sediments and reduce light essential to submerged aquatic vegetation, such as sea grasses. Wakes and waves are among the factors influencing the movement of sand into a dredged channel and therefore are of current research interest. Boat wakes in restricted areas bounded by vertical sea walls can create hazardous conditions. Standing waves and rogue waves are formed at the intersection of wakes and waves. On average approximately 10,000 waves per hour were processed to arrive at the figures presented in this report.

Figure 2. Typical weekend day at the Fort Lauderdale test site is shown below. Canal sea state and maximum wake measured are given in one-hour periods starting midnight.



Water and Internet related technology is reported here that demonstrates the making of new and practical environmental measurements.

Figure 3. Shown below, is the WETS 99 online database control panel. The online control panel is found at the www.wets.net Internet site. This panel points to input forms for database queries.

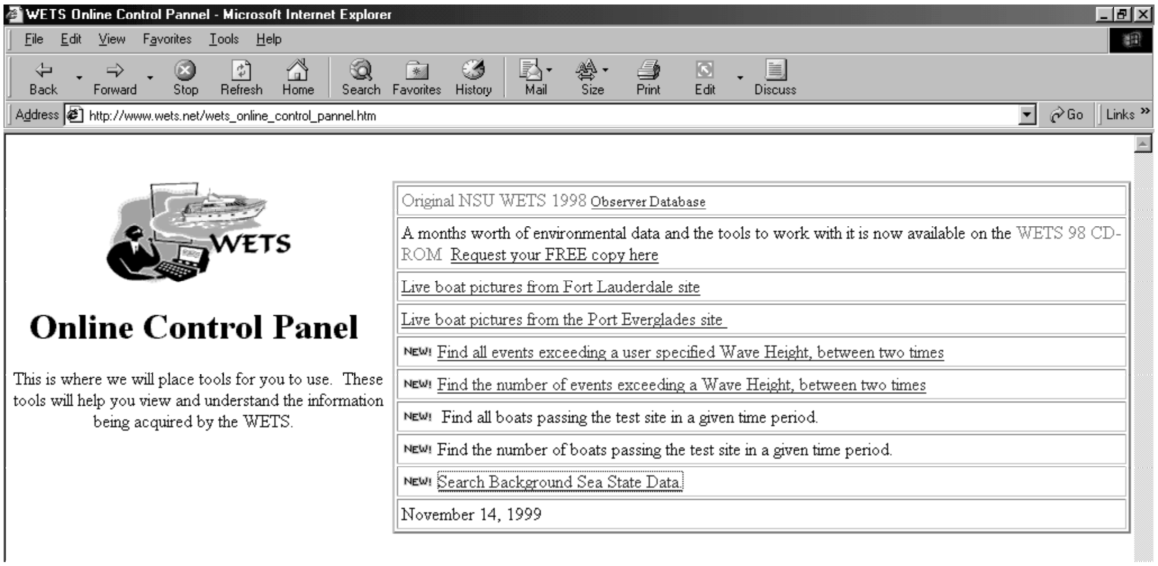


Figure 4. Shown below, is the WETS 99 image viewer. This viewer runs on a personal computer to rapidly access date and time stamped images.

A. Purpose and Scope

The 1999 Waterway Expert Traffic System or WETS research project, reported here is being conducted to accomplish three goals. The goals are to (1) reduce the data generated in the WETS98 study, (2) design, build, deploy, and test two identical, second generation versions of special equipment to monitor watercraft usage in an urban canal and (3) maintain and upgrade the ability to access information about the WETS project in real time over the Internet.

- The scope of work includes the development of the final report as an interactive report published on CDROM (included on the inside back cover). This interactive report includes the searchable database of all the analyzed and reduced data for the project from its inception in July 1998 until November 1999. Detailed reduction of the WETS 98 data is given. This data reduction reveals clearly identifiable trends in sea state and vessel traffic and provides quantifiable information on the size of the waves and wakes present in the urban canal.

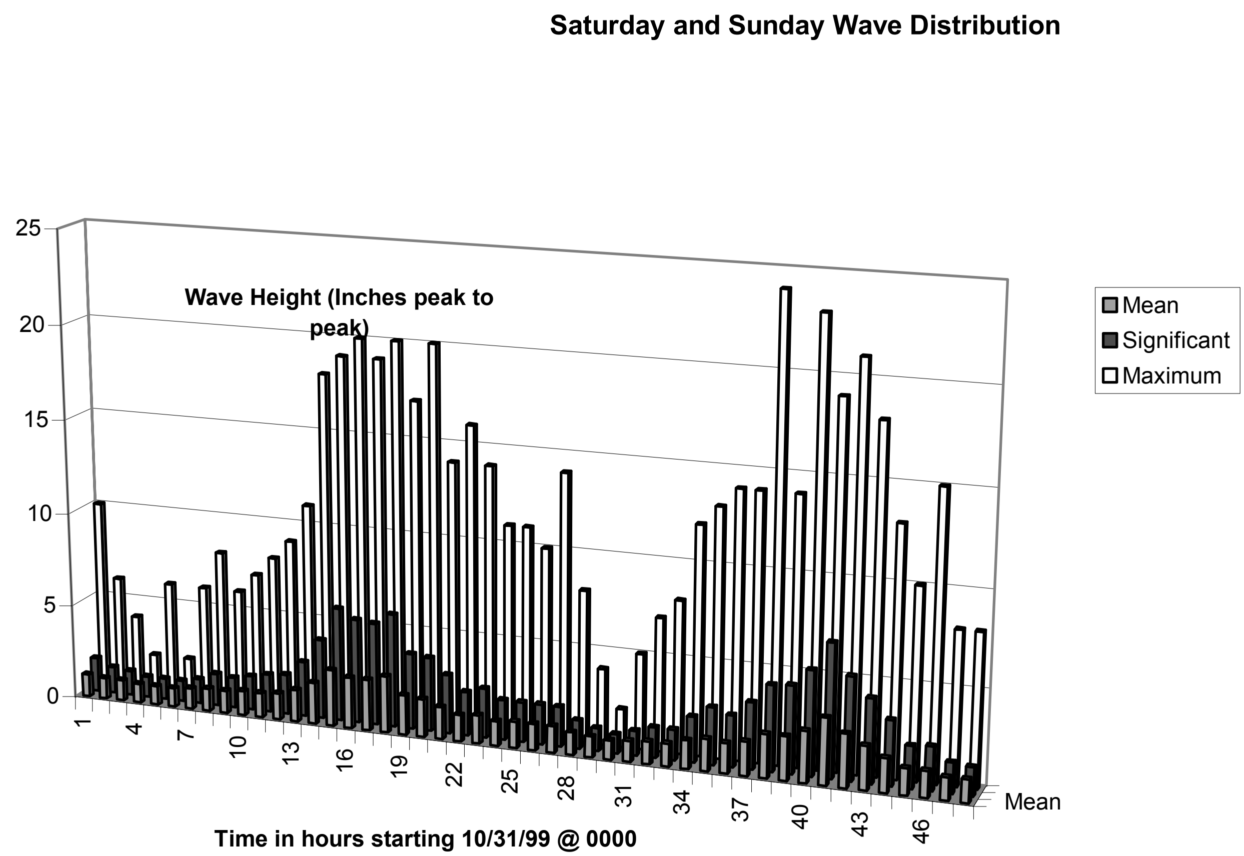
- This research adds upgrades to the original system that enhance and refine many of the WETS features and benefits. The work presented here documents the design and testing of two identical, second generation versions of special equipment to monitor watercraft usage. Documentation is provided for the expert system tools including the image viewer and wets expert system calculator. An added system feature is the ability to count vessel traffic using a LASER "trigger" or "trip wire " and to automatically generate a searchable relational knowledge base. Scalability is shown by the deployment of two nearly identical measurement systems with virtually unlimited public access to real time data over the Internet.

- This research provides for the development of a combined knowledge base that contains historic to real time information on waterway use, individual vessel wake and speed, and sea state for the two sites at which the WETS is deployed. Real time and historic information from both deployment sites is simultaneously available at the www.wets.net Internet web site. Independent information retrieval by the viewing public is made possible using a Windows NT server collocated at an Internet Service Provider (ISP). The NT server also provides for hierarchal levels of password-protected privileges for user groups.

1. Provide information on waterway use in an urban canal

We report detailed information on the frequency and occurrence of vessel traffic, boat wakes, and the canal sea state for a site located in Fort Lauderdale Florida. The information presented is obtained from both human observation and automated data collection. In addition to a sampling program by trained observers, first and second generation WETS system deployments were used for data collection. The analysis of the data from this site was automated or manually accomplished depending on the source of the data and the requirements for analysis. Typical weekend sea state is found to be periodic as shown.

Figure 5. Wave distribution is shown for 48 hours.



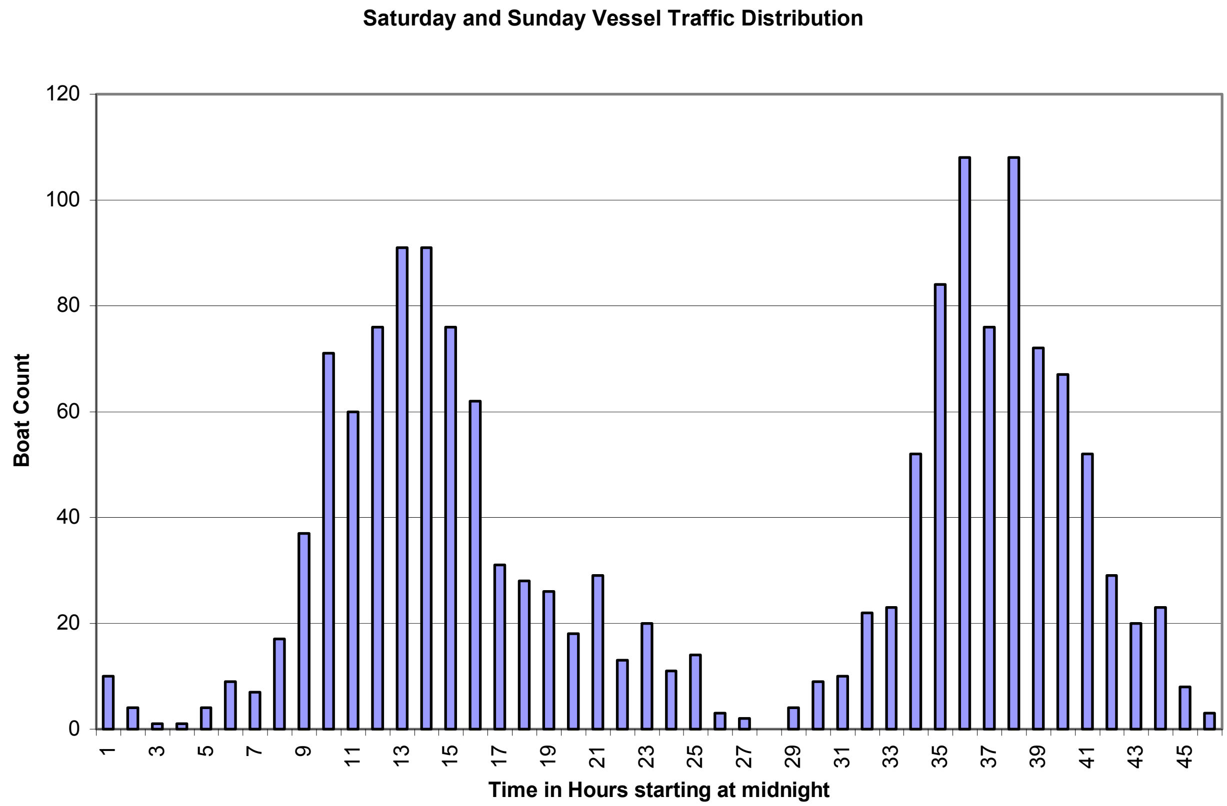


Figure 6. Shown above is verifiable boat count at the Fort Lauderdale test site for a typical weekend.

2. Develop scalable solution for environmental measurements

Today for a coastal zone automated environmental measurement system to be of importance as a management tool and to be of practical value it must be able to be deployed over a wide area and it must function in an integrated fashion as the number of occurrences of deployment of the system increases. The conduct of this research has been in part to demonstrate a scalable technology that measures and processes environmental information into a usable format in an automated fashion.

The expert system kernels, automated Internet databases, and resulting searches are indexed by site number to allow for scaling up the number of environmental measurement sites. This indexing provides a simple means of scaling up the number of test sites incrementing each site location by 1 in the root directory of the expert system kernel.

B. WETS 98 Reduction to practice of a Coastal Zone Management Tool

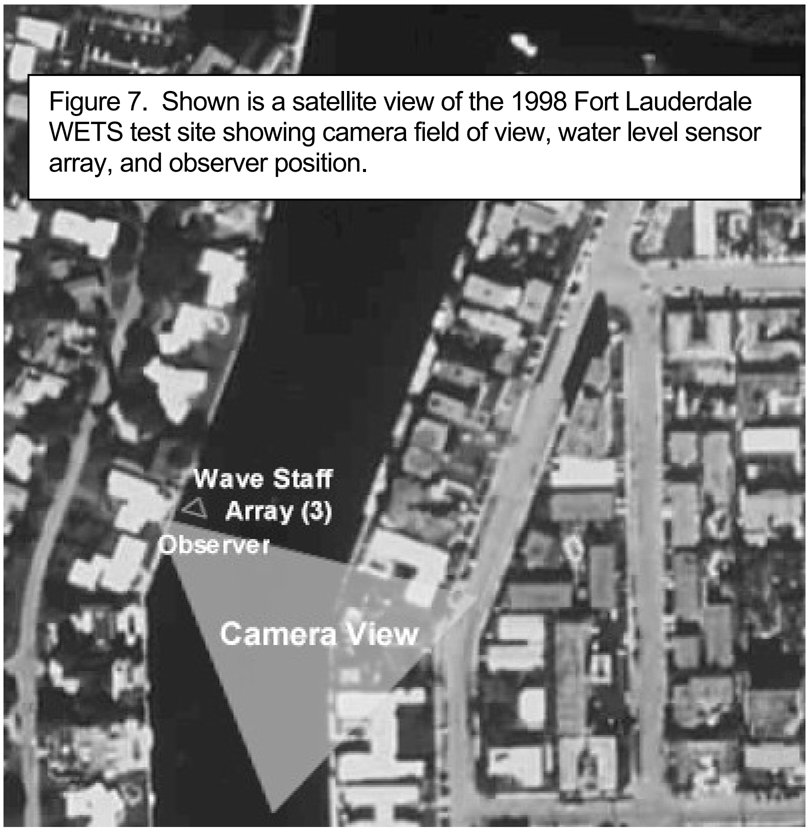


Figure 7. Shown is a satellite view of the 1998 Fort Lauderdale WETS test site showing camera field of view, water level sensor array, and observer position.

