SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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Hydraulic Pulsing in Managed Wetlands to Identify Physical Parameters

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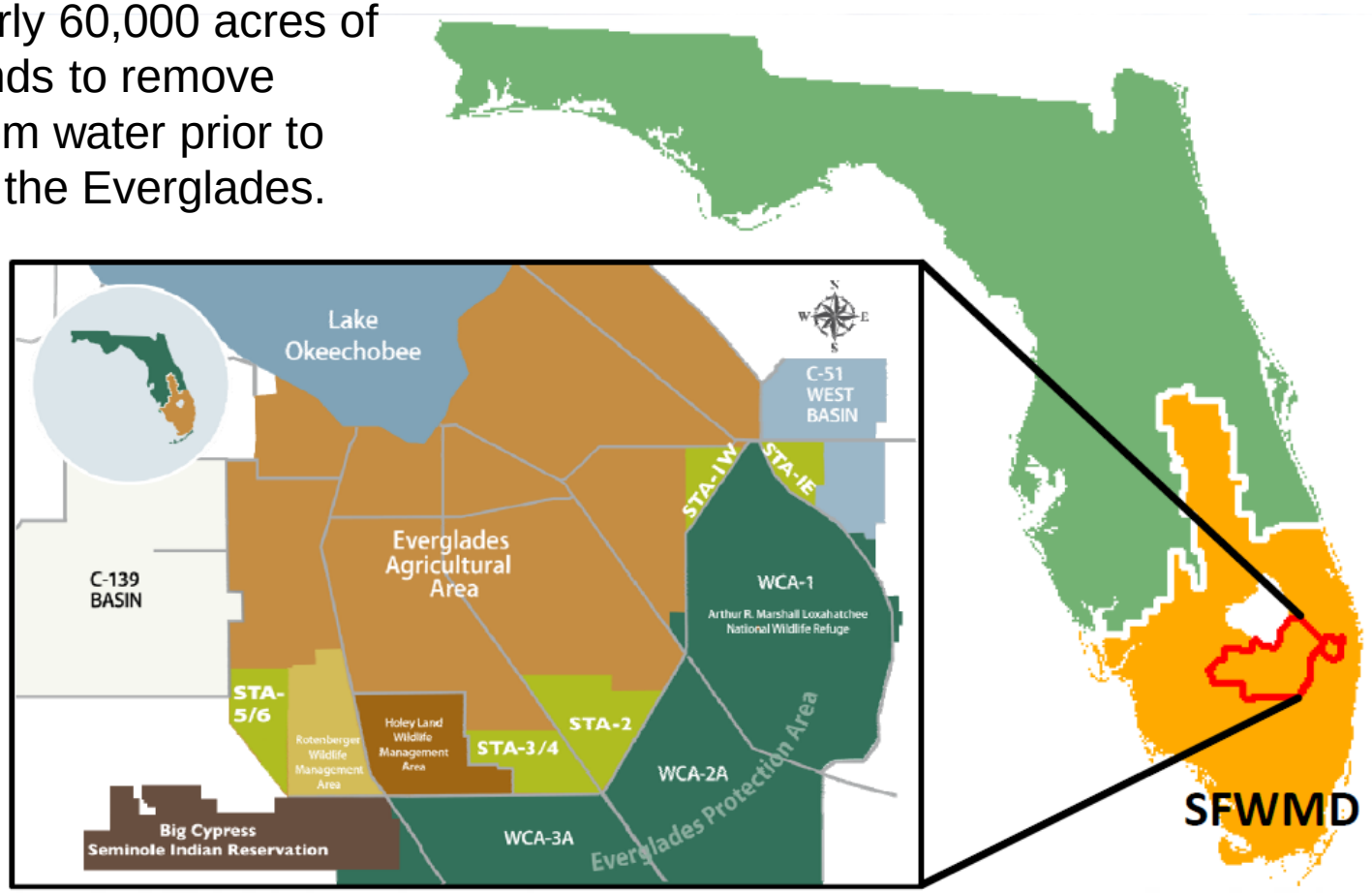
sfwmd.gov

