Tidal Flushing 101

Presented By: Hans Wilson, P.E.

Who We Are

- **Fifty years combined coastal and waterfront experience.**
- **Over 700 waterfront developments in the past ten years.**
- **Hans Wilson, P.E.**
  - **Florida Registered Professional Engineer**
  - **Licensed Captain**
  - **Designed over 100 marinas within US and Central America**
  - **President: Southwest Florida Marine Industries Association**
  - **Secretary: Marine Industries Association of Florida**
  - **Past Chair: Coastal Advisory Council**
  - **Past Chair: Captiva Erosion Prevention District**
  - **Past Member: Local Rules Review Committee – Lee County Manatee Protection Plan**
  - **NAUI SCUBA certified**

Hans Wilson & Associates, Inc.

Marine & Environmental Consultants

Knowledge – Quality - Service

What We Do

- Development Feasibility Studies for Waterfront Sites
- Marina/Waterfront Design and Renovations
- Bathymetric and Hydrographic Studies
- Channel and Marina Basin Dredging Design
- Environmental Resource Permitting
- Wetland Restoration and Creation
- Construction Observation and Administration
- Compliance Monitoring and Reporting
- Submerged Land Leases and Easements.

Knowledge – Quality - Service

Hydrographic Surveys

hy·drog·ra·phy -

1. the science of the measurement, description, and mapping of the surface waters of the earth, with special reference to their use for navigation.

2. those parts of a map, collectively, that represent surface waters.

ba·thym·e·try -

1. the measurement of the depths of oceans, seas, or other large bodies of water.

2. the data derived from such measurement, especially as compiled in a topographic map.

Knowledge – Quality - Service

Basis of Review

The Solution to Pollution is Dilution?

- 4.2.4.3 Additional Water Quality Considerations for Docking Facilities

- Docking facilities are potential sources of pollutants to wetlands and other surface waters. To provide the required reasonable assurance that water quality standards will not be violated, the following factors must be addressed by an applicant proposing the construction of a new docking facility, or the expansion of or other alteration of an existing docking facility that has the potential to adversely affect water quality:

- (a) Hydrographic information or studies shall be required for docking facilities of greater than ten boat slips. Hydrographic information or studies also may be required for docking facilities of less than ten slips, dependent upon the site-features described in paragraph 4.2.4.3(b) below. In all cases, the need for a hydrographic study, and the complexity of the study, will be dependent upon the specific project design and the specific features of the project site.

Knowledge – Quality - Service

Flushing Considerations

- 4.2.4.3(b) The purpose of the hydrographic information or studies is to document the flushing time (the time required to reduce the concentration of a conservative pollutant to ten percent of its original concentration) of the water at the docking facility. This information is used to determine the likelihood that the facility will accumulate pollutants to the extent that water quality violations will occur.

- Generally, a flushing time of less than or equal to four days is the maximum that is desirable for docking facilities. However, the evaluation of the maximum desirable flushing time also takes into consideration:

- Number of slips and docking facility configuration
- Tide amplitude and period (diurnal, semi-diurnal, mixed)
- Waterbody geometry
- Waterbody circulation and flushing
- Water quality
- Type/nature of the docking facility
- Services provided at the docking facility
- Other sources of water pollution in the area.

Devil is in the Details

- (c) If it flushed in less than four days, life if good (i.e. reasonable assurance is met).
- If it takes longer than four days to flush the site, a more complex evaluation of the site is required to determine if water quality will be compromised.
- (d) If the water leaves the site, make sure the receiving waters are capable of handling the pollutant load without compromising water quality.
- (e) Make sure your evaluation reflects actual site conditions. (Verify the variables in your model). It is also a good idea to collaborate with the permit evaluator on the assessment methodology.
- (f) Don't spill fuel and if you do, be prepared to clean it up quickly and efficiently.
- (g) Don't spill your sewage and if you plan on having liveaboards, prepare for ongoing treatment of their sewage.
- (h) Manage your solid waste and fish carcasses.

Knowledge – Quality - Service

Types of Docking Facilities

Semi-enclosed basin (most protected)

Flow through basin (good water quality, good protection)

Tidal pump basin (land use intensive)

Enclosed basin (lakes)

Open water basin (best water quality, least protection)

Knowledge – Quality - Service

Semi-enclosed Basin

- Typically excavated from uplands to create protected waters.
- Generally used as a material source to fill the adjacent uplands.
- Easier to secure from public access
- Difficult to maintain good water quality
- Trash sump for floating debris

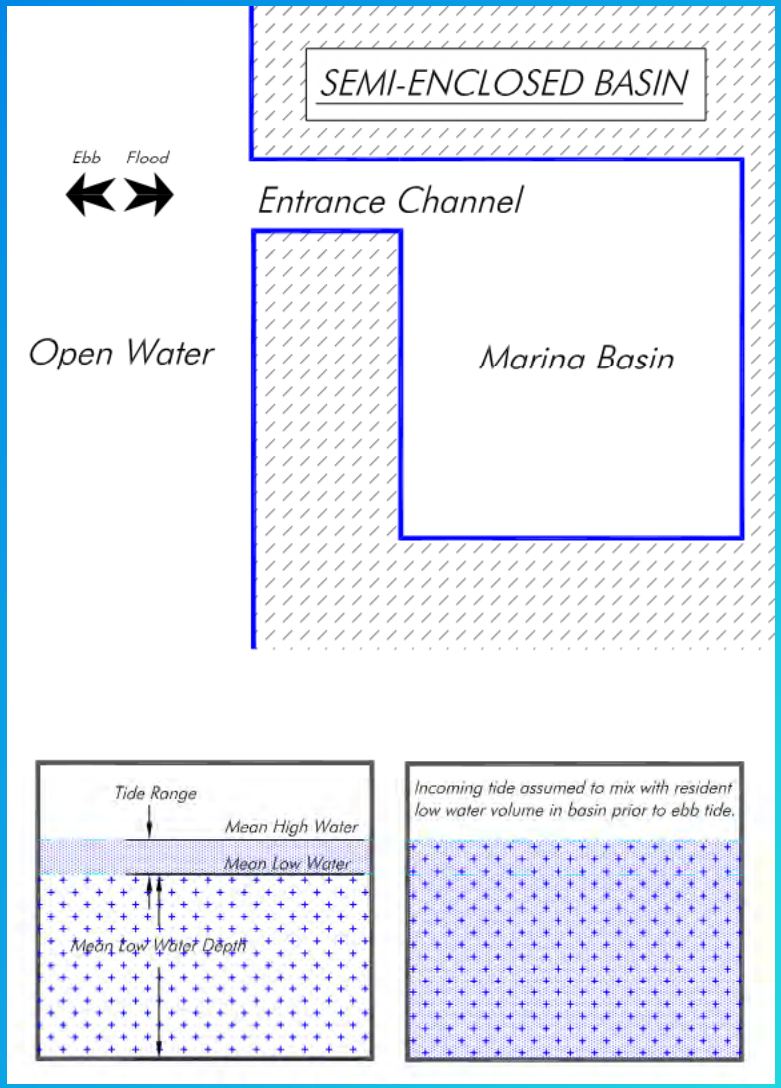
Knowledge – Quality - Service

Burnt Store Marina

Knowledge – Quality - Service

Semi-enclosed Basin

Basic Configuration



Flow Through Basin

- Good water quality
- Return flow factor tends to zero
- Ebb dominant system
- Protected harborage
- Easy to secure access, if private.
- Note orientation of vessels