A brief overview of the first WETS project is given. To monitor watercraft usage in an urban canal, this ambitious project took on the design, testing, deployment and follow on evaluation of new hardware for making vessel traffic surveys.

The Waterway Expert Traffic System or WETS 98 research project was conducted to design, build, deploy and test special equipment to monitor watercraft usage in an urban canal. This ambitious four-month project started in mid July 1998 and concluded on November 15, 1998.

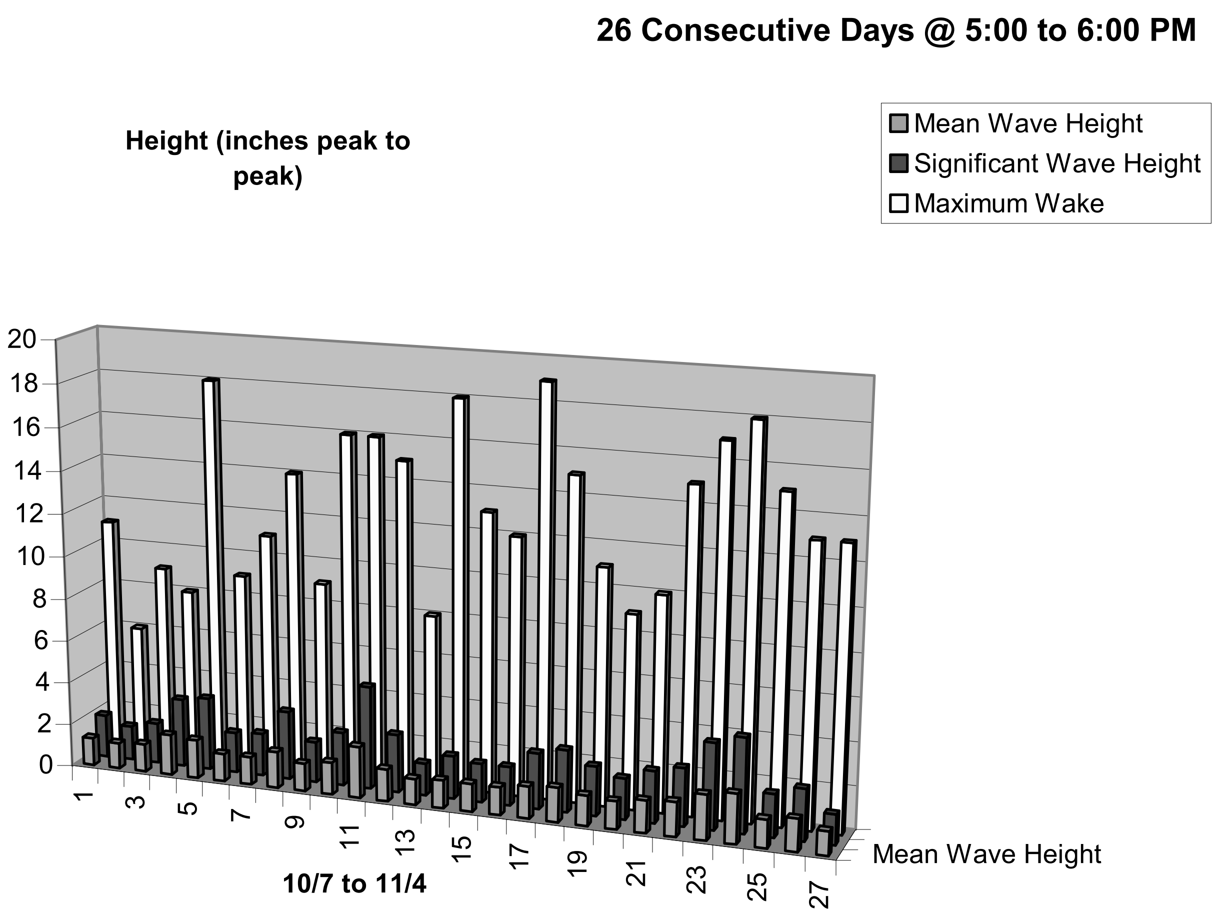
The WETS 98 project reduced to practice a machine and process to count vessel traffic using an automated method. This was the first project of its type to base in part on the location and detection of vessel traffic using a triangular array of three simultaneous measurements of water level. WETS 98 demonstrated that three wave staffs located in and urban canal could be used successfully to determine the course, speed, and position of a passing ship.

The WETS 98 final report is uniquely presented in an interactive format on a series of CD's. The first CD or master CD contains sufficient data to functionally stand-alone. This CD is intended for unlimited distribution. This unlimited distribution master CD gives a good overview of the project and contains sufficient information for the casual viewer. The tools that are provided on this CD can be used to query data on additional DATA CD's. The final report contains all the data CD's generated during the project.

The work done under WETS 98 included the generation of an observer database. This database provides comparison and to some extent validation of the data generated from the wets automated system.

Although the WETS 98 project collected a considerable amount of data, analysis of the data was pretty much left to the user. The WETS 99 effort processes the wets 98 data.

Figure 8. Processed data from the WETS 98 wave staff arrays.



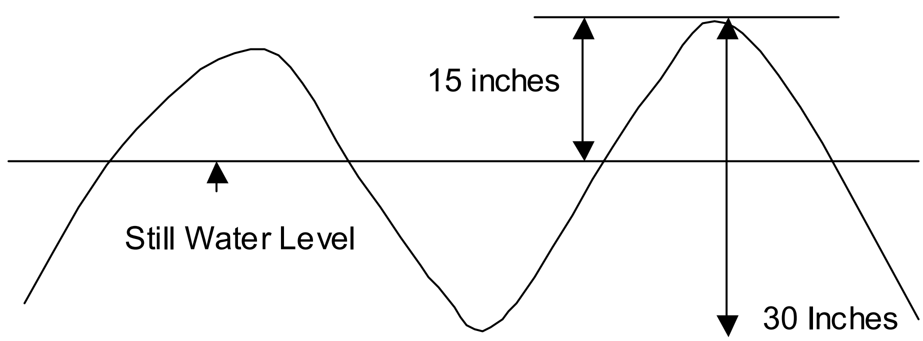
C. WETS 99 Data Reduction and Dual System Deployments

The WETS 99 saw a complete reduction of the automated water level data accumulated in the WETS 98 project and a partial reduction of raw data into calculated speed from boat wake using the expert system calculator. WETS 99 deployed two complete fully featured systems using second-generation WETS kernel technology with sensor inputs from a visible LASER trip wire, camera, compass, and array of wave staffs. This second generation technology automates the process of data collection and reduction more fully.

1. WETS 98 Wave height data reduction

Throughout this report all wave heights are measured in values of what is termed peak to peak or sometimes called just peak inches. A peak value is wave height measured from the crest to the trough.

Definition of Terms



Amplitude = 15 inches Height = 30 inches

Therefore a wake 15” from the still water line is equivalent to a wake of 30 inches peak to peak.

Appendix A given in the enclosed CD is a table of reduced wave height data by hour of the day for a 55 day period beginning 10/4/98 and ending 11/28/98. This detailed summary contains the following list of tabulated results:

- Date
- Hour (not corrected for daylight savings time)
- Mean Wave Height
- Standard Deviation of Wave Height (Sigma)
- Significant Height (Average of the highest one third of the waves)
- Top 10% (Average height of the highest 10% of the waves)
- Top 5% (Average height of the highest 5% of the waves)
- Top 2 % (Average height of the highest 2% of the waves)
- MAX maximum wave height wave recorded during the period of observation

D. Study Areas

1. Fort Lauderdale, Florida test site

The site is located in the Intercoastal waterway. The location is south of the Sunrise Blvd. Bridge on the west side of the Intercoastal in 10 feet of water 25 feet from shore.

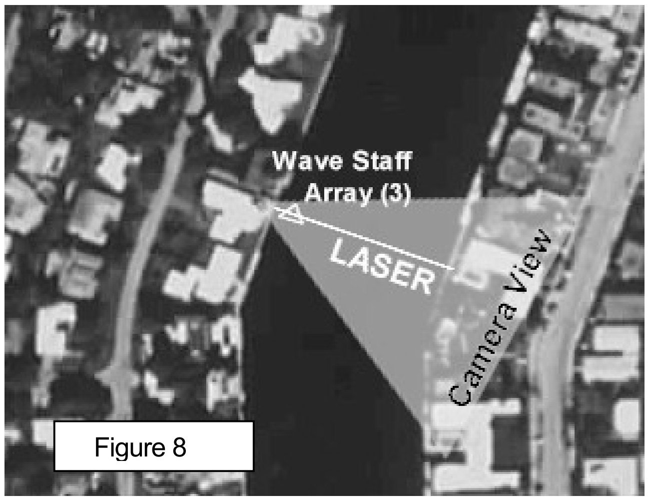


Figure 8

Exact site location is **25 degrees 43.8 minutes North Latitude, and 80 degrees 03.8 minutes West Longitude.** The site was mutually agreed on by the DEP and NSU. The canal site was selected because it is of local interest and under consideration for a change in speed and wake limits. The site was chosen because a cooperating resident willingly worked with our staff to provide space for computers. We were allowed to put numerous telephone lines into the house, through the back yard and into the waterway. A side benefit to the resident was the upgrade in telephone service to ISDN. Geometry of the WETS 98 Fort Lauderdale site was upgraded to align the field of view of the camera with the wave staff array. The LASER trip was aligned with the wave staff array and the camera. This alignment provides for significant improvements in the ability to do quick look analysis on the data. In addition to lining up the sensors in the field of view of the camera, time was synchronized among all the sensor systems providing improvement over the 1998 system. The site bathymetry and the 1999 sensor layout for the Fort Lauderdale site are given below.

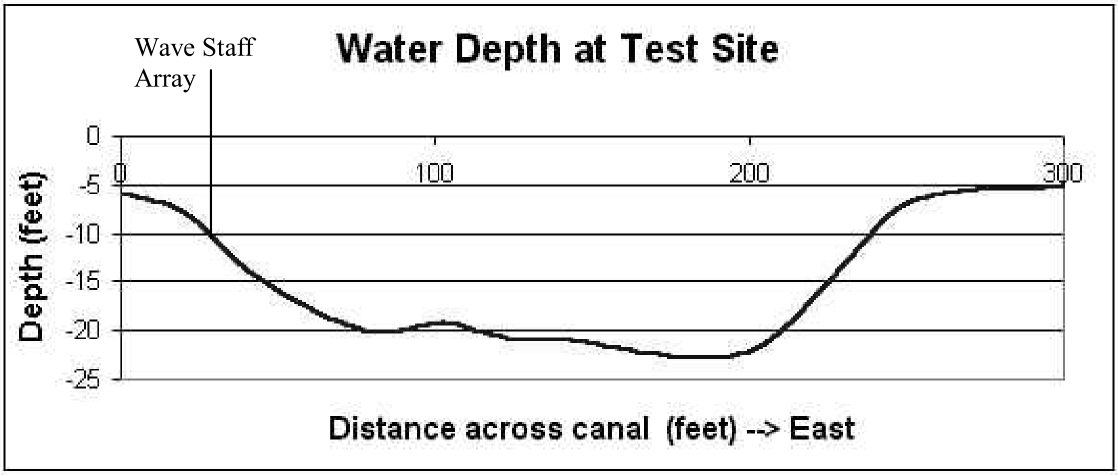


Figure 9.Shown above is water depth at test site.

Figure 10. Shown are three snapshots of the test site taken installation day.

2. Port Everglades, Florida test site

Figure 11. Installation Day

The site is located in the Intercoastal waterway. The location is on the south side of Port Everglades on the east side of the Intercoastal outside of the channel in 6 feet of water 25 feet from shore. **The location is 26 degrees 05.475 minutes North Latitude, and 80 degrees 06.752 minutes West Longitude.** The site was mutually DEP and NSU. The Port Everglades site was selected because it is of local interest and in the immediate vicinity of the NOVA Southeastern University Oceanographic Center. The site was chosen because NSU provides space for computers and a direct connection to an Internet gateway over a Local Area Network (LAN) connected by a wireless link. To establish the site we ran an “in ground burial type” telephone line from the wave staff array to a laboratory building on the east side of the property. A side benefit to the project was the availability of a robust LAN with Internet gateway. Geometry of the WETS 98 Port Everglades site was chosen to align the field of view of the camera with the wave staff array. The LASER trip was aligned with the wave staff array and the camera. The sensor layout for the Port Everglades site is given above.