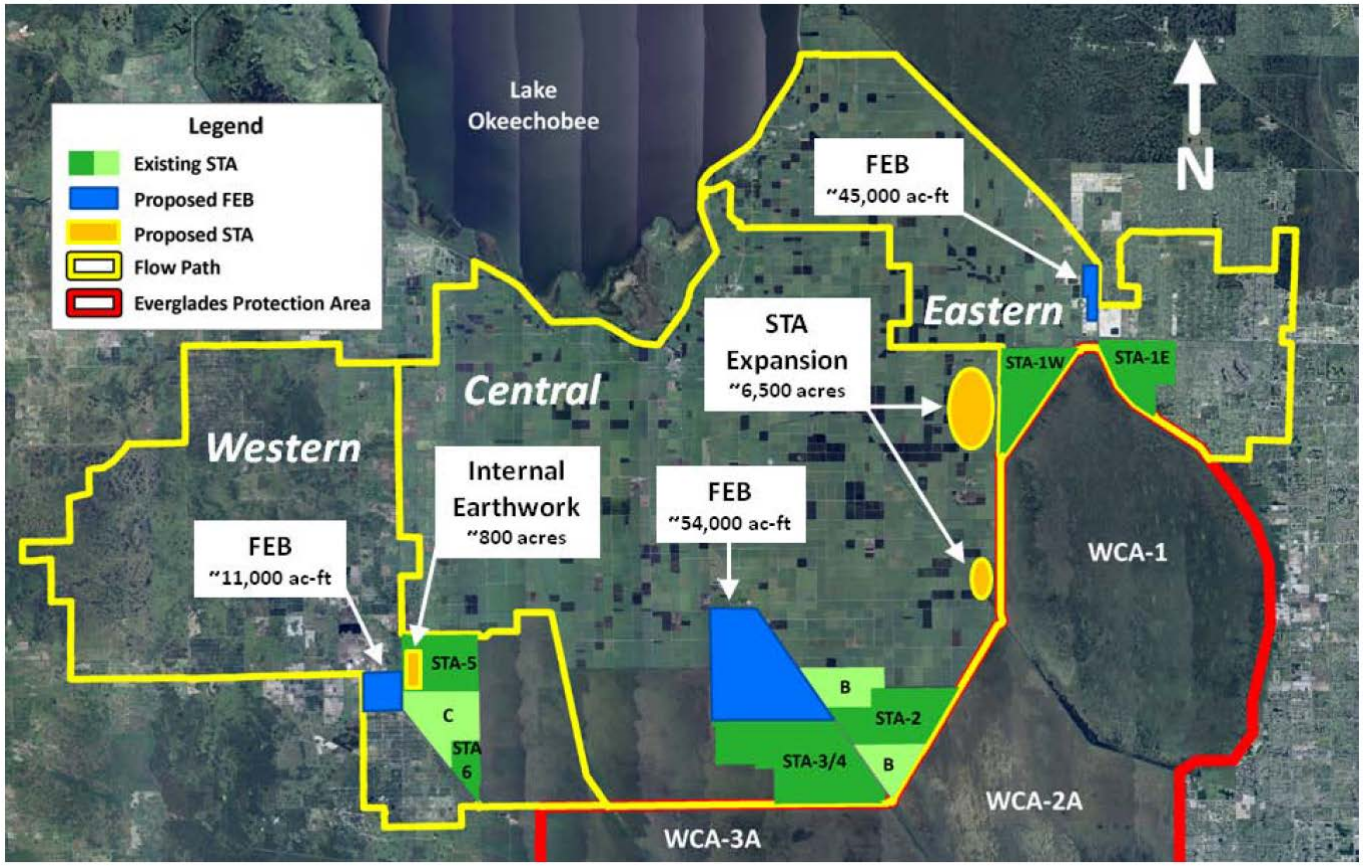
South Florida's Stormwater Treatment Areas (STAs)

The South Florida Water Management District (SFWMD) has constructed nearly 60,000 acres of managed wetlands to remove phosphorous from water prior to discharging into the Everglades.



Planned Projects (per the Restoration Strategies Program)

Additional planned projects will expand the existing wetland areas and add upstream storage features known as Flow Equalization Basins (FEBs).