Knowledge – Quality - Service

Gulf Harbour

Knowledge – Quality - Service

Tidal Pump Basin

- **Uses interior tidally influenced wetlands to add additional tidal prism to the volume in the basin.**
- **Requires significant acreage to meet the four day standard.**
- **Heavy detrital inflow to the basin.**
- **Lots of great critter habitat.**

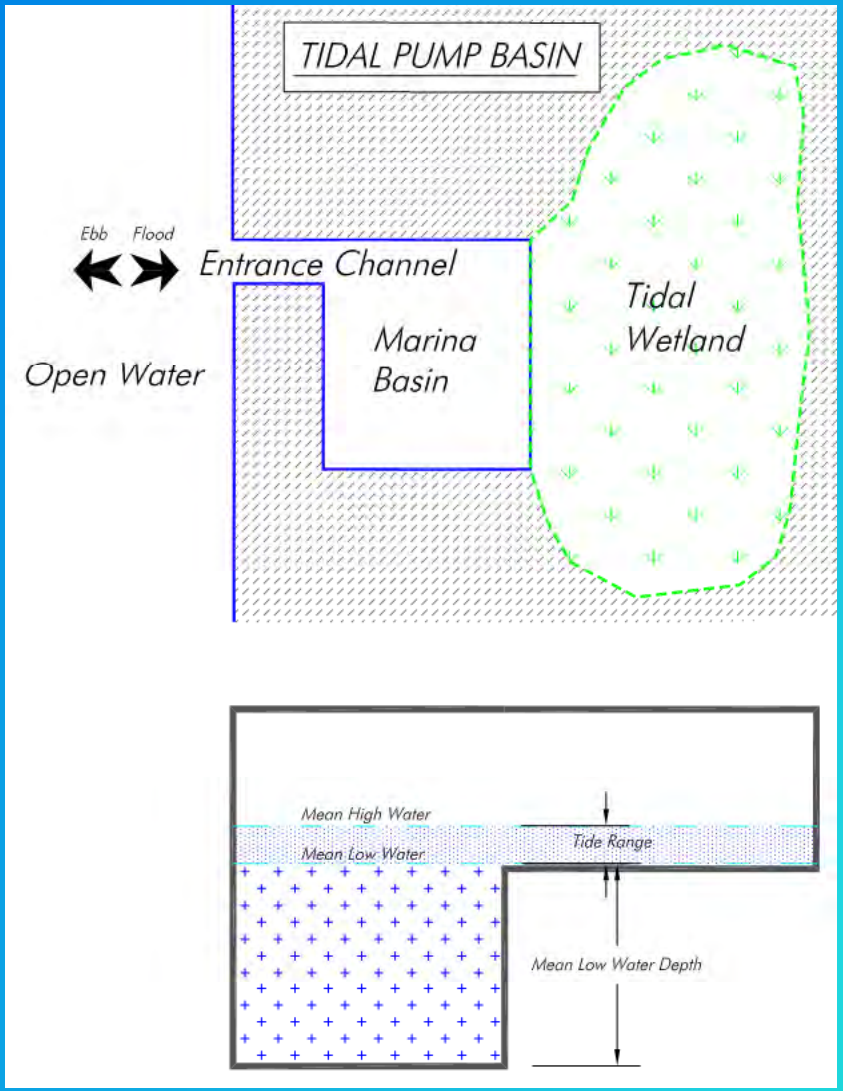
Tidal Pump Basin

A Micro Plan

Created in 2010, photo taken at low tide.