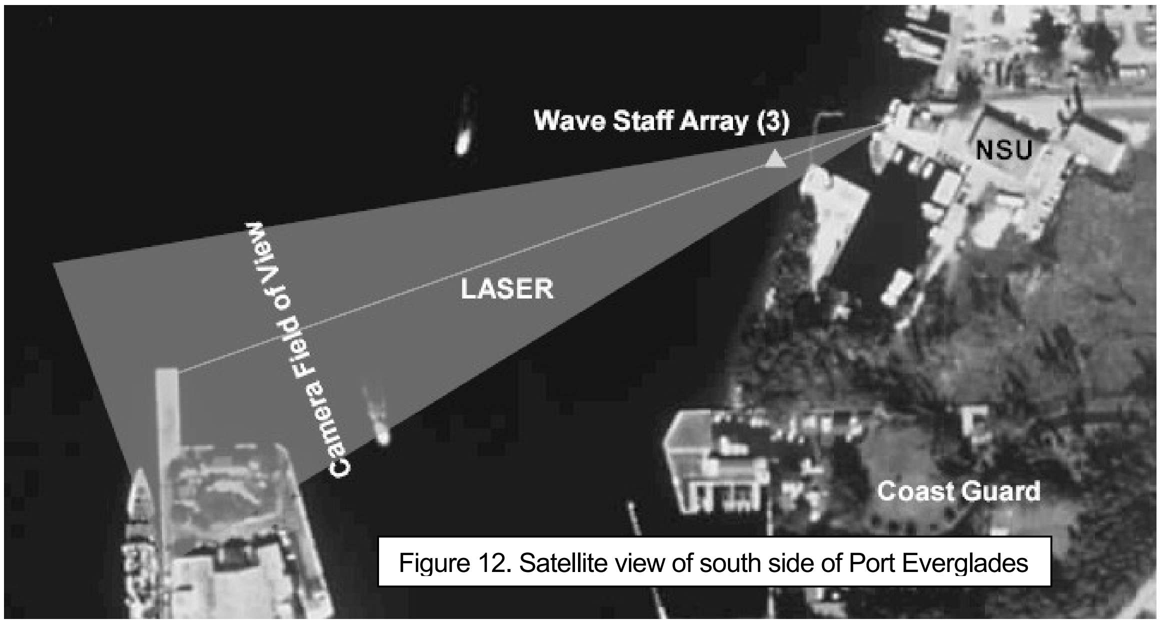


Figure 12. Satellite view of south side of Port Everglades

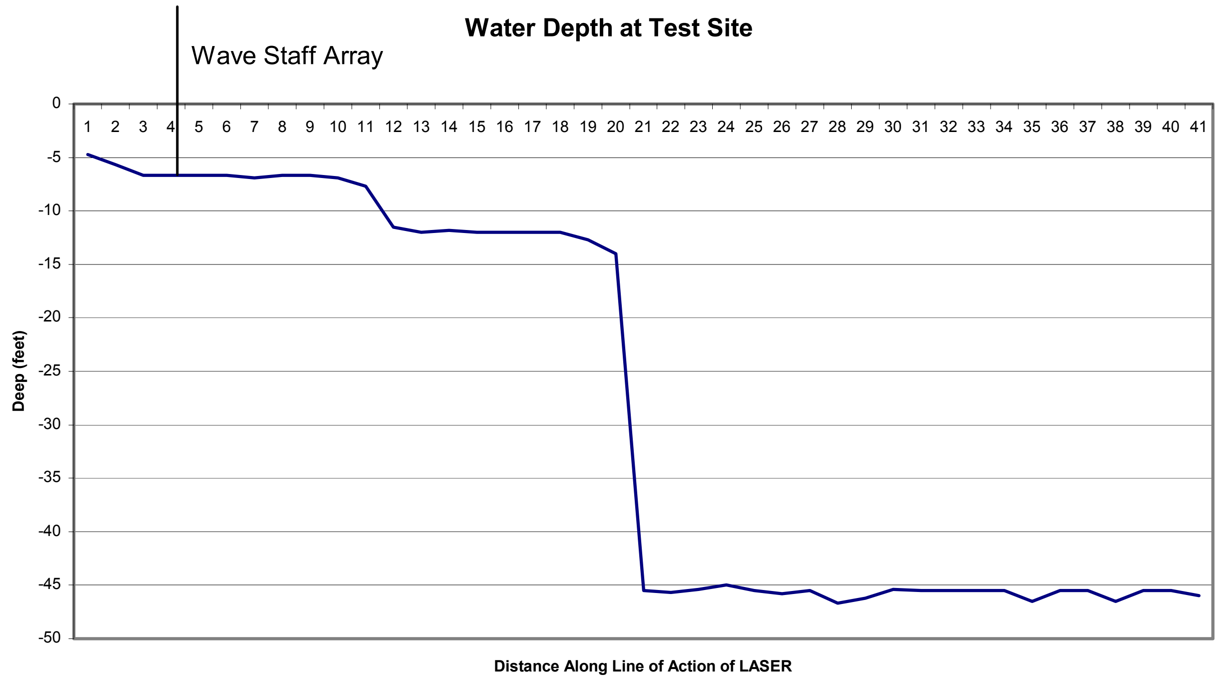


Figure 13. Bottom depth along the line of action of the LASER, Port Everglades, FL.

The demonstration site in Port Everglades is practical, fully automated, and suitable for long-term low cost deployments. The demonstration site is based on second-generation WETS kernel technology with sensor inputs from a visible LASER trip wire, camera, compass, and array of wave staffs. It is strategically located adjacent to the NOVA Southeastern University Oceanographic Center. Both the Ft. Lauderdale site and the Port Everglades site now have simultaneously operating systems.

Figure 14. Given above is the view looking west WETS of the Port Everglades installation.

Section II

Database Development

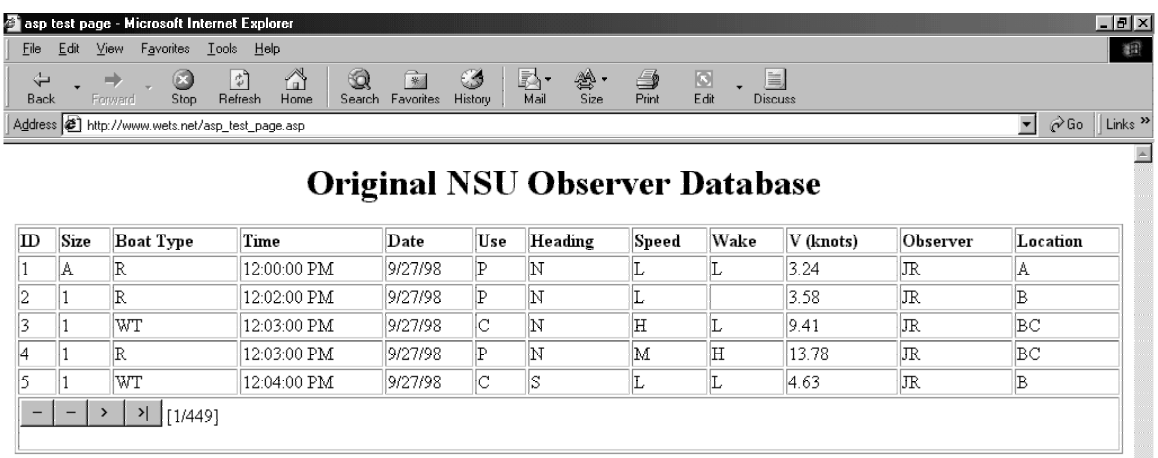
Similar data bases were generated and combined for analysis

A. WETS 98 Observer Database

The survey portion of the monitoring provides detailed information and ground truth of how many, what kinds, how, and when watercraft is being operated at the research site. The observer counts the number of watercraft present as a function of time and record details of each. The records include estimates of the boat speed, heading, length of the vessel, and mode of operation. The observer also logs observations of the wave climate and watercraft.

The observer's day consisted of 1 hour of travel, four hours of observation, and three hours of data input and review. At NSU OC data from logs were entered into a relational computer database. Observations taken from the field logs were compared as necessary with the time stamped video logs.

Figure (15) The original NSU Student Observer Database is available from the Control Panel at the www.wets.net Internet site.



Original NSU Observer Database

ID	Size	Boat Type	Time	Date	Use	Heading	Speed	Wake	V (knots)	Observer	Location
1	A	R	12:00:00 PM	9/27/98	P	N	L	L	3.24	JR	A
2	1	R	12:02:00 PM	9/27/98	P	N	L		3.58	JR	B
3	1	WT	12:03:00 PM	9/27/98	C	N	H	L	9.41	JR	BC
4	1	R	12:03:00 PM	9/27/98	P	N	M	H	13.78	JR	BC
5	1	WT	12:04:00 PM	9/27/98	C	S	L	L	4.63	JR	B

[1/449]

In this effort we monitored the research site 4 hours a day 7 days a week, over a 3 to 5 week period. By incrementing the observation period later each day over a twelve to twenty hour period (e.g., Day 1: 8AM-12noon; Day 2: 12 noon-4PM; Day 3: 4PM-8PM; etc.), we sought to sample the activities at each site over time. A site was be sampled three times, at the same time period, on the same day of the week, during the observation period. This required 21 days of observation. Data was not taken during thunderstorms, heavy rain, or when lightning is present. Data will not be taken outside of daylight hours.

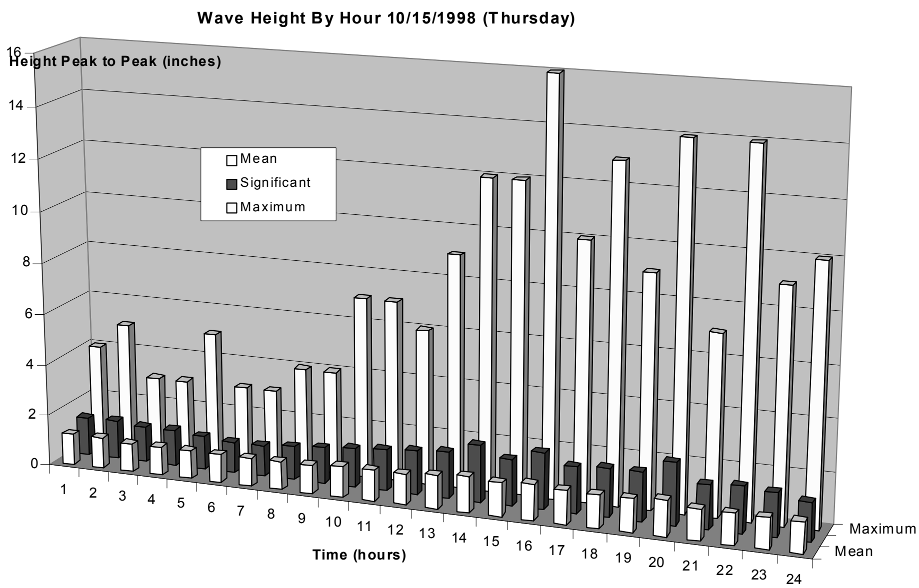
B. Data Reduction and Error Analysis of WETS 98 CD Rom Record Set

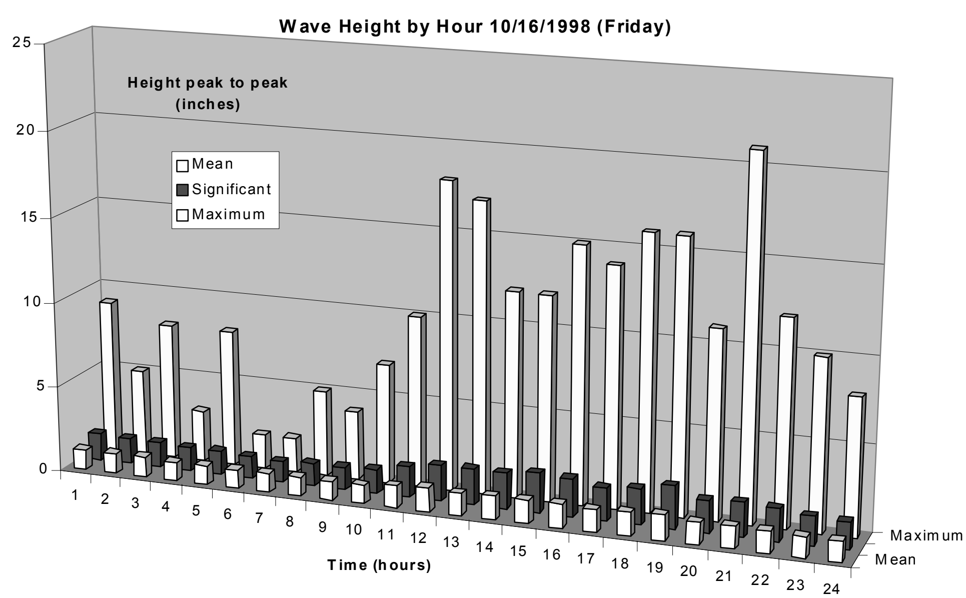
Data reduction of the wets 98 CD ROM record set (6 DCROMS of pictures and wave height data) was accomplished both in an automated and manual fashion. By writing visual basic computer programs to analyze the wave data, the data reduction was automated, and all the data was completely reduced. Manually making the interpretation and entering the reduced data into the database, accomplished reducing the picture data, and updating the observer database. These arduous and difficult processes succeeded in completely reducing only one of the six CD ROM's of data collected during WETS 98. An abbreviated set of picture files only was entered into the WETS 99 combined database for an additional 3 CD-ROM's for daylight hours only. This manual process of data reduction is completely eliminated and replaced with a real time automated process in the WETS 99 data collection system.