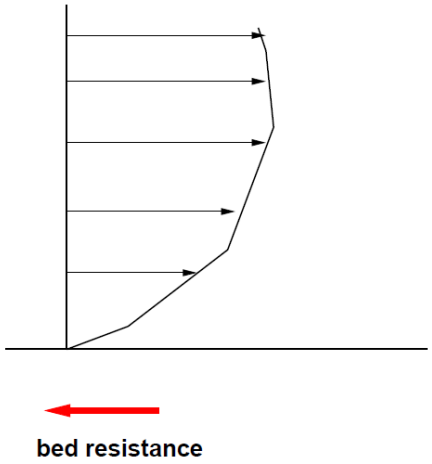


Understanding the Dynamics of the STAs is Critical

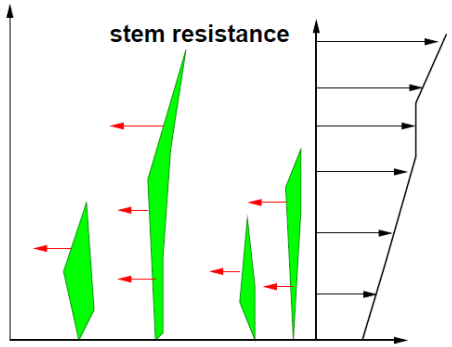
To better understand these complex systems, use of hydraulic perturbation (wave) tests has helped to:

- Ensure that the theoretical basis behind STA hydraulic formulations are sound
- Extract system's physical parameters to match the calculations of
  - Total discharge
  - Wave speed
  - Wave attenuation
- Benchmark key behavior of the system
- Make it possible to inform and scientifically support and defend operational management decisions

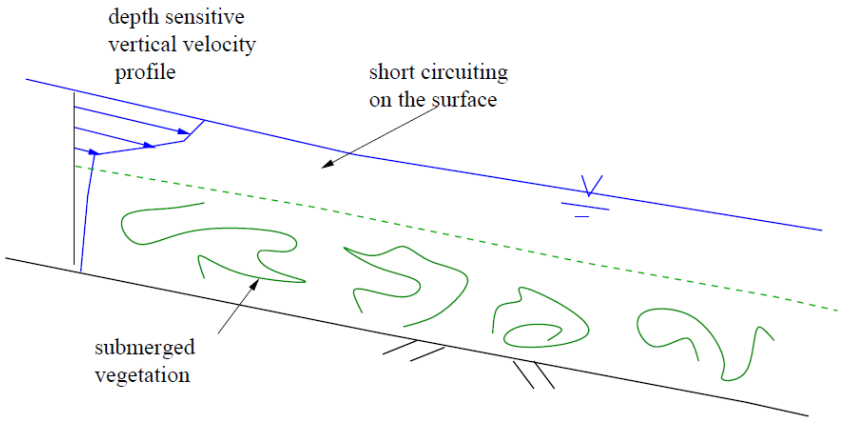
The Complexities of Understanding Flow Mechanics…