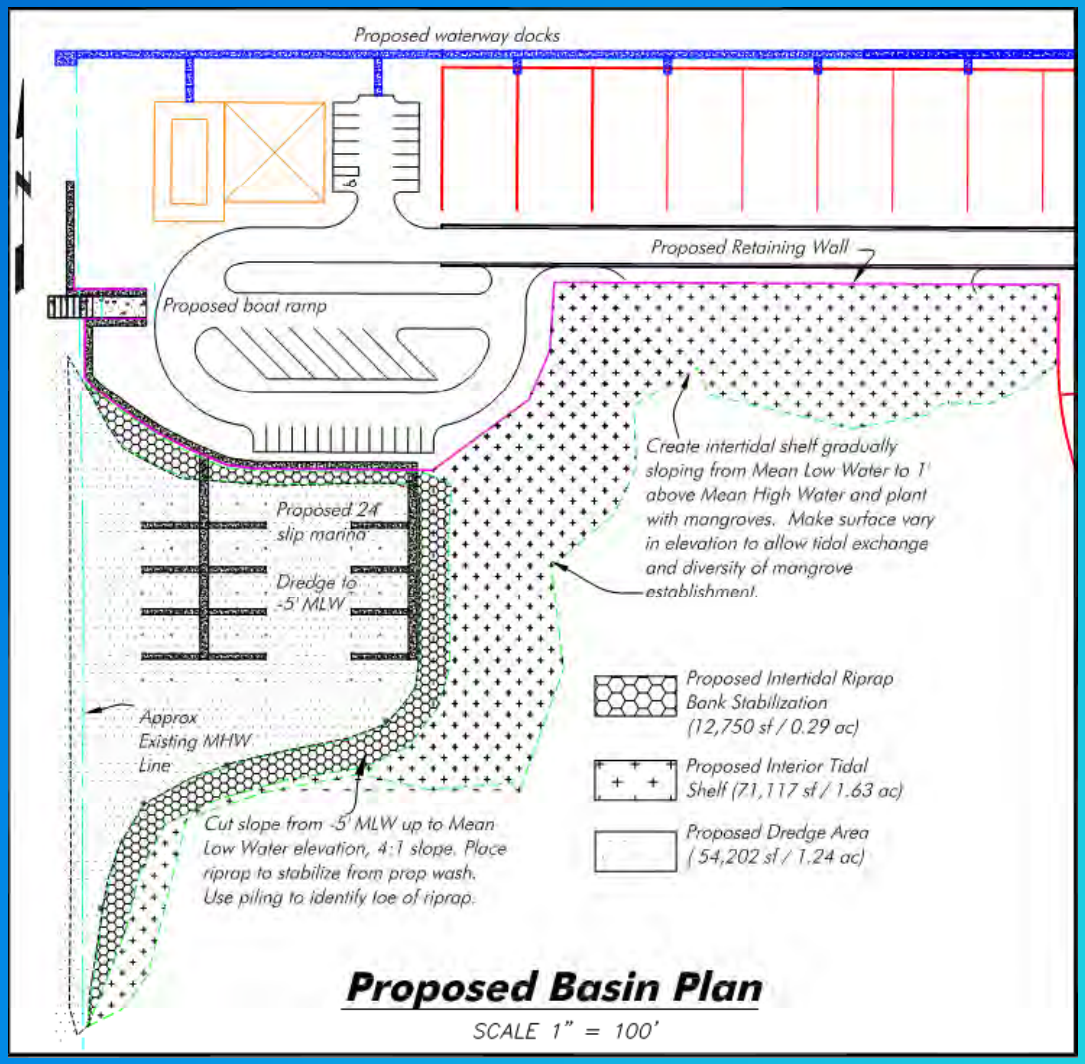
Knowledge – Quality - Service

Tidal Pump Basin



Tidal Pump Basin

Typical Design Plan



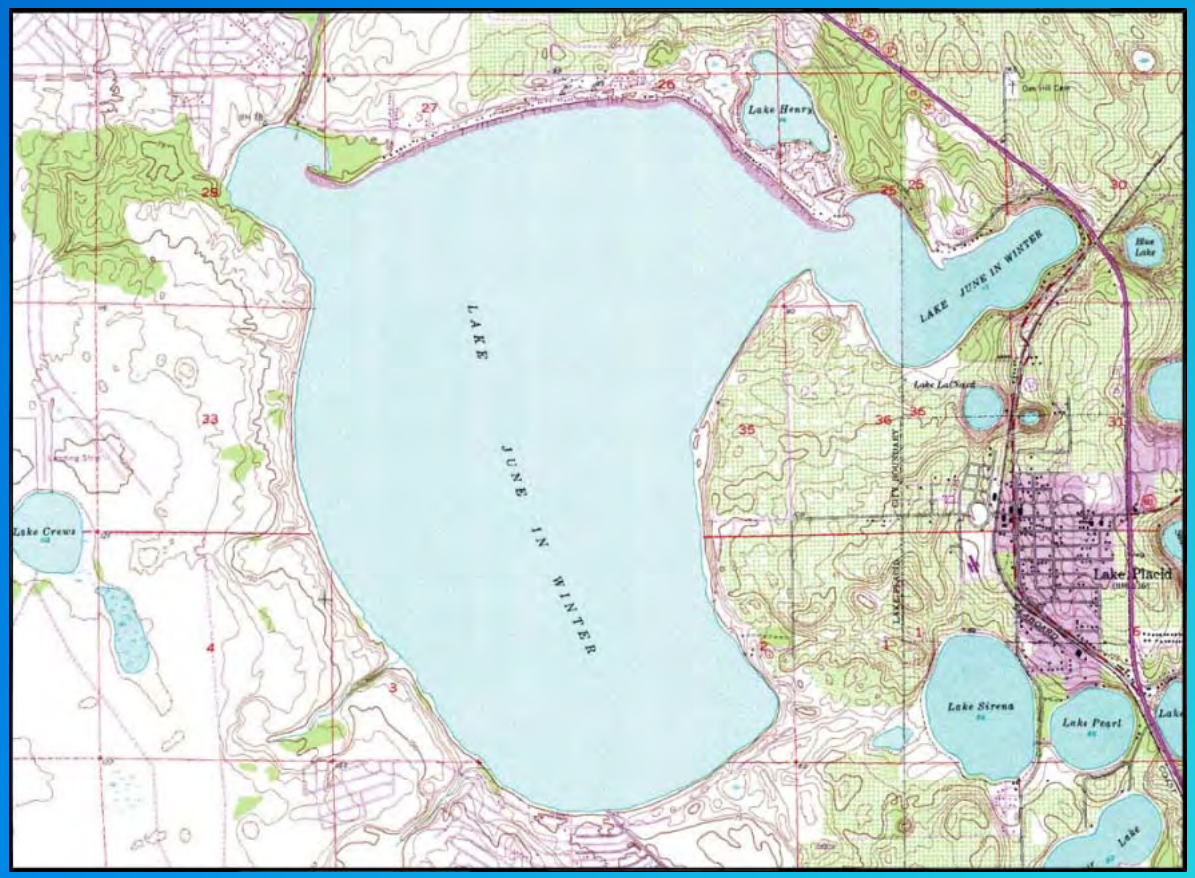
Note that the total area devoted to enhanced tidal flushing is 1.92 ac. (riprap shelf and tidal wetlands). The total area of the actual marina basin @ -5' MLW is 1.24 ac.

Knowledge – Quality - Service

Enclosed Basin

- No tidal influence, wind mixing primary flushing component.
- Freshwater inflow and evaporation secondary components.
- Shallow better than deep. Littoral shelves important for nutrient loading.
- Carrying capacity a consideration.
- Seasonal temperature inversions potentially a problem.

Enclosed Basin



East/West predominate wind direction.

Water depths close to 20’.

Note freshwater inflow in upper left hand corner.

Management of surrounding uplands critical to lake health.

Knowledge – Quality - Service

Open Water Basin

- Typically best water quality because of both tidal and wind mixing.
- Exposed location requires breakwater or floating dock assembly for vessel protection.
- Alternative use of boat lifts to secure vessels.
- Usually requires a submerged land lease.

Open Water Basin

Spring lines and bow to the river critical for safe mooring.

Boats on lifts preferred.

No constrictions to tidal flow other than pilings and vessels at the surface.

Note occupancy.

Knowledge – Quality - Service

Hydraulic Models

- There are a wide variety of flushing models, all varying in sophistication and scope. The greater the degree of modeling the movement of a particle of water, the greater the processing capacity of the computer and the time to process the model runs.

- The model is only as good as the calibration to real time conditions.