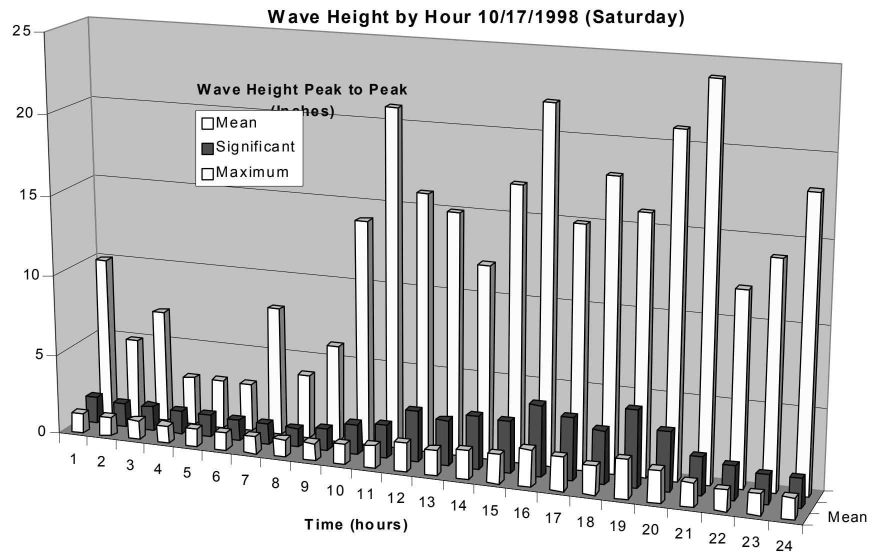
Plotted from data tabulated in Appendix A for the Fort Lauderdale site, and given next, are seven stacked bar graph plots. The plots are of reduced wave height data for one week, by day, and by hour for seven consecutive days starting on Thursday October 15 1998. The complete set of this type of data reduction is given in Appendix B (see enclosed CD ROM).

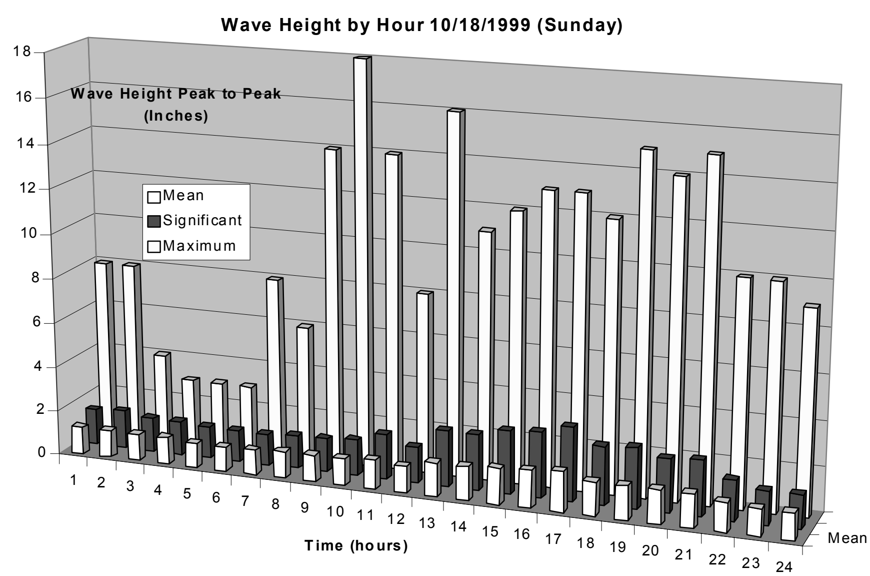
Plotted by hour are the mean wave height, significant wave height (significant wave height is defined as the average of the one third highest waves), and the maximum wave height. Note for the one-week period the wave heights are grouped by hour starting at Midnight (0000) and running for 24 hours.

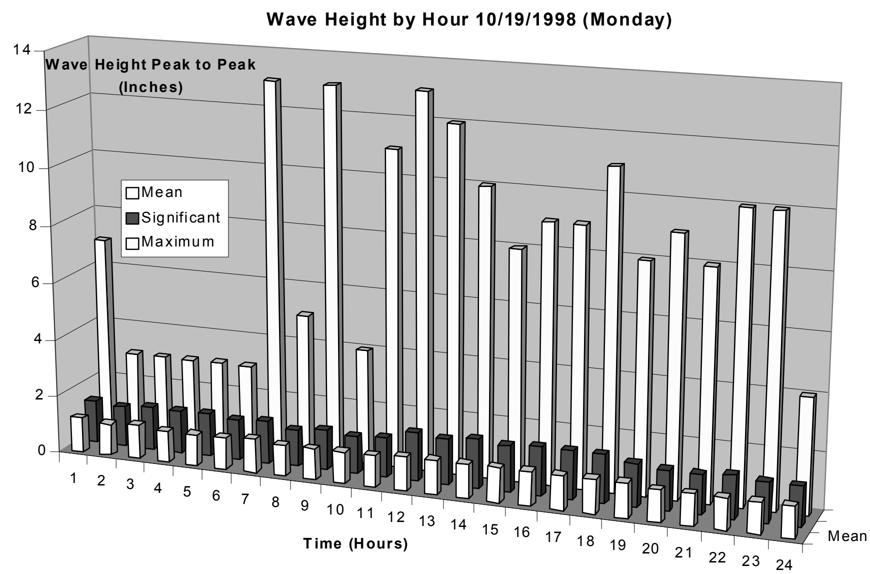
Figure 16. Given below is seven Stacked Bar Graph Plots showing one week of data collected during the WETS 98 Project and reduced as part of the WETS 99 project.

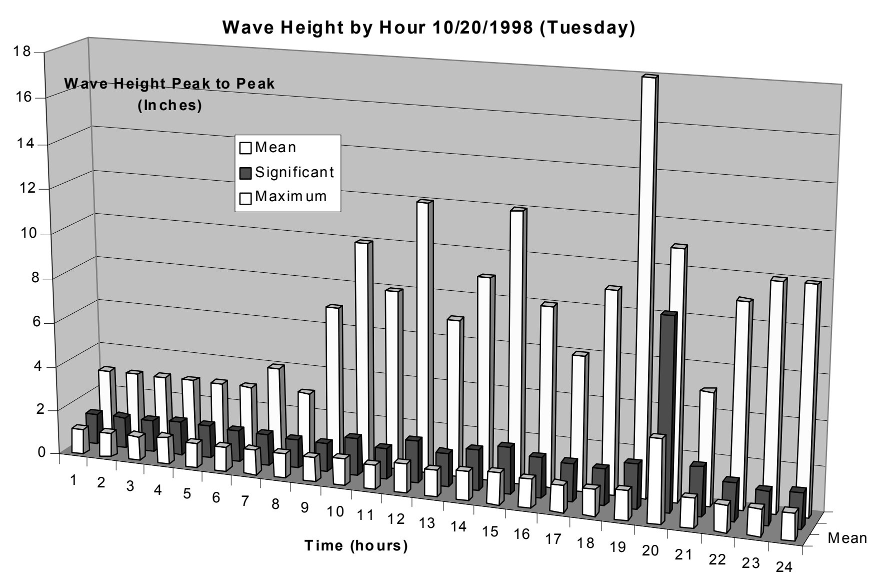





Wave Height by Hour 10/17/1998 (Saturday)
Wave Height Peak to Peak (Inches)
Mean
Significant
Maximum
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)
Mean


Wave Height by Hour 10/18/1999 (Sunday)
Wave Height Peak to Peak (Inches)
Mean
Significant
Maximum
0
2
4
6
8
10
12
14
16
18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)
Mean


Wave Height by Hour 10/19/1998 (Monday)
Wave Height Peak to Peak (Inches)
14
12
10
8
6
4
2
0
Mean
Significant
Maximum
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (Hours)
Mean


Wave Height by Hour 10/20/1998 (Tuesday)
Wave Height Peak to Peak (Inches)
18
16
14
12
10
8
6
4
2
0
Mean
Significant
Maximum
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)
Mean

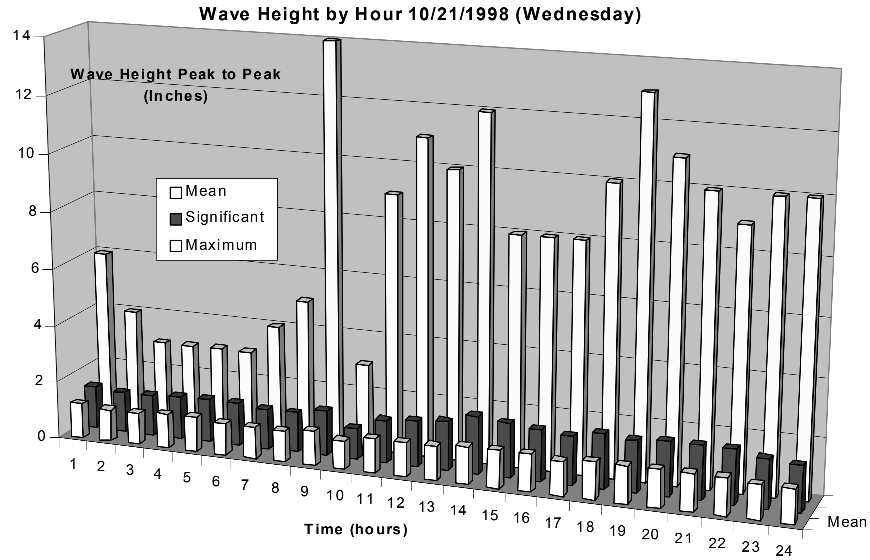
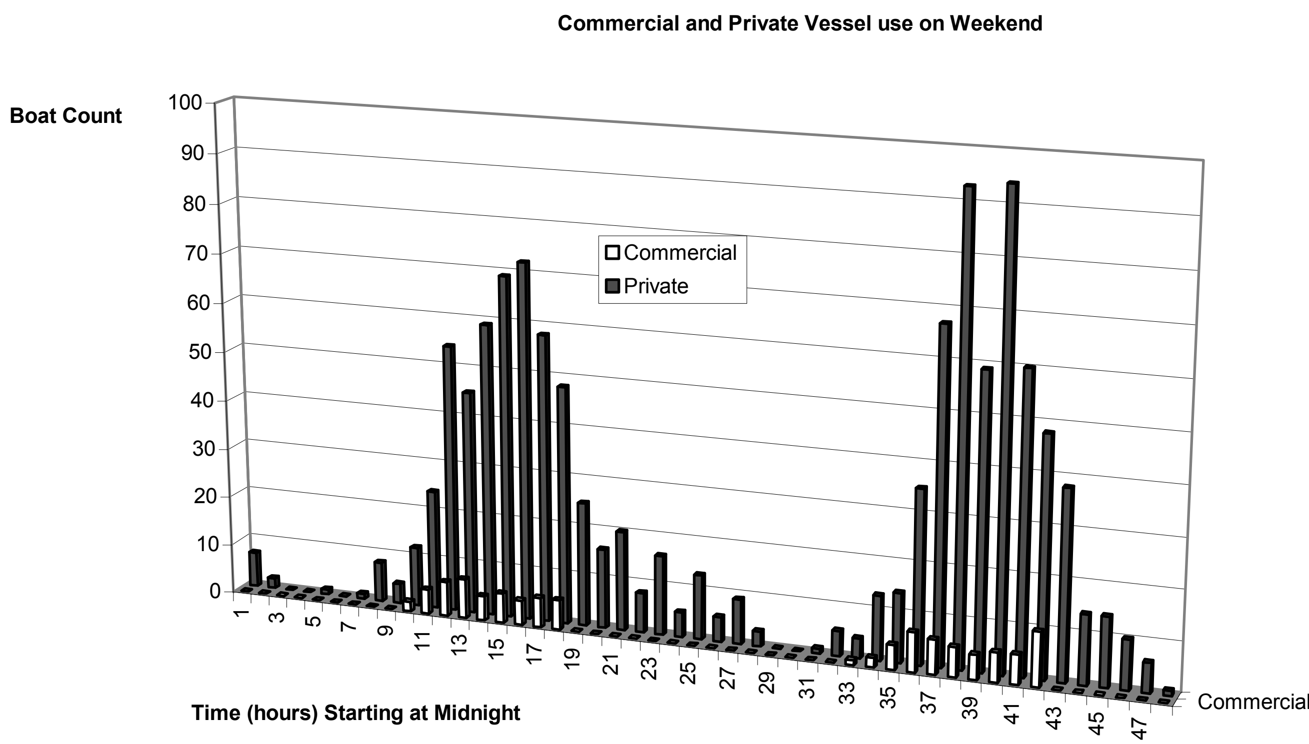


Figure 17. Reduction of data for the wets 1998 boat count gives the following type of plot.



C. Student Derived WETS 98 Machine Vision Database Extensions

In order to extend the knowledge base in WETS 98 observer database with reduced data from the wets 98 machine vision records, a record for each passing boat is needed. To obtain this record from the machine vision records a graduate student from NSU reviewed the records with the expert system tools developed in wets 98. The machine vision records consisted of a picture every ten seconds and digital records of water level from three wave staffs with orientation known from the output of a heading compass.

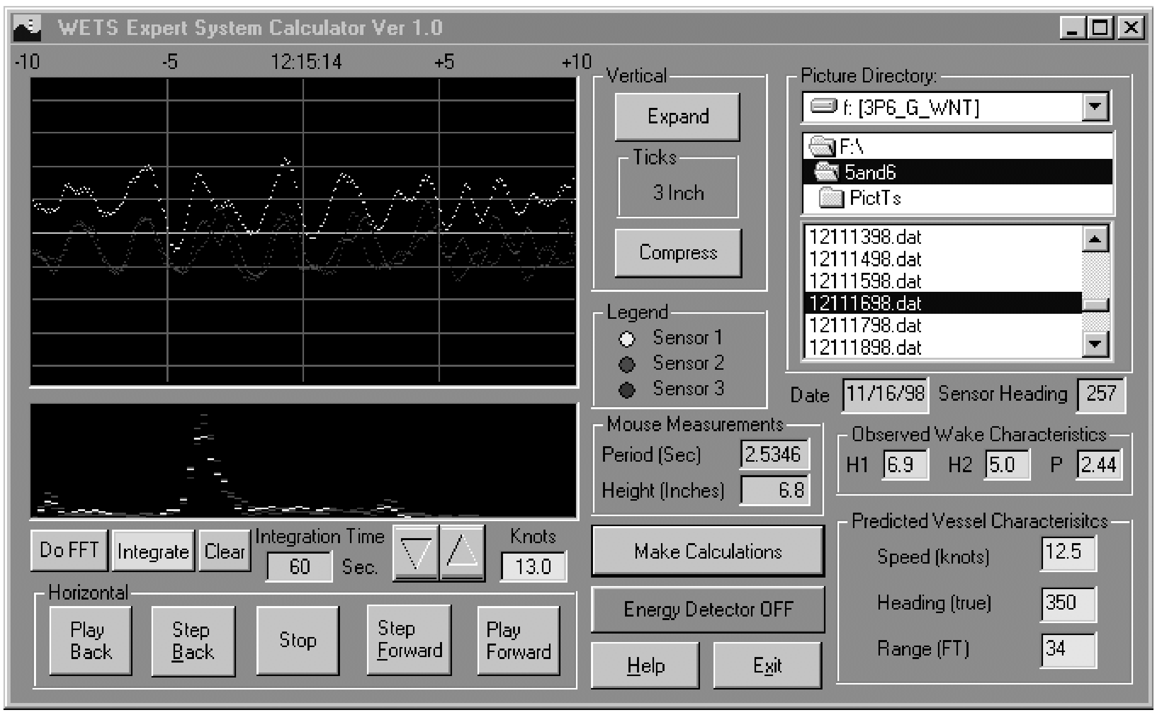


Figure 18. WETS Expert system Calculator runs on a PC and is used to calculate the wake size, and the speed, range and heading of the waterway traffic. This calculator also serves as a spectrum analyzer. This data was then input into the combined database.