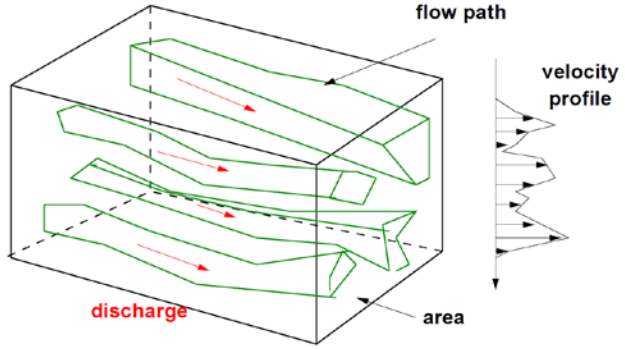


(a) Velocity profile for Manning's equation



(b) Velocity profile for flow resisted by stem drag

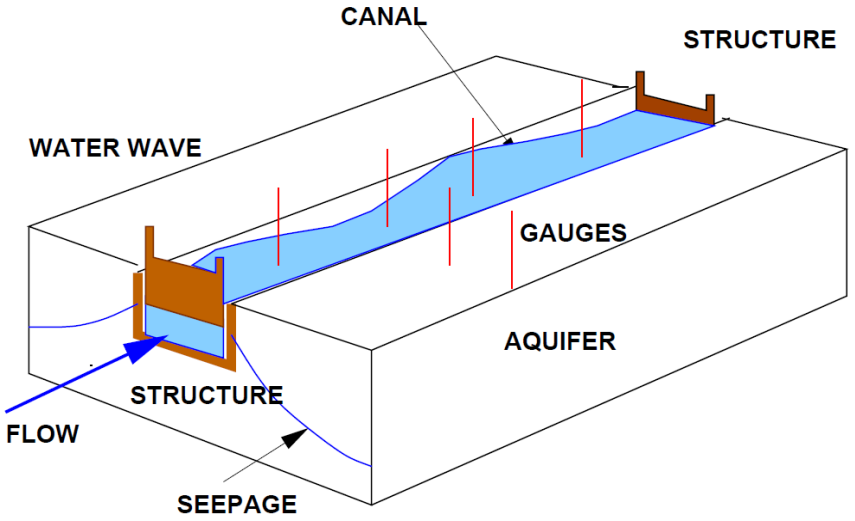




$$\text{bulk velocity} = \frac{\text{total discharge}}{\text{area}}$$

Basic Idea Behind the Wave Test

- Approach quasi-steady state conditions
- Send a series of continuous sinusoidal or square waves through the medium or canal
- Monitor the wave speeds and wave attenuations at locations of interest
- Convert wave speeds and attenuations into parameter values of partial differential equation
- Develop functions q(h,s) that describe all wave behaviors



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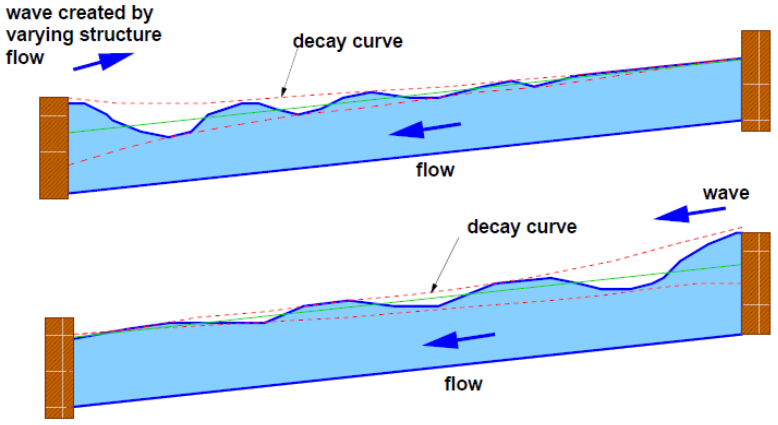
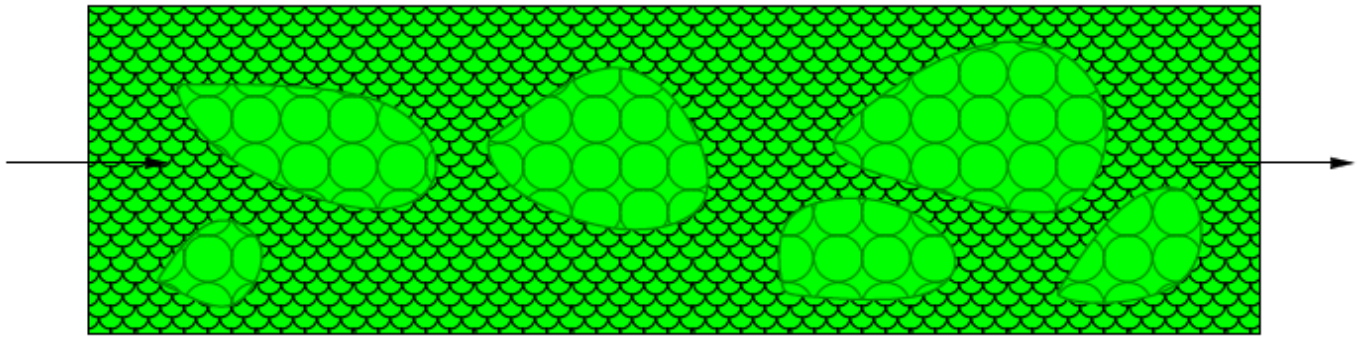
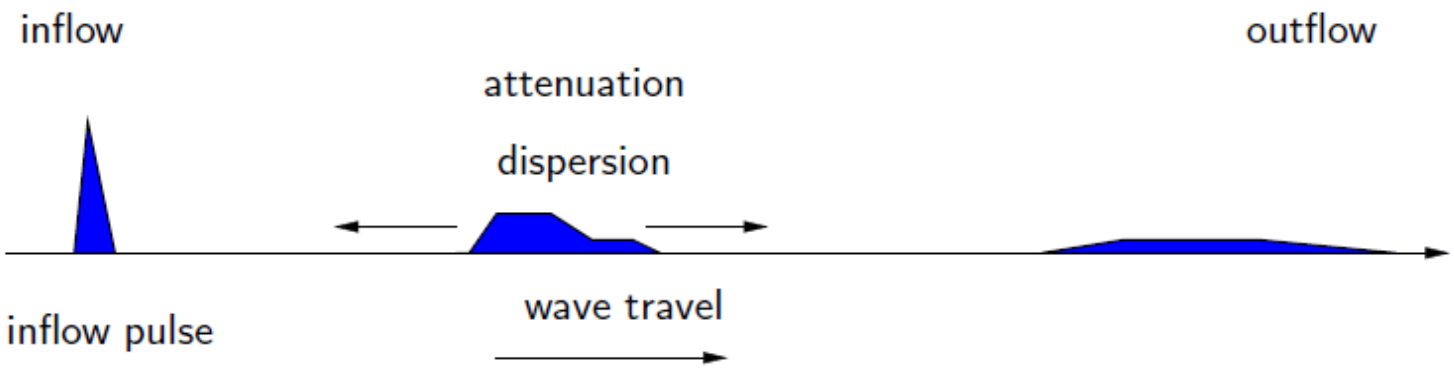