- Garbage in = garbage out.

Governing Equations

- continuity equation $$\frac{\partial \zeta}{\partial t} + \frac{\partial UH}{\partial x} + \frac{\partial VH}{\partial y} = 0$$
- Longitudinal Momentum:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV = -\frac{\partial}{\partial x}\left[\frac{p_s}{\rho_o} + g(\zeta - \eta - \gamma)\right] + \frac{\tau_{sx}}{\rho_o H} - \frac{\tau_{bx}}{\rho_o H} + D_x$$

- Lateral Momentum:

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + fU = -\frac{\partial}{\partial y}\left[\frac{p_s}{\rho_o} + g(\zeta - \eta - \gamma)\right] + \frac{\tau_{sy}}{\rho_o H} - \frac{\tau_{by}}{\rho_o H} + D_y$$

- where $(\eta+\gamma)$ represent the Newtonian tidal potential, earth tide, self attraction and load tide, τ_{bx}, τ_{by} represent the bottom stresses, *U* and *V* are depth averaged velocities, *H* is the depth, ζ is the water surface elevation and D_x and D_y are turbulent diffusion parameters.

E.P.A. Model

for semi-enclosed marina basins

The Environmental Protection Agency (EPA) has developed a Coastal Marinas Assessment Handbook, which contains a simple methodology for evaluating the flushing period for marinas. This theory assesses the tidal exchange within a semi-enclosed waterbody based on the amount of water that flows in and out of the basin on any given tidal cycle. This is a useful approximation when estimating the time it takes for a pollutant to disperse to 10% of the initial spill concentration. The following formula is the basis for evaluating the flushing period within a semi-enclosed marina:

Knowledge – Quality - Service

E.P.A. Model

the Secret Formula

$$T_f = \frac{T_c \text{ Log } D}{\text{Log } \left(\frac{AL + bAR - IT_c}{AH}\right)}$$

T_f = Time of flushing in days
T_c = Tidal cycle, high tide to high tide (diurnal, semi-diurnal, or mixed tides)
A = Surface area of marina, square feet
D = Desired dilution factor (10% typical)
R = Tide range, feet (annual range based on DEP tide stations posted closest to the project site)
b = Return flow factor (dimensionless, important)
I = Non-tidal freshwater inflow (cubic feet/hour)
L = Average depth at low tide, feet
H = Average depth at high tide, feet

Knowledge – Quality - Service

E.P.A. Model - the Assumptions (not the band)

The following assumptions will be applied to calculating the flushing periods for the marina.

- **It will be assumed that the tidal prism volume completely mixes with the basin waters on each tide cycle.**

- The representative pollutant will decrease in concentration with each tide cycle, but will never be completely eliminated from the system.

- The entire basin system has uniform vertical sides, since it is completely seawalled. Estimates for basin volumes are based on the design depths.

- There is no daily influx of freshwater runoff. There is surficial runoff during the rainy season, but this will be considered negligible on an annual basis. As a result the IT_c term in the equation will equal zero.

- The majority of the flushing is based on tidal flow.

Knowledge – Quality - Service

The Big Picture

For larger scope projects a more sophisticated model is required.

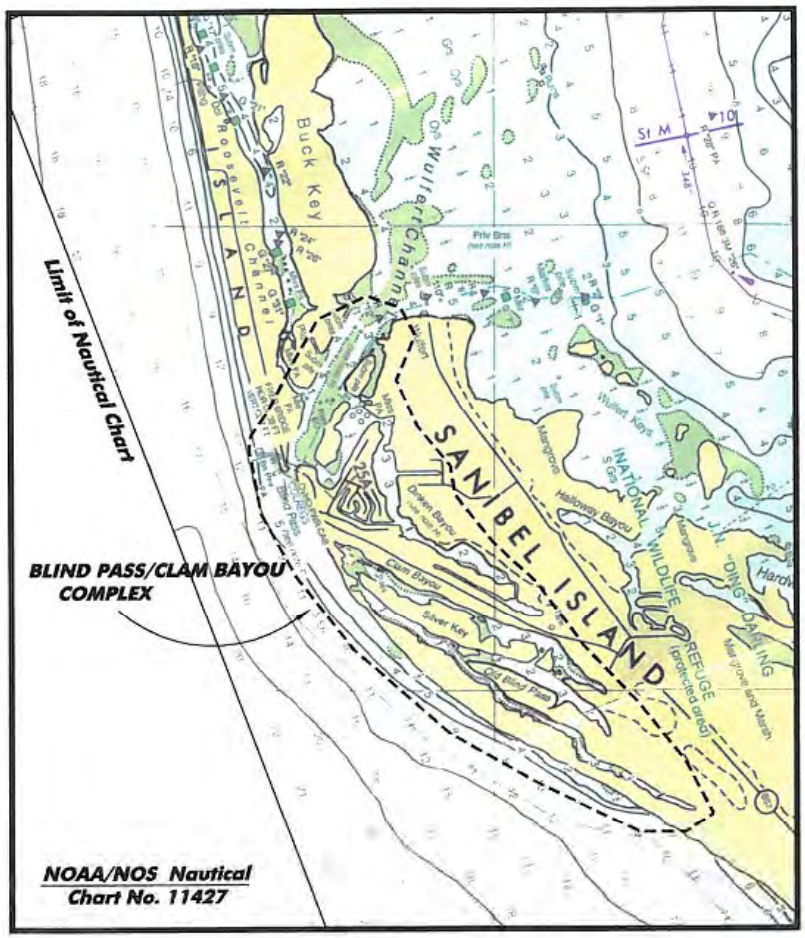
A more sophisticated model requires more time and money to evaluate.

Typically this is outside the scope and/or budget necessary for evaluating marina facilities.

However, when resources are impacted and the ramifications of the proposed restoration action affects a large area, it is useful to understand in concept what the restoration result may be.

BLIND PASS ECO-ZONE
Feasibility Study

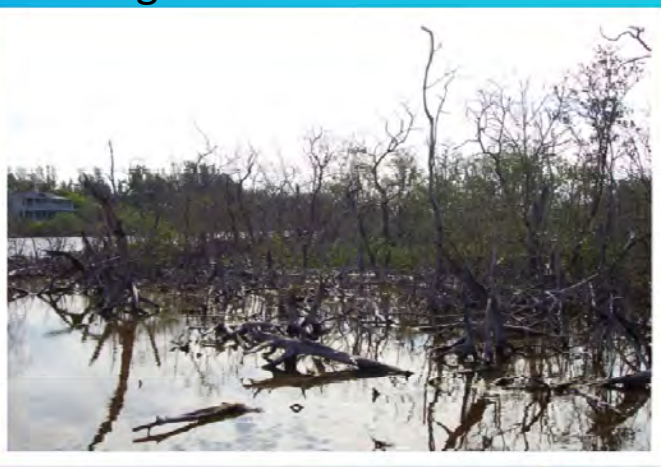
June 2003



Prepared for: Lee County, City of Sanibel and Captiva Erosion Prevention District

Prepared by: Hans Wilson & Assoc.Inc., Erickson Consulting Engineers, and Gooderham & Assoc. Inc.