The WETS project: data entry consisted of the conversion of pictures and wake wave heights into useable database form for analysis and the organization of the data into easily accessible format for WETS program users.

To obtain a new data record the graduate student while simultaneously viewing the pictures in Image Viewer and the corresponding wave heights in the WETS Expert System Calculator would form a record for each passing boat. Data was discarded for any time period where either pictures or wave heights were not present. To correct for time differences between Image Viewer display time and the Calculator display time, careful observation was a must.

The Form layout consisted of several key fields, with assisting fields to provide information needed to correspond boats with their records. The key fields included:

- Event Number: Corresponding number to boat passage on each day
- Observer: on-site observer or data analyzer
- Speed: approximate, comparable to calculated velocity
- Wake size: depends upon wake height as seen in Calculator
- Time: display time on the Image Viewer
- Wake time: display time on the Calculator

And the assistant fields are the following:

- Size: approximate; 5 categories
- V (knots): processed by the Calculator
- Use: private, commercial, educational, police
- Location: in terms of position in canal

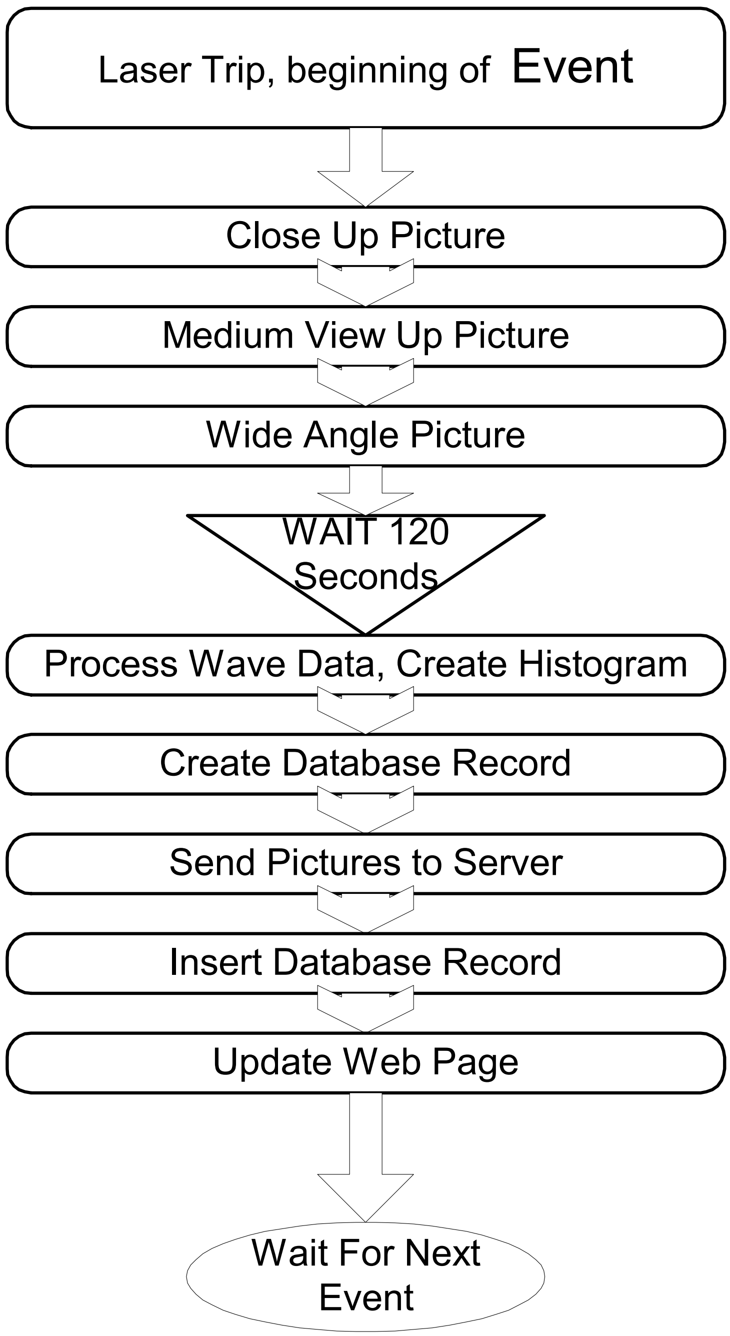
Starting at 12:00am on each particular day, each boat passage was given a sequential number (starting at 1), so a total number of boats can be obtained for each day. For time periods where numerous boats passed by within seconds, the location and heading fields will be helpful to the user. An "other" field was added to inform the user of extenuating circumstances. For example, during the first months of the experiment pictures were being taken every ten seconds. When a boat passed by between picture shots, "no picture" was added to the "Other" field. If a boat turned around in the area around the test site it was noted in the "Other" field.

The work product for this student effort was an observer database that extended the "original observer database" with the data gleaned from the machine vision records using the expert system tools. NSU Oceanographic center graduate students conducted both database efforts. Both efforts were marked by long periods of human observation and computation. It is now estimate one day of machine vision database could be reduced in three hours by a student if a quantitative speed was not calculated with the expert system calculator. If this calculator was use the time for data reduction was longer than the actual time of data collection.

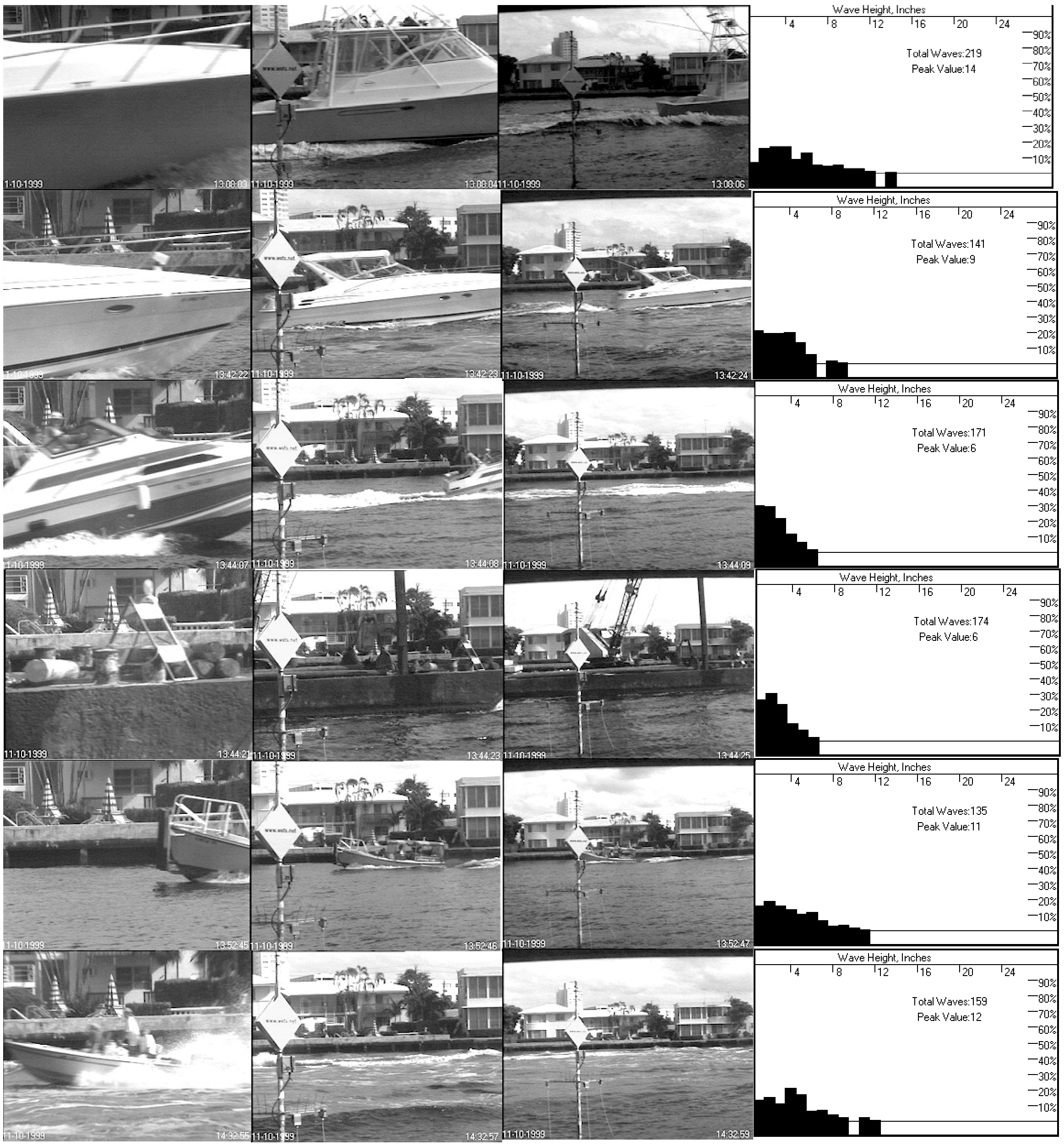
D. WETS 99 Machine Vision Database

The processing flow chart for compiling an entry into the machine vision database is given in Figure 19 below.

Event Processing Diagram



A few representative samples of entries into the machine vision database are given in Figure 20 below. All samples were taken from 11/10/99, a Wednesday afternoon between 1:00 and 2:30 PM. The top four vessels are south bound and the bottom two are north bound. Even from this limited sampling conclusions may be drawn as to the look and the actual size of wakes. The entire machine vision database is on the enclosed CD-ROM. This database is suitable for educational and for coastal zone management use.



Section

III Database Analysis

What we did with the data and how we did it.

A. Structured Queries

Structured quires were developed to answer basic questions of about vessel traffic and waterway use in the urban canals under study. The quires demonstrate the type of information that may be readily gleaned from the knowledge base. Data analysis included searching the data for the largest wake each hour and then tabulating and plotting this data for periods of interest.

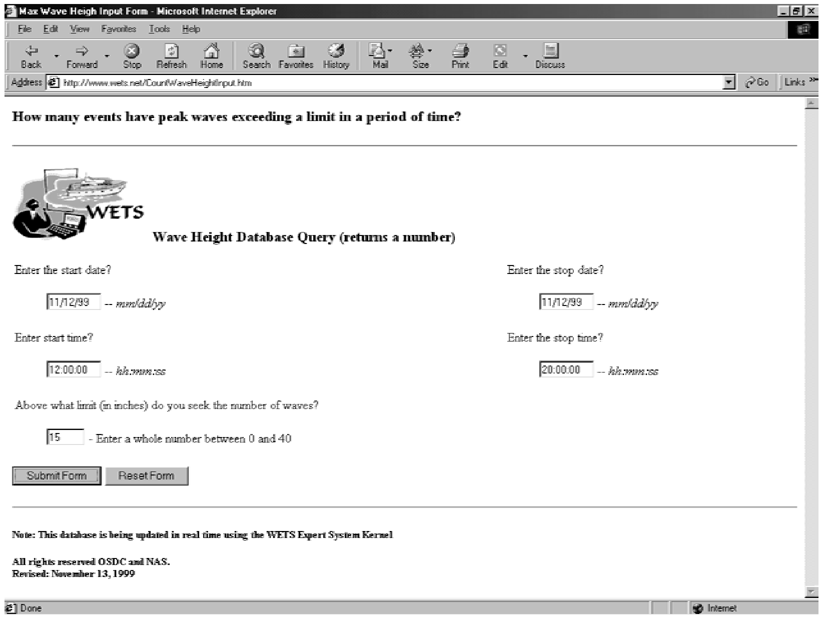
Quires were developed for a number of situations of interest only a few of which are reported here. At the time of this writing the databases are continuing to grow both through manual and student input and by automated input. The Port Everglades system is just coming online beginning to fill a database.

We have now achieved a level of understating about the use of various Microsoft products such as Front Page and Access such that structured quires may be added to the WETS with relatively little difficulty. This is in stark contract to almost all of the rest of the time spent on this effort where we appeared to be up against a significant barrier in our ability to translate questions into answers over the Internet.

A breakthrough in our ability to write SQL queries and interface the results to an Internet site now means we may significantly expand the scope of our analyses and understanding of various vessel traffic related situations.

1. How many wakes occur in excess of X inches in time T?

Figure 21 the insert below (on following page) is taken from the online entry form, which drives the database query to answer this question. This technology uses active server pages.


Max Wave Heigh Input Form - Microsoft Internet Explorer

Address: http://www.wets.net/CountWaveHeightInput.htm

How many events have peak waves exceeding a limit in a period of time?