Wave Behavior in Space and Time





both attenuation and dispersion can be measured

they relate to flow roughness n_b, depth dependency γ, and slope dependency α

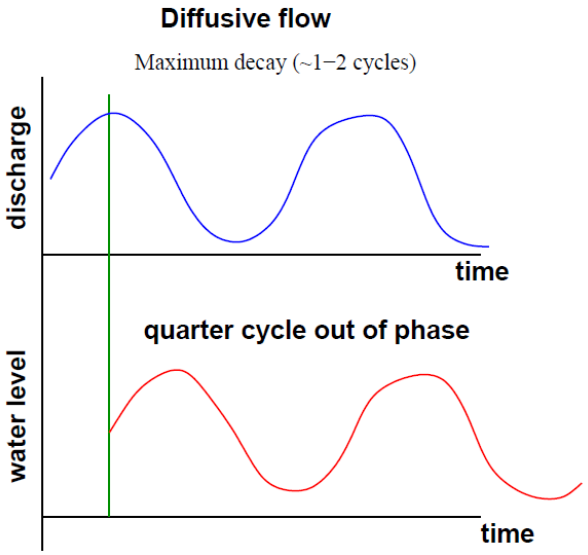
Wave Function Parameters

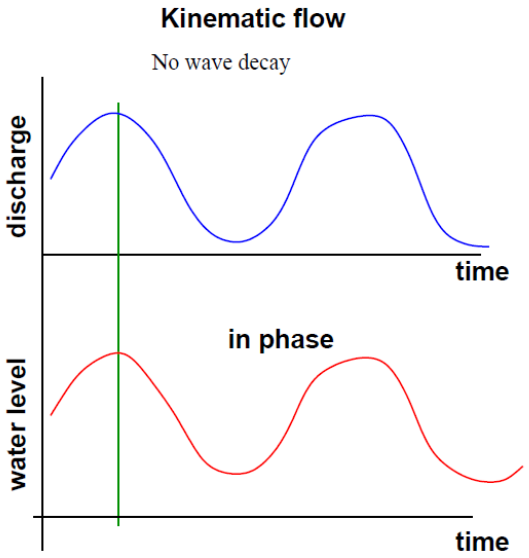
Three parameters are used to match three physical characterizations of hydraulics

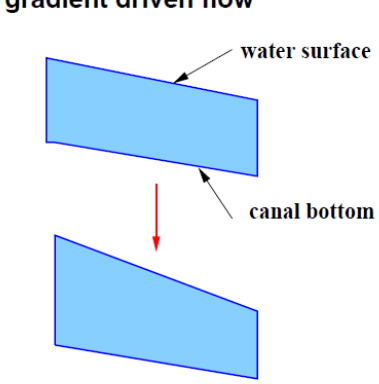
- γ Gamma characterizes wave speed
- α Alpha characterized wave amplitude decay
- n_b Manning's constant characterizes the total discharge

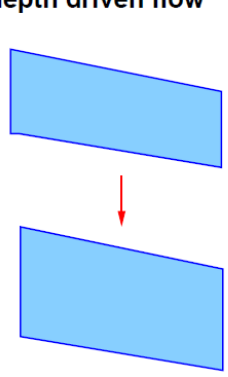
$$q = \frac{1}{n_b} h^{1+\gamma} |s_f|^{\alpha} \mathrm{sgn}(s_f)$$

Waves Can Tell so Much!