Mangrove Devastation



Knowledge – Quality - Service

Blind Pass Ecosystem

Knowledge – Quality - Service

Blind Pass Ecosystem

Knowledge – Quality - Service

Blind Pass Ecosystem

Clam Bayou impounded.

Stormwater drowns approximately 49 acres of previously tidally flushed mangrove wetlands.

Over 100 ac. more wetlands threatened by impoundment.

Residential flooding.

Fluctuations in salinity, from Gulf over wash and stormwater.

Knowledge – Quality - Service

ADCIRC Model

Erickson Consulting Engineers, Inc. (ECE) performed a computer model study to evaluate the project alternatives relative to improving circulation and restoring flushing in Clam Bayou and the Blind Pass Eco-zone. The two-dimensional model (ADCIRC) is a vertically integrated hydrodynamic model, which is appropriate to simulate shallow, well-mixed, tidally dominated barotropic type systems. The model is well-accepted by engineering professionals and scientists within the hydrodynamic modeling community.

Three significant options (and variations) – Connect directly to the Gulf of Mexico; Connect to Dinkins Bayou; Connect Dinkins Bayout directly to the Gulf of Mexico via dredging of Blind Pass

The ADCIRC model used water level measurements to calibrate the model.

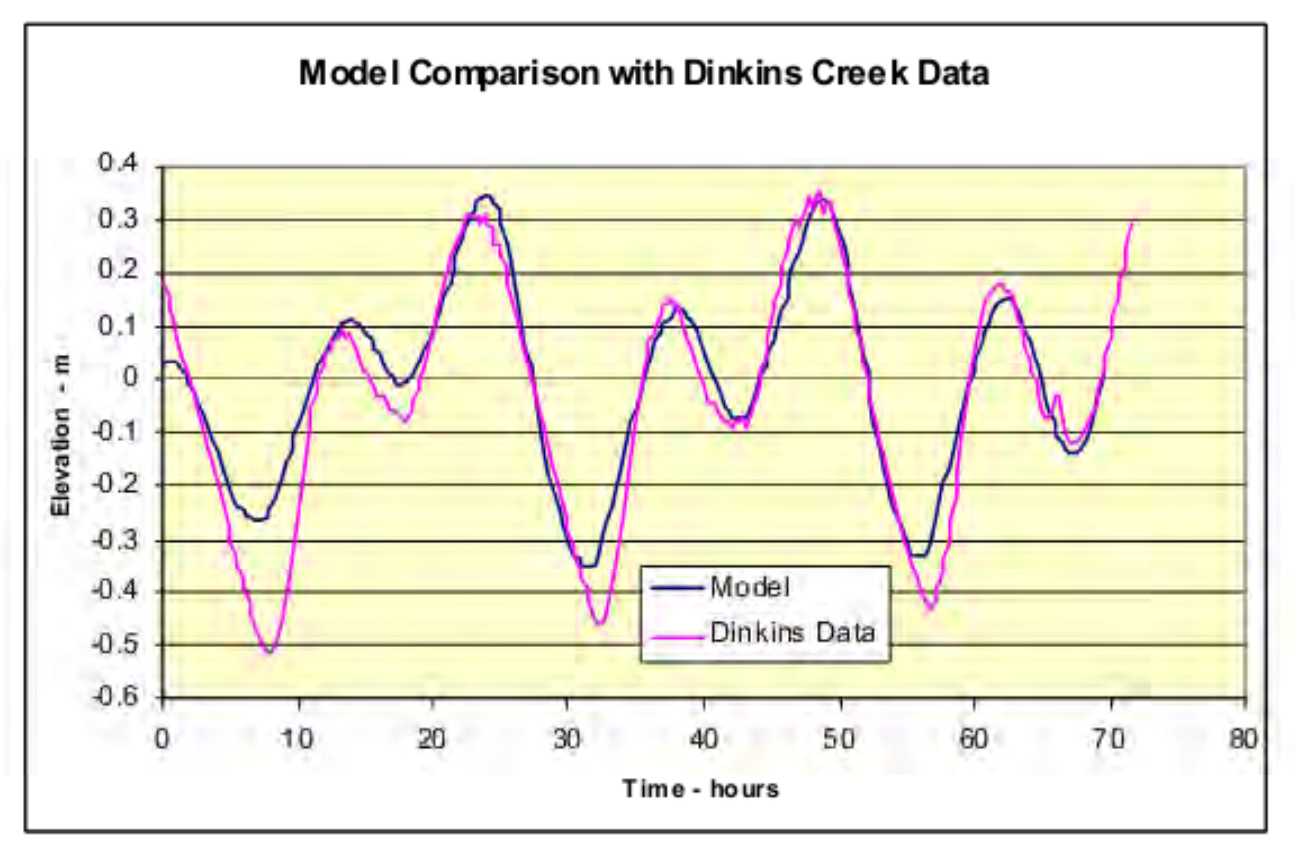
The model predicted the immediate post-project tidally induced flows, current velocities and flushing characteristics for various design alternatives.

Three-dimensional analysis is not necessary to simulate flows for the (relatively shallow) Blind Pass Eco-zone - Pine Island Sound Estuary system.

Knowledge – Quality - Service

Model Calibration

Is it real or is it Memorex?



It's Real !