Wave Height Database Query (returns a number)

Enter the start date? 11/12/99 -- *mm/dd/yy*

Enter the stop date? 11/12/99 -- *mm/dd/yy*

Enter start time? 12:00:00 -- *hh:mm:ss*

Enter the stop time? 20:00:00 -- *hh:mm:ss*

Above what limit (in inches) do you seek the number of waves?

15 - Enter a whole number between 0 and 40

Submit Form | Reset Form

Note: This database is being updated in real time using the WETS Expert System Kernel

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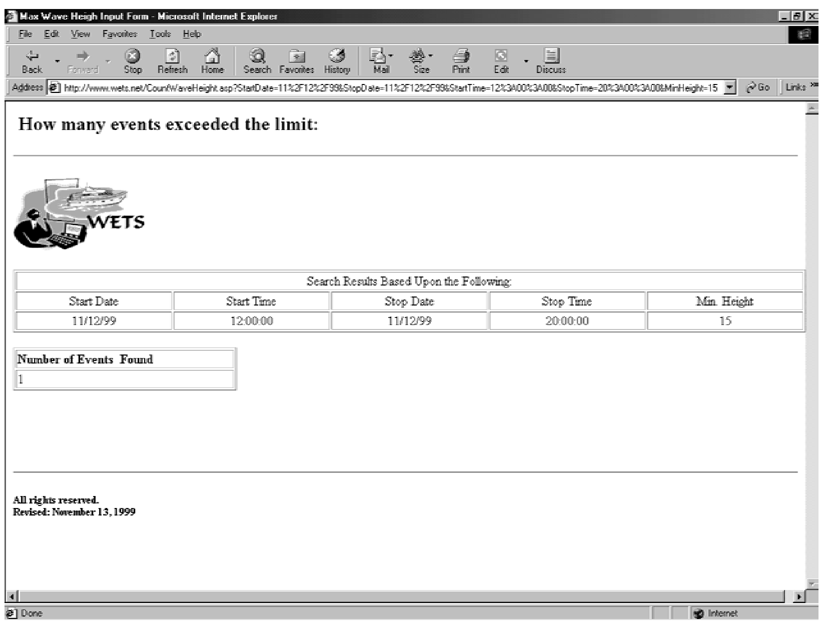
Max Wave Heigh Input Form - Microsoft Internet Explorer

Address: http://www.wets.net/CountWaveHeight.asp?StartDate=11%2F12%2F99&StopDate=11%2F12%2F99&StartTime=12%3A00%3A00&StopTime=20%3A00%3A00&MinHeight=15

How many events exceeded the limit:

Search Results Based Upon the Following:				
Start Date	Start Time	Stop Date	Stop Time	Min. Height
11/12/99	12:00:00	11/12/99	20:00:00	15

Number of Events Found
1

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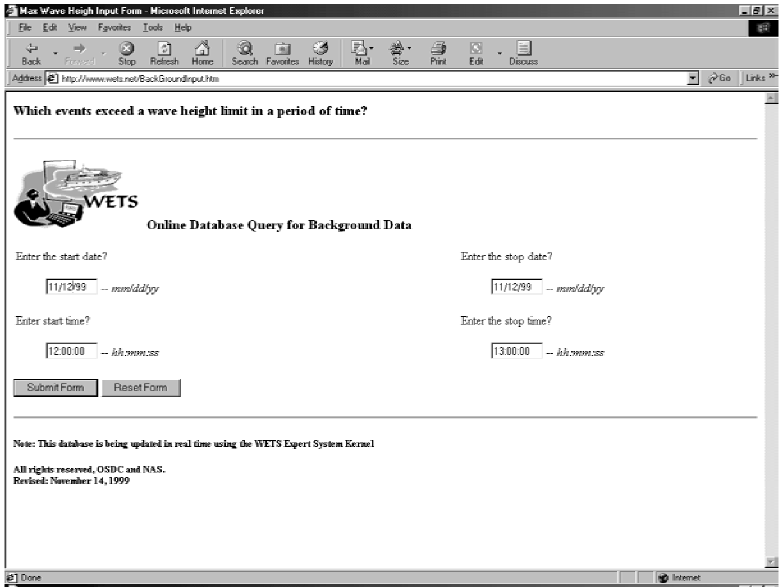
2. What is the sea state in time T?

This question is answered in the three forms shown below. These forms Figure 22 (on the following page) were captured from the WETS Internet site. This query provides information on the sea state and a tide measurement from three wave staffs.


Max Wave Heigh Input Form - Microsoft Internet Explorer

Address: http://www.wets.net/BackGroundInput.htm

Which events exceed a wave height limit in a period of time?

WETS

Online Database Query for Background Data

Enter the start date? 11/12/99 -- *mm/dd/yy*

Enter the stop date? 11/12/99 -- *mm/dd/yy*

Enter start time? 12:00:00 -- *hh:mm:ss*

Enter the stop time? 13:00:00 -- *hh:mm:ss*

Submit Form | Reset Form

Note: This database is being updated in real time using the WETS Expert System Kernel

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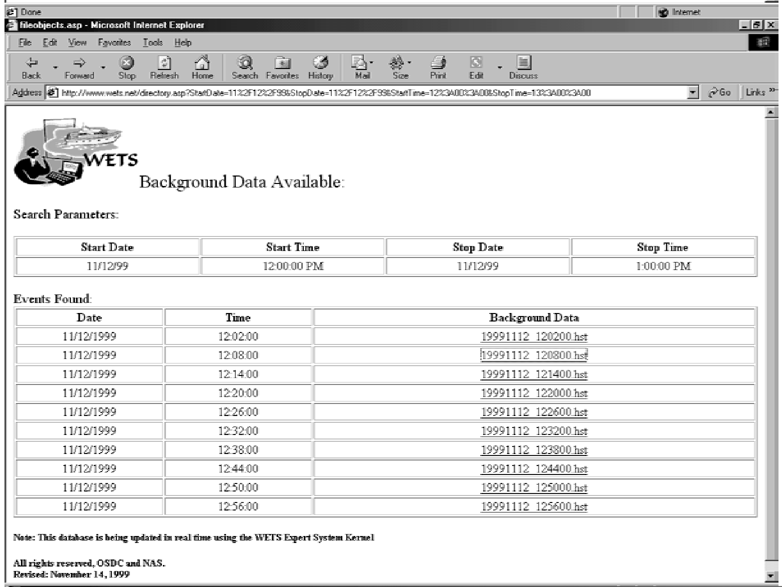
fileobjects.asp - Microsoft Internet Explorer

Address: http://www.wets.net/directory.asp?StartDate=11%2F12%2F99&StopDate=11%2F12%2F99&StartTime=12%3A00%3A00&StopTime=13%3A00%3A00

WETS

Background Data Available:

Search Parameters:

Start Date	Start Time	Stop Date	Stop Time
11/12/99	12:00:00 PM	11/12/99	1:00:00 PM

Events Found:

Date	Time	Background Data
11/12/1999	12:02:00	19991112_120200.hst
11/12/1999	12:08:00	19991112_120800.hst
11/12/1999	12:14:00	19991112_121400.hst
11/12/1999	12:20:00	19991112_122000.hst
11/12/1999	12:26:00	19991112_122600.hst
11/12/1999	12:32:00	19991112_123200.hst
11/12/1999	12:38:00	19991112_123800.hst
11/12/1999	12:44:00	19991112_124400.hst
11/12/1999	12:50:00	19991112_125000.hst
11/12/1999	12:56:00	19991112_125600.hst

Note: This database is being updated in real time using the WETS Expert System Kernel

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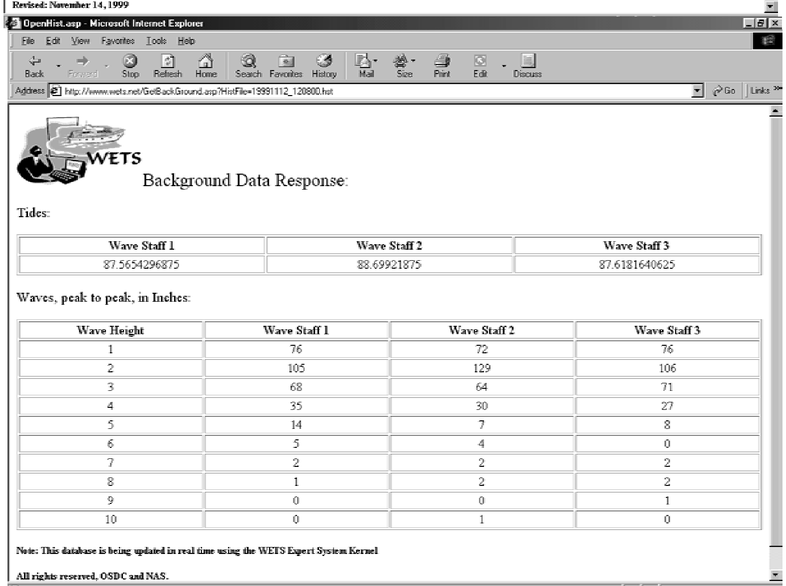
OpenHist.asp - Microsoft Internet Explorer

Address: http://www.wets.net/GetBackGround.asp?HistFile=19991112_120800.hst

WETS

Background Data Response:

Tides:

Wave Staff 1	Wave Staff 2	Wave Staff 3
87.5654296875	88.69921875	87.6181640625

Waves, peak to peak, in Inches:

Wave Height	Wave Staff 1	Wave Staff 2	Wave Staff 3
1	76	72	76
2	105	129	106
3	68	64	71
4	35	30	27
5	14	7	8
6	5	4	0
7	2	2	2
8	1	2	2
9	0	0	1
10	0	1	0

Note: This database is being updated in real time using the WETS Expert System Kernel

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B. WETS Expert System Kernel

1.0 What do we mean?

The WETS expert system is the compilation of analytical and engineering methods that receive inputs from sensor subsystems and yield information to a human user in a way that implies a beneficial artificial intelligence. That is, the expert system answers questions about a situation or process. The actions of the expert system are based on sensor inputs and a question formed by the expert system user. Analytical and engineering methods range from application of first principles of physics to application programming languages.

Special programs were written containing the intellectual property of the analytical and engineering methods. To execute the mathematical programs inherent to the expert system programming languages were used to connect hardware with software and the end user. Programming languages used in the expert system development include but are not limited to Visual Basic, Sequential Programming Language (SQL), Hyper Text Markup Language (HTML), machine language, and languages specific to various microcomputers including g the stamp II computer.

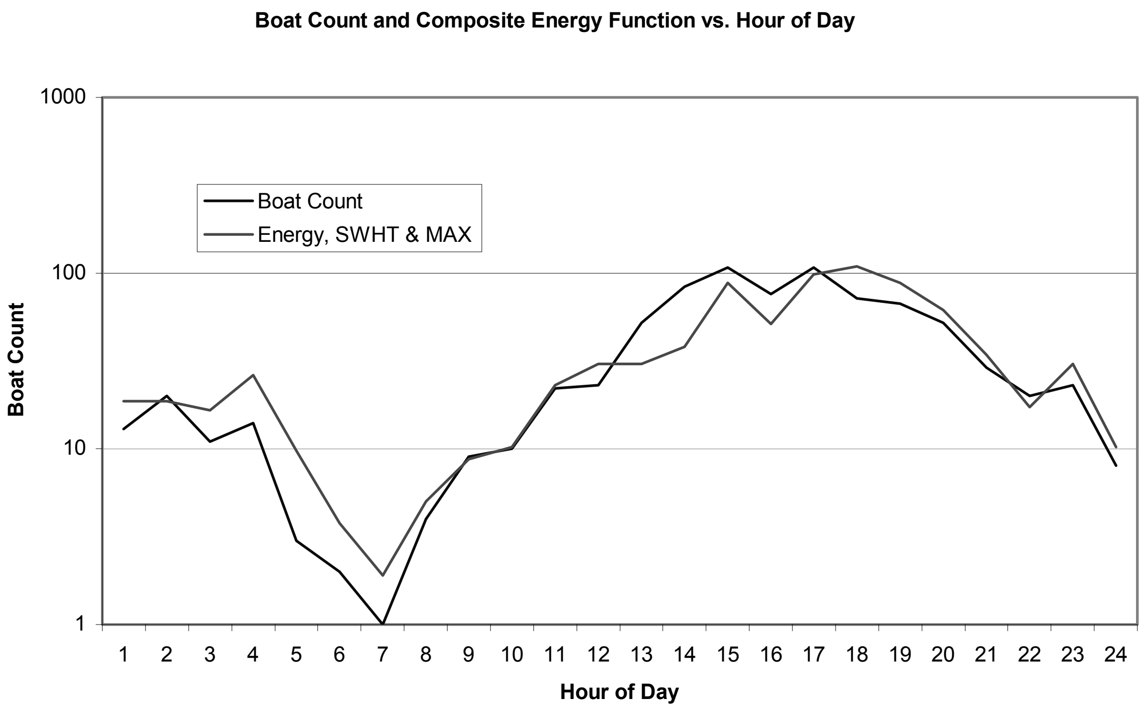
The computer hardware used for the processing of the expert system sensor inputs ranged from stamp microcomputers (one for each wave staff) to NT 4.0 servers running dual 450 MHz Pentium II processors. NT servers were used both as shore side controllers (located at the test site) and as Internet servers (located at the ISP).

The analytical and engineering methods taken together with the hardware and software form the WETS. The expert system kernel is considered to be the heart of the matter consisting entirely of intellectual property specific the application presented herein.

2.0 Examples of known relationships.

As a result of this experimentation we now know (either analytically, experimentally, or both) relationships between variables in the system. For example below we may relate the “energy” (as measured from a single wave staff) in the system with the presence of vessel traffic. The pattern in the relationship is clear and is probably valid for a number of narrow urban canals and waterways. Note for the figure below (on the following page) the minimum seen at the seventh hour is actually at 3:00 AM and all the other hours are shifted accordingly. Also for this figure which is significantly different than any other figure presented in this report the vertical scale is logarithmic and the “energy” is a non standard formulation of the "function". While this formulation is not valid for a direct calculation of energy it is perfectly valid as part of the expert system kernel and the knowledge base used to make the WETS valuable as a tool for coastal zone management.