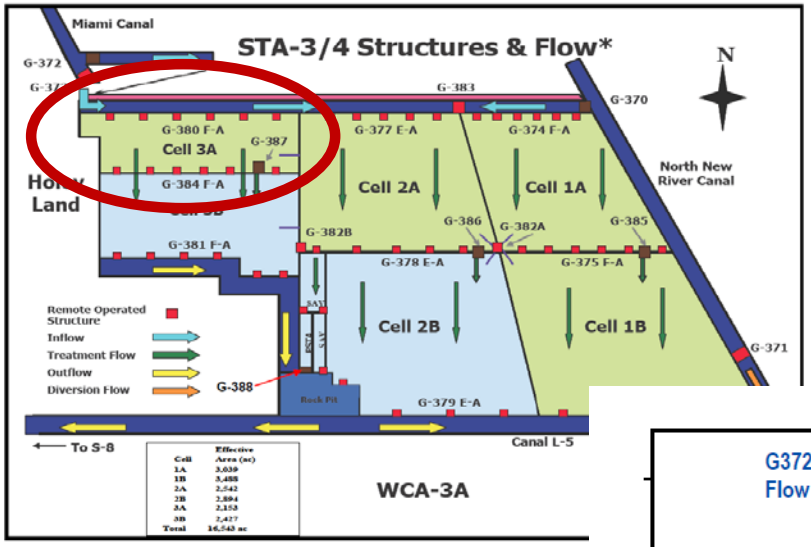


Wave Test Outcomes Inform Other Useful Parameters as Well

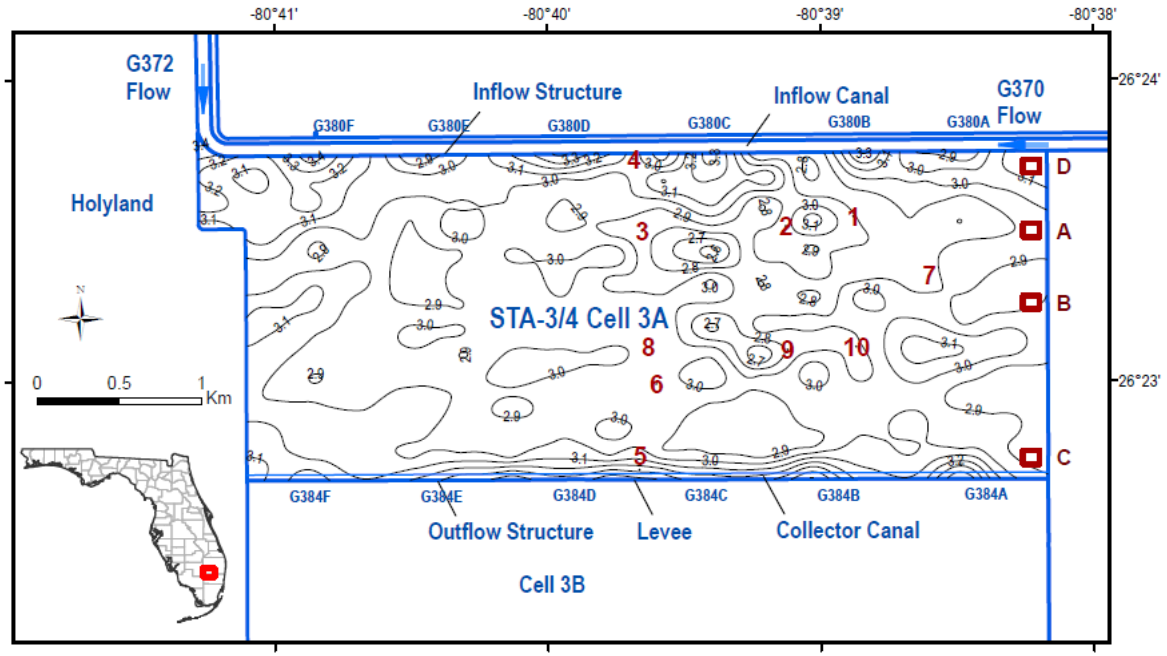
For Example:

- Bulk resistance coefficient
- Spatially varying resistance coefficients
- Sensitivity of influence: How much influence can be observed with the operation
- Expected times of influence: Time for operational influence to be felt at points in space
- Emptying time
- Filling time
- Residence time

An Example Field Experiment



A wave test was performed in Cell 3A of STA 3/4. Inflow was varied and stages were monitored at various points in the wetland footprint.