Knowledge – Quality - Service

Options

Table IX-1. Description of Flushing Alternatives for the Blind Pass Eco-zone

Alternatives	Description	Principal Flushing Analysis (Mass Concentration)	Mass Concentration Variation (a) and (b)
Baseline	Existing Conditions	Dinkins Bayou (100%) Clam Bayou (0%)	
Alternative 1 **Alternative 1a** **Alternative 1b**	Flushing Channel Connecting Dinkins and Clam Bayou	Clam Bayou (100%) Dinkins Bayou (100%)	**Alternative 1a** Dinkins Bayou (100%) Clam Bayou (0%) **Alternative 1b** Dinkins Bayou (0%) Clam Bayou (100%)
Alternative 2 **Alternative 2a**	Flushing Channel from Dinkins to Clam Bayou, with Gulf opening to Clam Bayou	Clam Bayou (100%) Dinkins Bayou (0%)	Dinkins Bayou (100%) Clam Bayou (0%)
Alternative 3	Pass opening between Gulf and Clam Bayou	Clam Bayou (100%)	
Alternative 4	Blind Pass Open	Dinkins Bayou (100%)	
Alternative 5 (Combined Alternative 1 and 4)	Blind Pass Open, Flushing Channel from Dinkins to Clam Bayou	Clam Bayou (100%) Dinkins Bayou (100%)	**Alternative 5a** Dinkins Bayou (36 ppt) Clam Bayou (20 ppt) **Alternative 5b** Dinkins Bayou (0%) Clam Bayou (100%)
Alternative 6	Blind Pass Open, Wulfert Channel Dredged to Dinkins Bayou, flushing channel	Clam Bayou (100%) Dinkins Bayou (0%)	

Final Result

The City of Sanibel realized the gravity of the situation and potential significant loss of habitat.

City installed a box culvert beneath San-Cap Road to connect Dinkins Bayou with Clam Bayou.

Lee County and the Captiva Erosion Prevention District moved forward with dredging Blind Pass and significantly improving flushing to Pine Island Sound and Dinkins Bayou

Hans Wilson & Associates, Inc. contracted with the Bayous Preservation Association to document flushing improvements in Dinkins Bayou, pre and post Blind Pass Dredging.

Placement of the culvert beneath San-Cap Road had greater significance in flushing Dinkins Bayou than dredging of Blind Pass.

(Run the video of the model)