Figure 23. Given is an example of expert system knowledge base functional relationship.



3.0 Applications to future work.

What we have done here sets the stage for a wide variety of future applications. Cleary vessel traffic studies can now be automated for urban canals. For most applications a single staff is sufficient for relating vessel traffic to sea state. It appears that the expert system may be used for applications involving adaptive information and regulatory signs. It is not out of the realm of possibility to make signs adapt the waterway regulations they post based on real time inputs of sea state (and hence vessel traffic) and a know knowledge base which includes knowledge of date and time. A number of other environmental applications are possible. An expert system could provide information and feedback to boaters on mammals in the environment. An expert system could provide feedback to the DEP on the health of nearby marinas or sensitive areas.

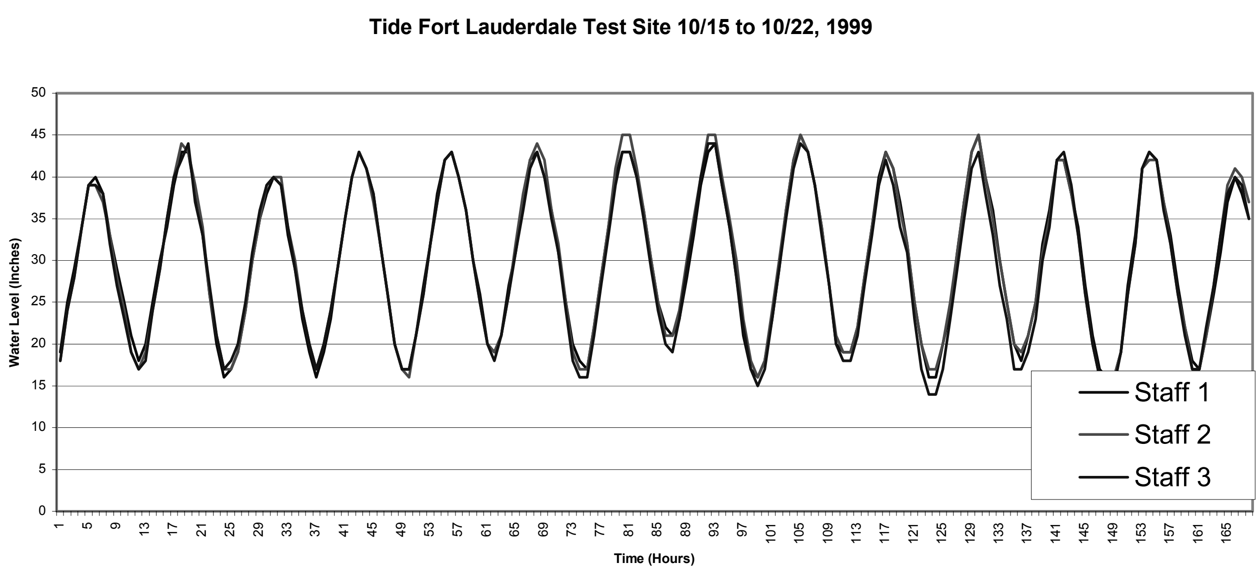
Section
IV Analysis of Stochastic Signals

Basic principals of random data analysis are applied to obtain information about each site

A. Water Level

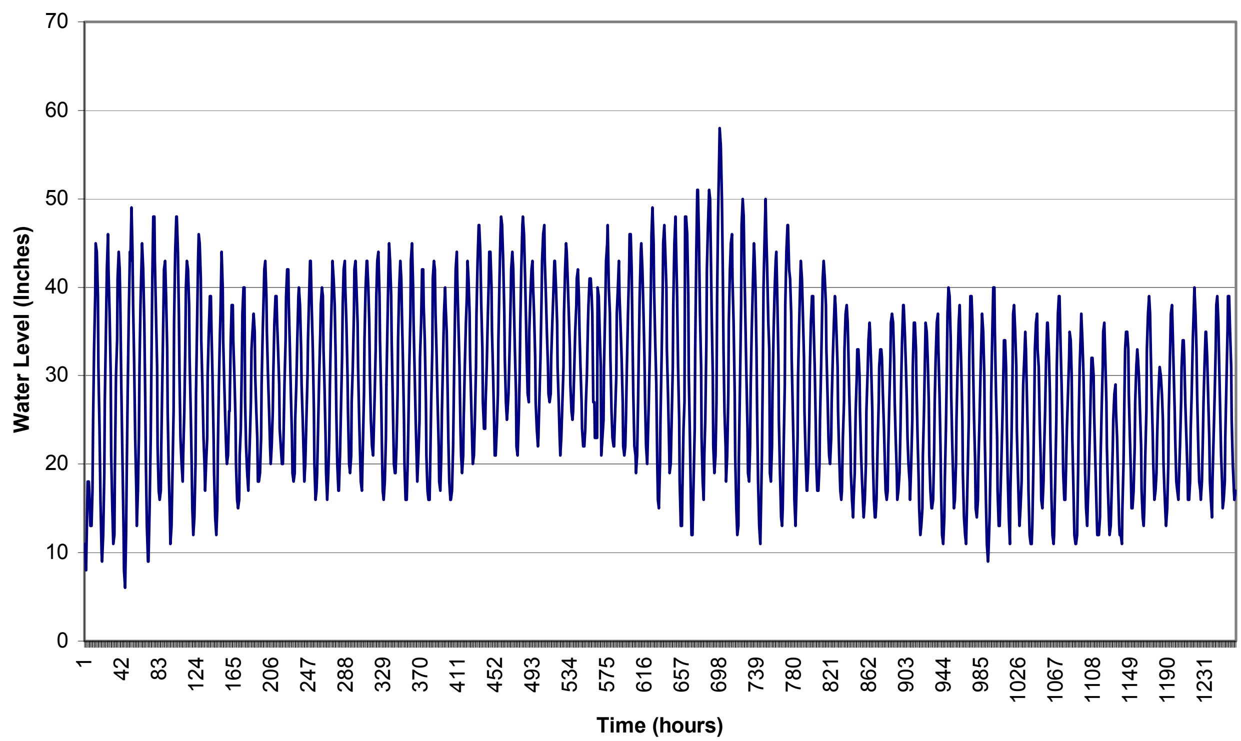
The canal is continually in motion, over its surface, and with time at any given point. The level of surface is changing constantly about some instantaneous water level, which we call the still water level, which itself is changing slowly with the tides.

Our wake and wave measurements have within them the tide. Other effects on the still water level such as wind setup, storm surge, or the opening of a loch can be seen in the records of water level. Plotted in this figure is the individual response from each wave staff over a one-week period. The figure shows a tide with a 12-hour period providing for two highs and two lows in one 24-hour period. The shift, or phase lag, of the tides is approximately 1 hour per day. For this record the magnitude of the tide is approximately 30 inches peak as show in Figure 24 below.



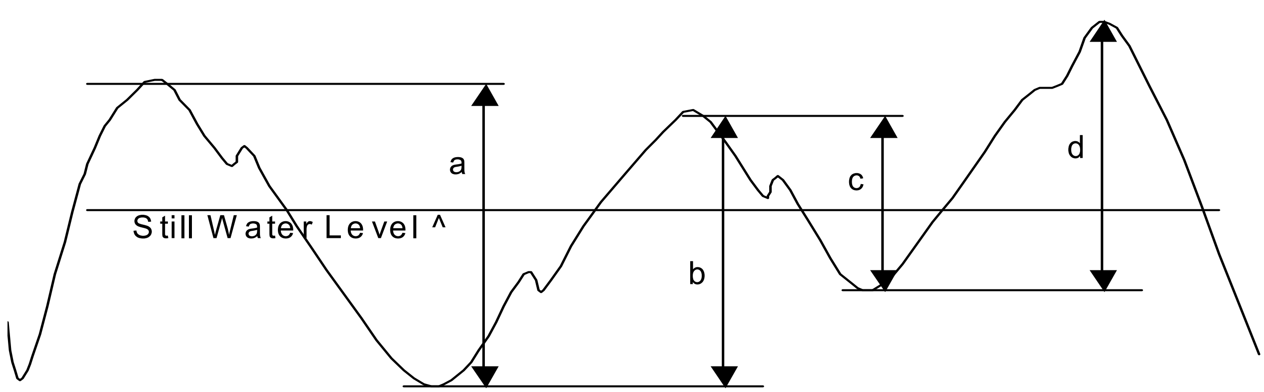
A longer record of tide from a single wave staff is given in Figure 25 below (on following page). This low frequency oscillation of the still water level is in response to environmental forcing.

Tide Fort Lauderdale Test Site 10/4 to 11/29, 1998



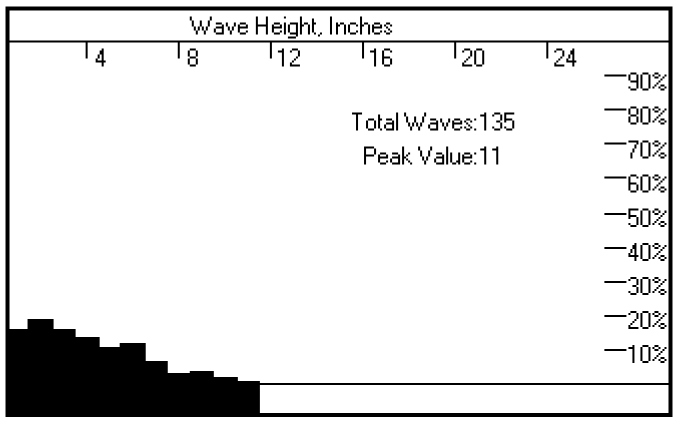
Note: Wave heights in a random profile can be defined as the averaged vertical distance between the crest and the trough of two consecutive waves (crest to trough method). Therefore wave height H1 and H2 are equal to and defined by the following equations.

$$H1 = (a + b) / 2 \text{ and } H2 = (c + d) / 2$$



B. Histogram of Vessel Traffic

Given below in Figure 26 is a bar graph of wave the wave heights showing the distribution, as measure by the wave staffs, starting at the time of a single vessel passage and continuing for 80 seconds. We have chosen all the rectangles of the histogram to have the same base width (1 inch). This width is defined as the class interval or the arbitrarily selected difference between successive classes of wave heights.

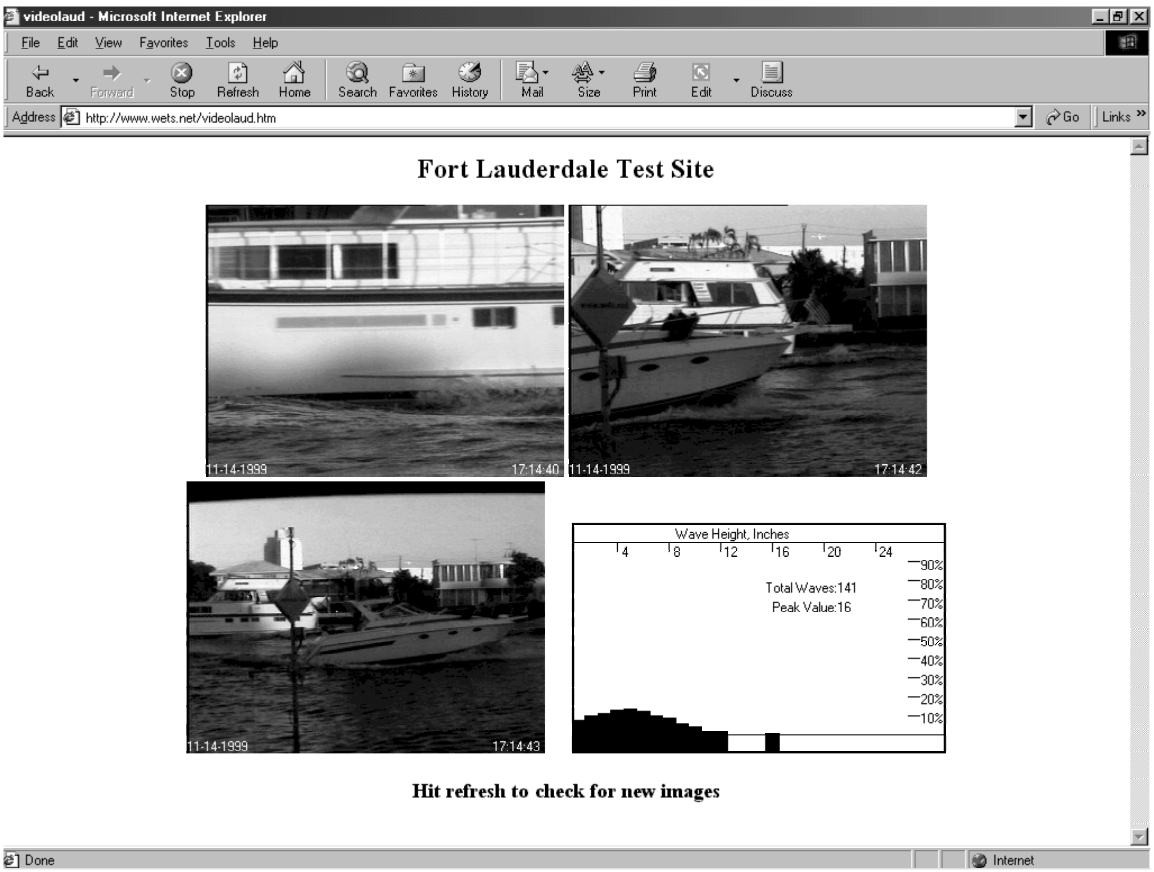


Such a graph is called a wave height histogram, or simply a wave histogram. The above histogram was event driven. The boat was on the far side of the canal at the Fort Lauderdale site as shown in Figure 27 below when it tripped the LASER and started the process.