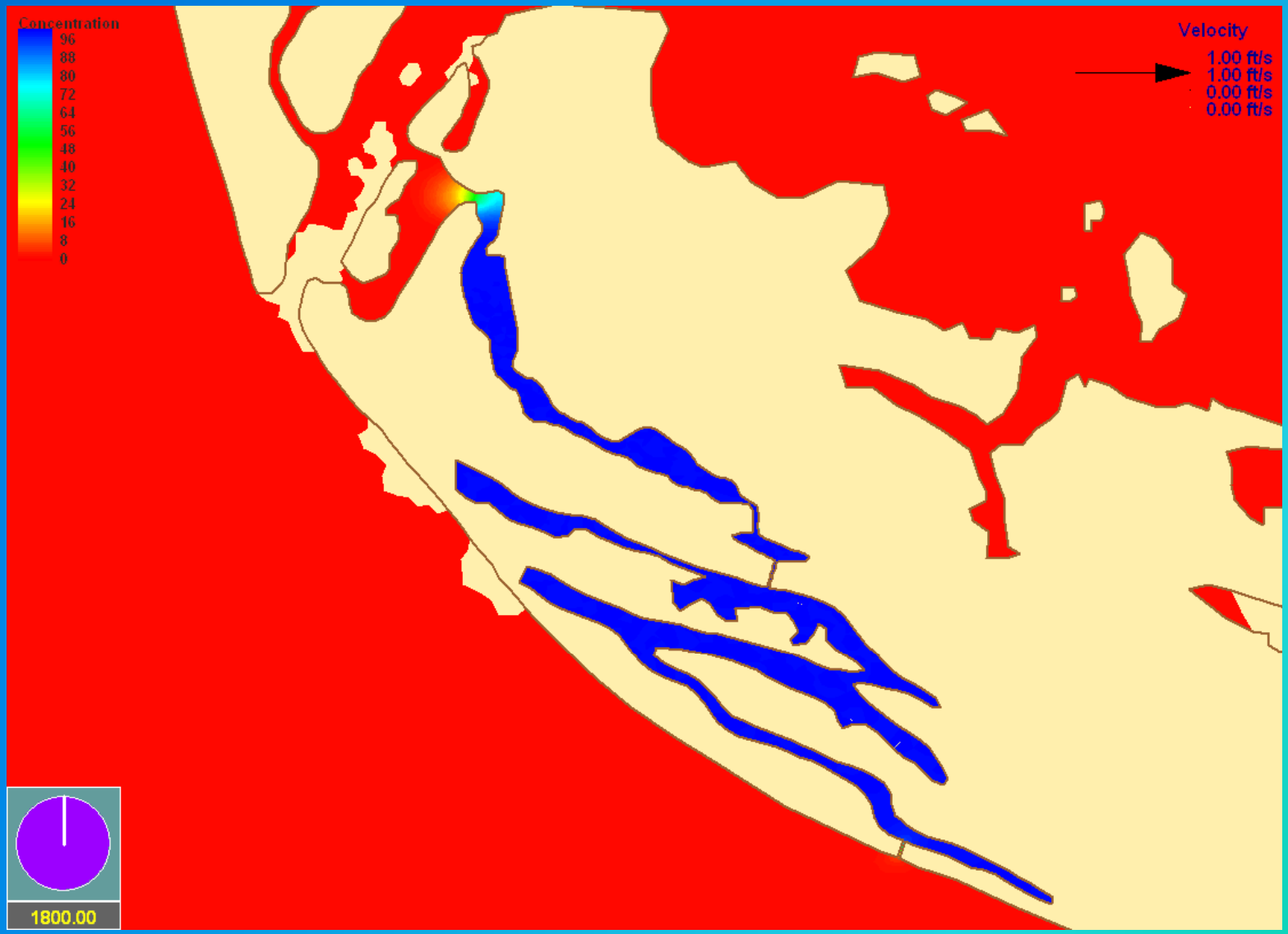
Knowledge – Quality - Service

ADCIRC Model Results

Blind Pass Pre Closure

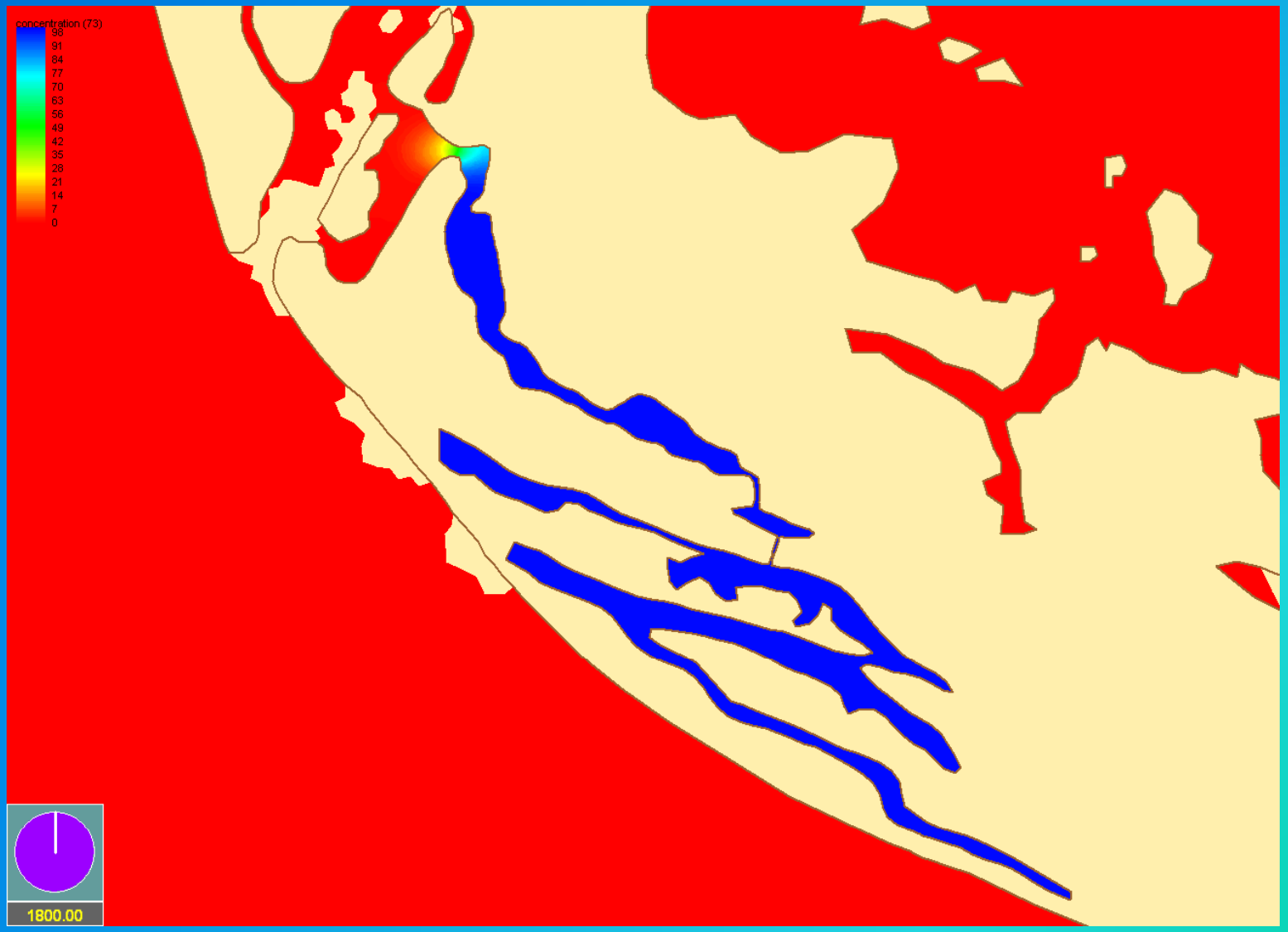
ADCIRC Model Results

Flushing Culvert and Gulf Connection



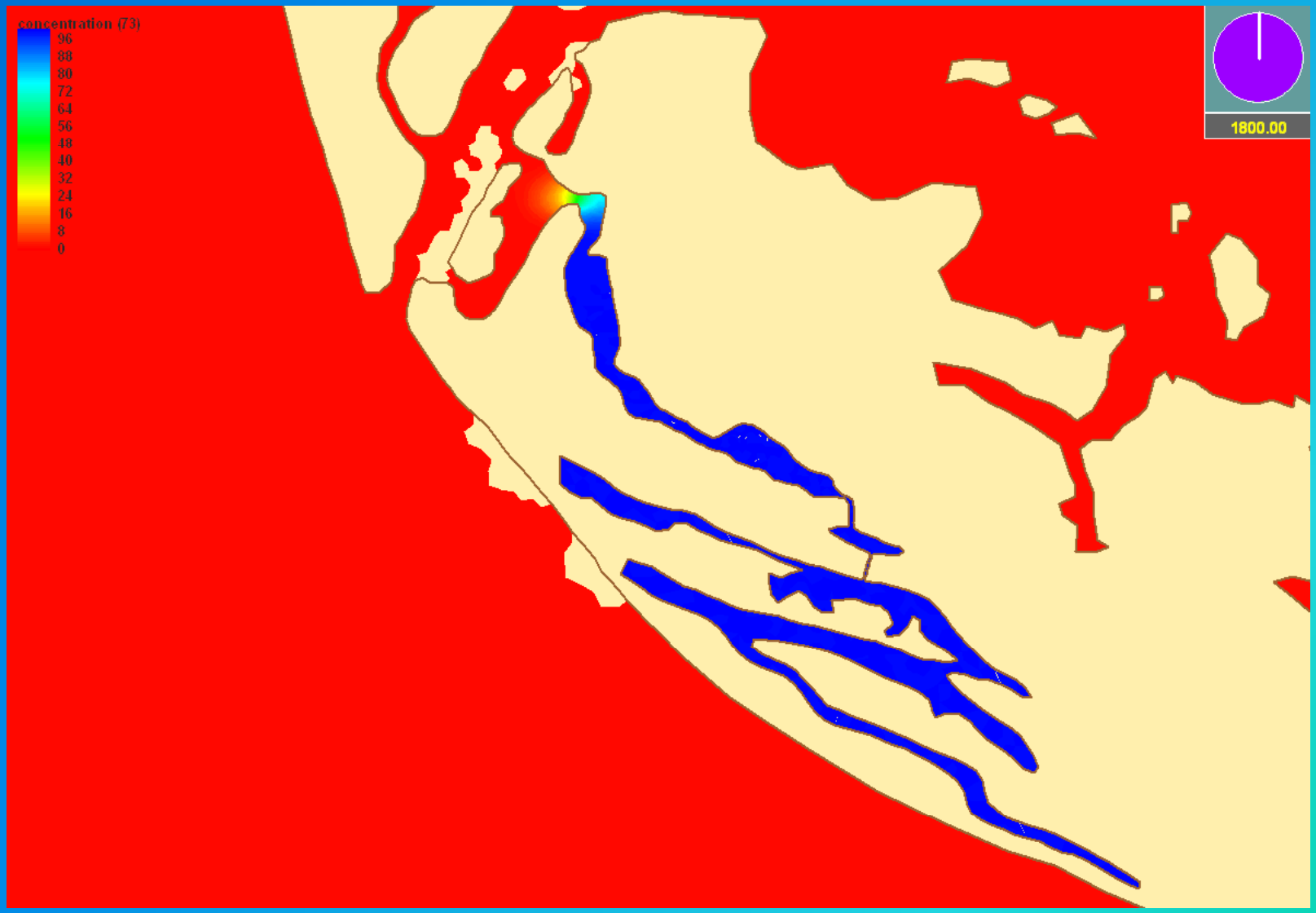
ADCIRC Model Results

Flushing Culvert Only



ADCIRC Model Results

Dredge Blind Pass/ Install Flushing Culvert



Tools of the Trade

Flushing Studies typically involve collecting field data to verify the model estimates and determine any anomalous conditions that might exist on the site.