In addition to event driven histograms, histograms were generated continuously, recorded, and sorted by 6-minute intervals. The histogram given below is the summation of ten, 6-minute histograms.

C. Histogram of Boat Wake Sizes

Histograms of boat wake sizes were generated as event driven events for each boat. The data is displayed in real time over the Internet. The screens capture, Figure 28, shown below shows two boats caught as a single event. The resulting histogram is therefore a combination of waves and wakes from both vessels.

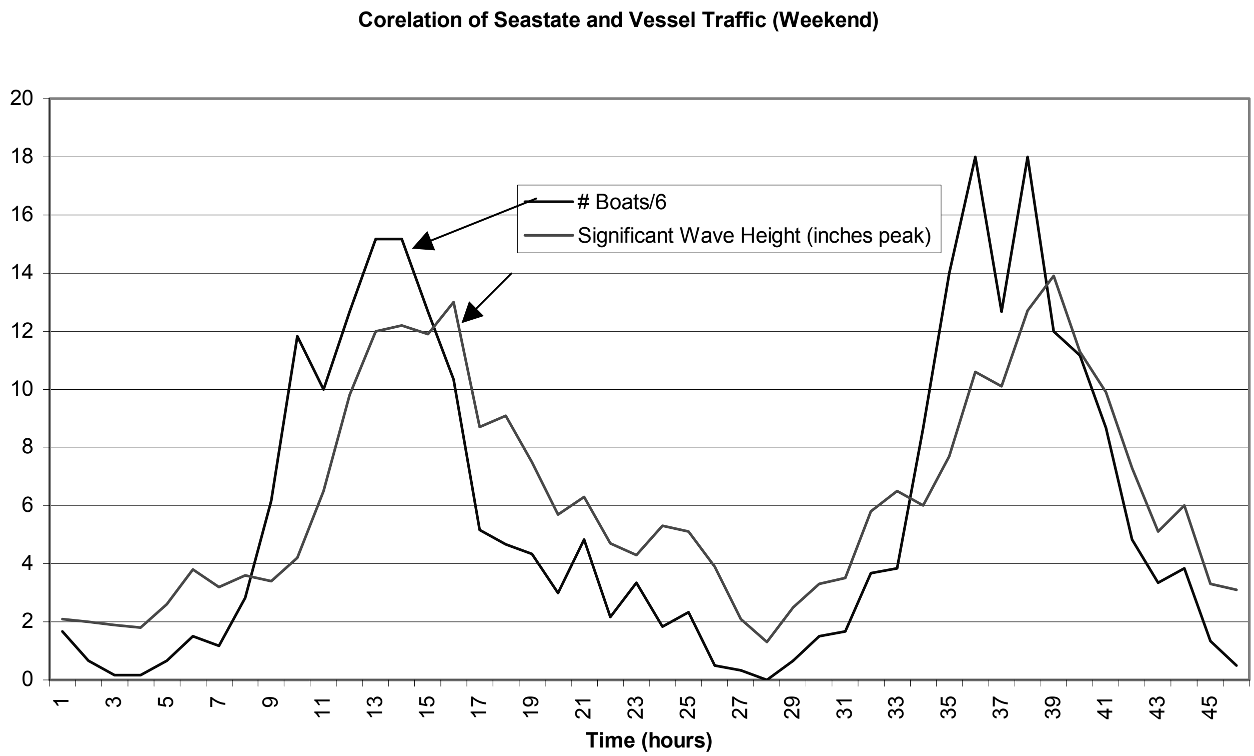


Section V Survey Results

Detailed review of the data collected at each test site

A. Ft. Lauderdale Site

Sea state at the Fort Lauderdale site correlated strongly (see Figure 29 below) with vessel traffic. In the fetch limited waterway wind speed and duration do little to excite the water. Boats are the only real excitation. Given below is a sample time series for a typical weekend.



Automated processing yielded a nice plot of wake maximum by hour. As seen in Figure 30 below (on following page) the maximum wake limit at the Fort Lauderdale site of 15 inches amplitude (30 inches peak) was exceeded 5 times in 55 days (1320 hours) of automated monitoring.

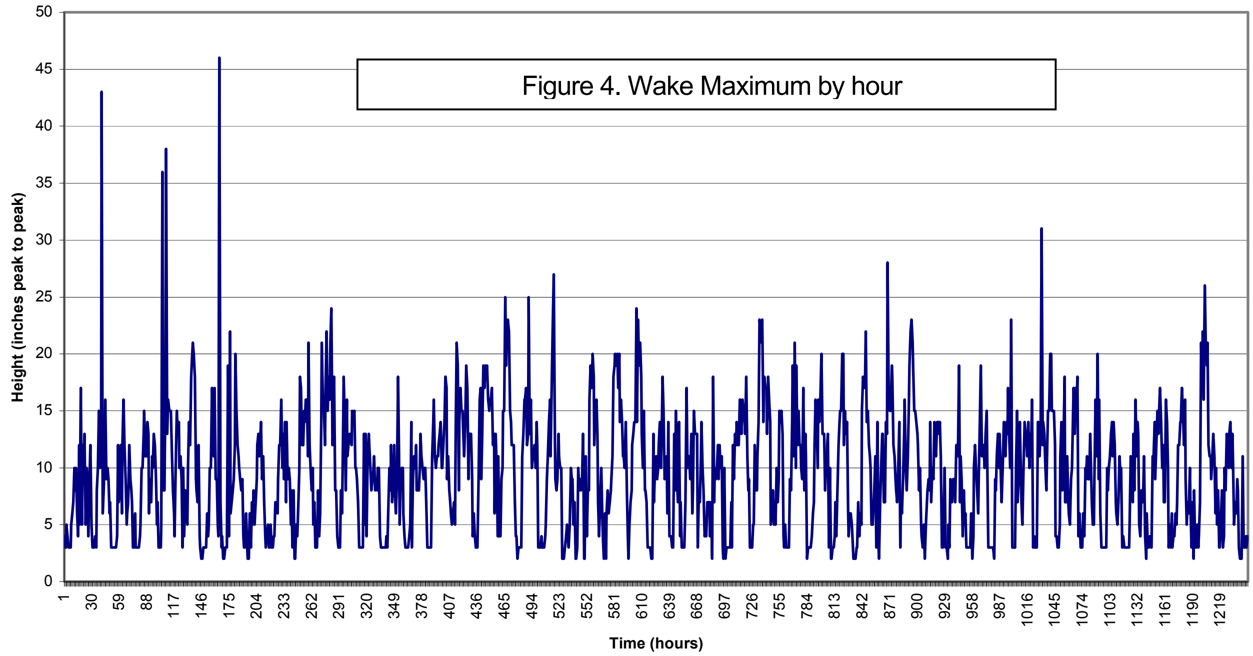


Figure 31 Stacked area graph of the presence of various boat types as a function of time for the period 10/31 and 1/1 1998. A typical Saturday and Sunday.

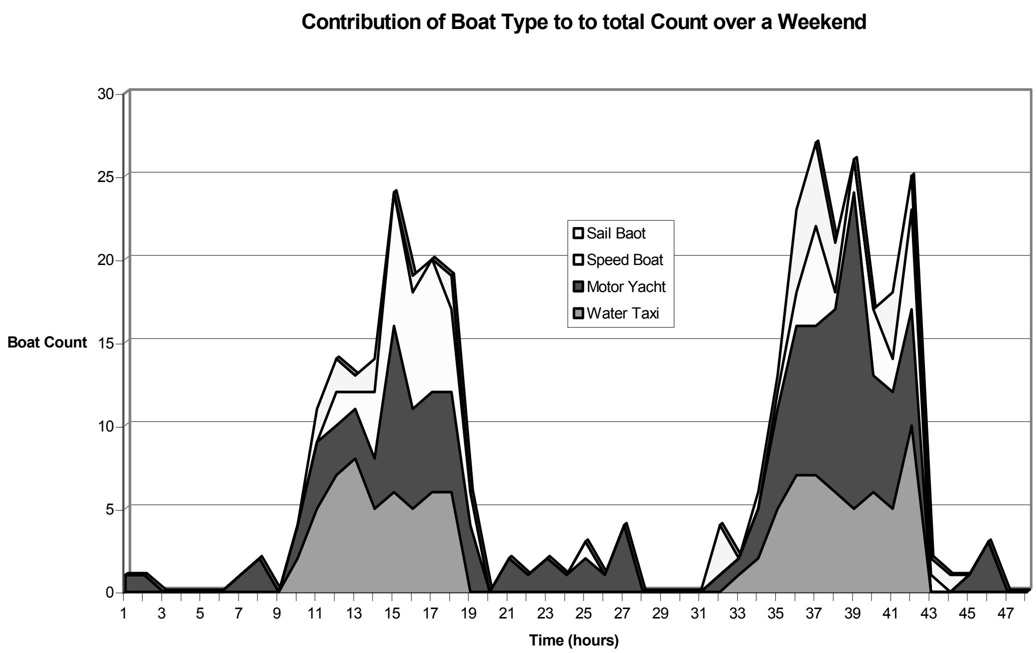


Table 1 Saturdays October 31, 1998 Observations Exported from "table observer" Database. Hour is from 0000 to 24000 starting from the top down.

Date	Water Taxi	Motor Yacht	Speed Boat	Sailboat
10/31/98	0	1	0	0
10/31/98	0	1	0	0
10/31/98	0	0	0	0
10/31/98	0	0	0	0
10/31/98	0	0	0	0
10/31/98	0	0	0	0
10/31/98	0	1	0	0
10/31/98	0	2	0	0
10/31/98	0	0	0	0
10/31/98	2	2	0	0
10/31/98	5	4	0	2
10/31/98	7	3	2	2
10/31/98	8	3	1	1
10/31/98	5	3	4	2
10/31/98	6	10	8	0
10/31/98	5	6	7	1
10/31/98	6	6	8	0
10/31/98	6	6	5	2
10/31/98	0	4	2	0
10/31/98	0	0	0	0
10/31/98	0	2	0	0
10/31/98	0	1	0	0
10/31/98	0	2	0	0
10/31/98	0	1	0	0

Table 2 Sunday November 1, 1998 Observations Exported from "table observer" Database. Hour is from 0000 to 24000 starting from the top down.

Date	Water Taxi	Motor Yacht	Speed Boat	SailBoats
11/1/98	0	2	1	0
11/1/98	0	1	0	0
11/1/98	0	4	0	0
11/1/98	0	0	0	0
11/1/98	0	0	0	0
11/1/98	0	0	0	0
11/1/98	0	0	0	0
11/1/98	0	1	0	3
11/1/98	1	1	0	0
11/1/98	2	3	0	1
11/1/98	5	6	1	1
11/1/98	7	9	2	5
11/1/98	7	9	6	5
11/1/98	6	11	1	3
11/1/98	5	19	2	0
11/1/98	6	7	4	0
11/1/98	5	7	2	4
11/1/98	10	7	6	2
11/1/98	0	0	1	1
11/1/98	0	0	0	1
11/1/98	0	1	0	0
11/1/98	0	3	0	0
11/1/98	0	0	0	0
11/1/98	0	0	0	0

B. Port Everglades Test Site

The Port Everglades installation provides for the collection of data within an active commercial deep-water seaport. The in water installation shown below was successfully completed on November 15, 1999. The installation required written approval from Port Everglades Port Authority because the port owns the land on which the wave staff was erected.

Figures 32. Given is the view looking west across the test area. In the right of the picture, in the background, the city of Fort Lauderdale can be seen.

Data and data reduction from this deployment is beyond the scope of the present work. The system has been brought online sufficiently to demonstrate scalability of the WETS. It should be noted that this system was deployed at a late date at this site because of the inability of a site to be secured in Pompano Beach in a timely fashion. This site has the potential of collecting data until the port is dredged in the year 2002. Currently no system is available in Port Everglades to provide real time tides within the port. At the time of this writing numerous special interest groups have shown a desire to acquire tide data if it was made available. These groups include but are not limited to Broward County, Port Pilots, and the South Florida Ocean Measurement Center.

Section VI WETS as a Management Tool

Fast and accurate data collection for Coastal Zone Management

A demonstrated, new technology application now exists to aid in coastal zone management. The Waterway Expert Traffic System is shown below is being used for real time data collection with live dissemination over the Internet.

WETS Features

- Automated, accurate measurement of sea state and vessel traffic
- Scaleable low cost Internet based data distribution
- Expert system type approach to sensor integration

WETS Benefits

- Automated data acquisition reduces the need for human observers reducing the cost associated with vessel traffic surveys.

- WETS can be deployed in inland waterways anywhere vessel surveys are required. The system may be deployed 62.5 feet outside of navigational channels under Army Corps of Engineers nation wide permit #5.

- Automated data processing allows for significantly more data to be collected, analyzed, and displayed in a useful format. The benefit to the user is a better data set is obtained at lower cost.

- The shore side and landside electronics is considered to be telephone terminal equipment. Therefore wiring and local permitting is as simple as for a telephone.

Acknowledgements

Bill Demarco – Florida marine Patrol, for his continuing dedication to his work, the betterment of the environment, and his help with this project, which included training student observers.

Joan Geralds – Fort Lauderdale resident, for volunteering her residence for more than a year "If it will help?" and for being the first to do so.

Aaron Shefter – New Age Systems, for being the thoroughly competent electronic and software engineer that he is, and for sticking with a project (and learning what is needed to stay on the cutting edge of technology) for 15 years.

Rocky Galetta – Industrial Divers, for his continuing dedication to knowledge and the betterment of the environment and for doing all the WETS in water work at cost.

Anthony Venezia – For his understanding, encouragement, support, and for doing what is needed to help his father and the project.

NSU Graduate students who all worked long hours and did a great job of data collection and reduction, in order of appearance on the project, *Jose Rios, Heather Balchowsky, and Christine Hudak.*