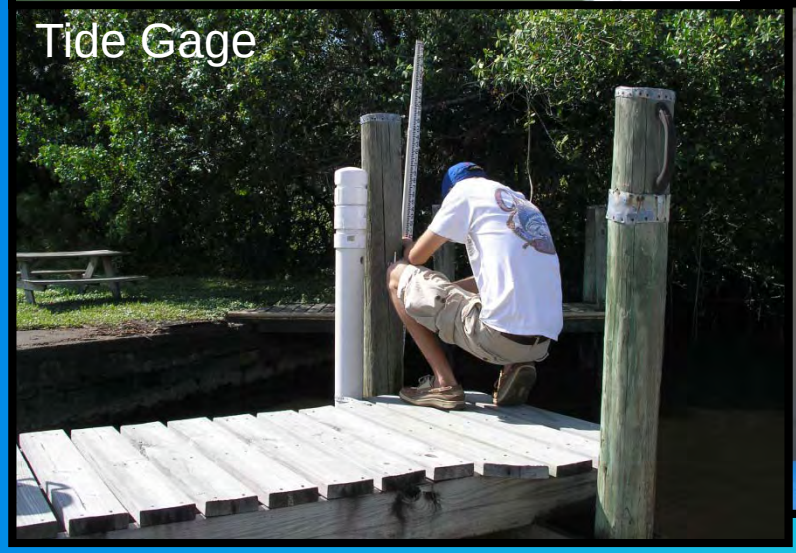
- **Current Meters**
- **Drogues**
- **Marking dyes (Rhodamine WT, Uranine) incl. fluorometry**
- **Tide Guages**
- **Anemometer**
- **Bathymetric Survey equipment**
- **Common Sense**
- **Experience**

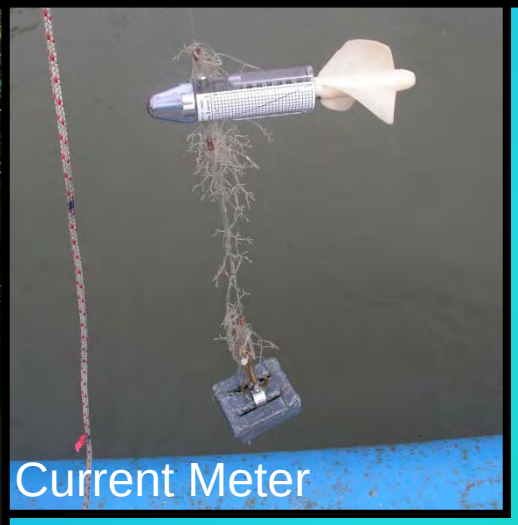
Knowledge – Quality - Service

Tools of the Trade – Uranine Marking Dyes

Knowledge – Quality - Service

Tools of the Trade – Velocities/Tides



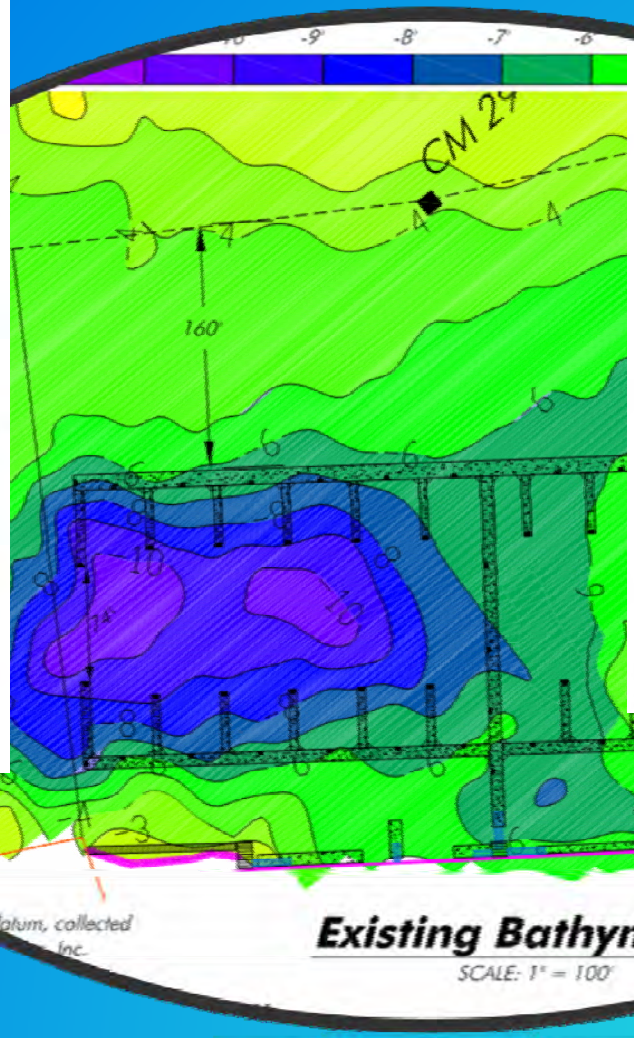


Knowledge – Quality - Service

Tools of the Trade – Bathymetric Surveys

Echo-sounder

GPS system



Computer with the Dual Serial I/O PC Card

Transducer to be connected to the Echo-sounder

Knowledge – Quality - Service

Conclusion

- **Focus on good water quality, not four days.**
- **Docking facilities are *POTENTIAL* sources of pollution. The industry is changing (improving).**
- **Remember the reasonable assurance test. It may not flush in four days but it might be improved overall for a net environmental benefit.**
- **Make sure the model is properly calibrated.**
- **The solution to pollution is to manage it at the source. Dilution is a fall back (and reasonable) option.**

Obligatory Sunset Closing Slide

Thank you!!

Hans Wilson & Assoc. Inc.
1938 Hill Ave. Fort Myers, FL 33901
239-334-6870 hans@hanswilson.com

Knowledge – Quality - Service