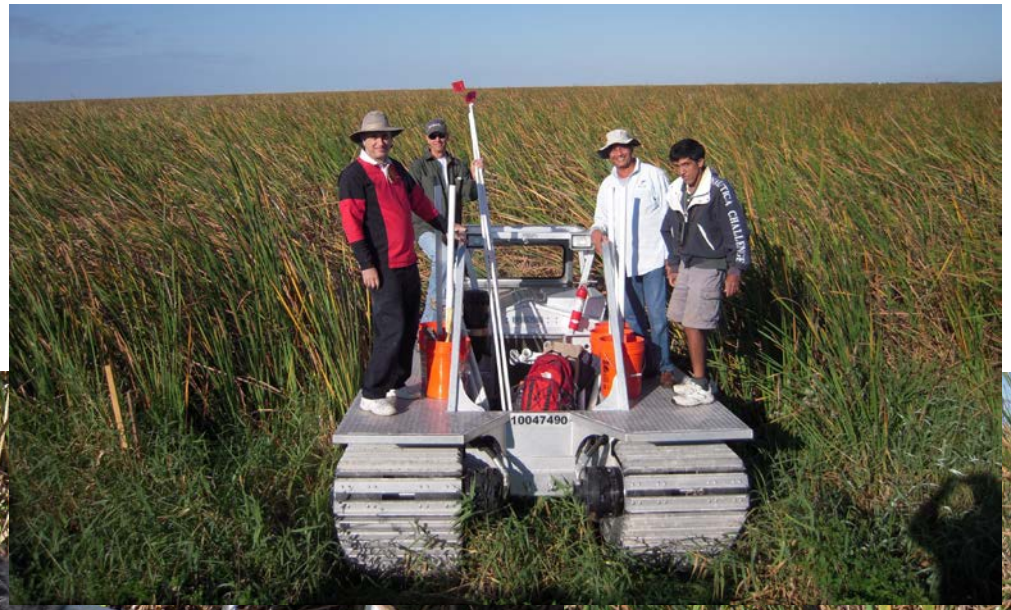


Wave Field Test Experiment Apparatus

Low cost, reusable pressure transducers are used to temporarily expand the monitoring network

No need for ground truthing since only relative stage differences are needed

Deploying in “Resistant” Emergent Vegetation



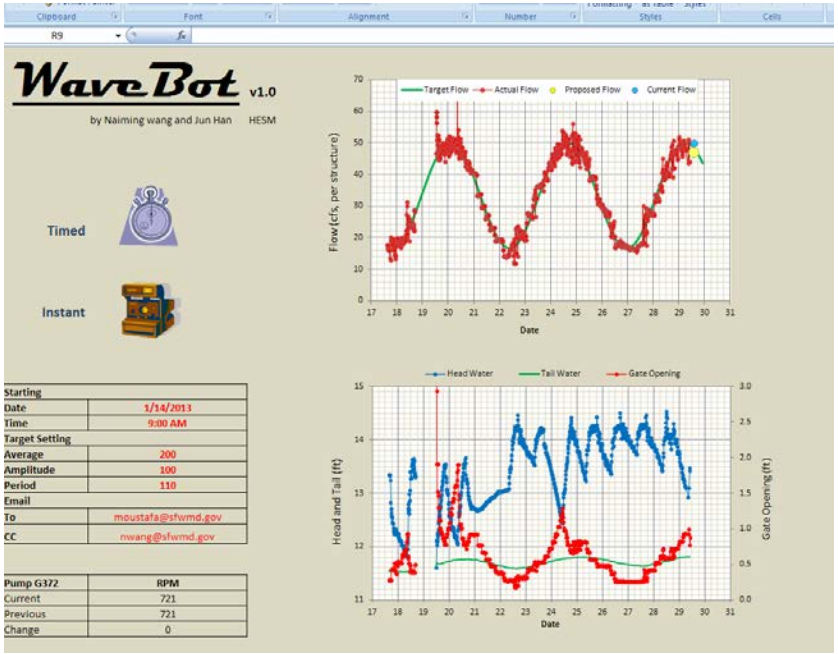
Wave Test Inflow Design

Table 11.3: Sumary of the waves

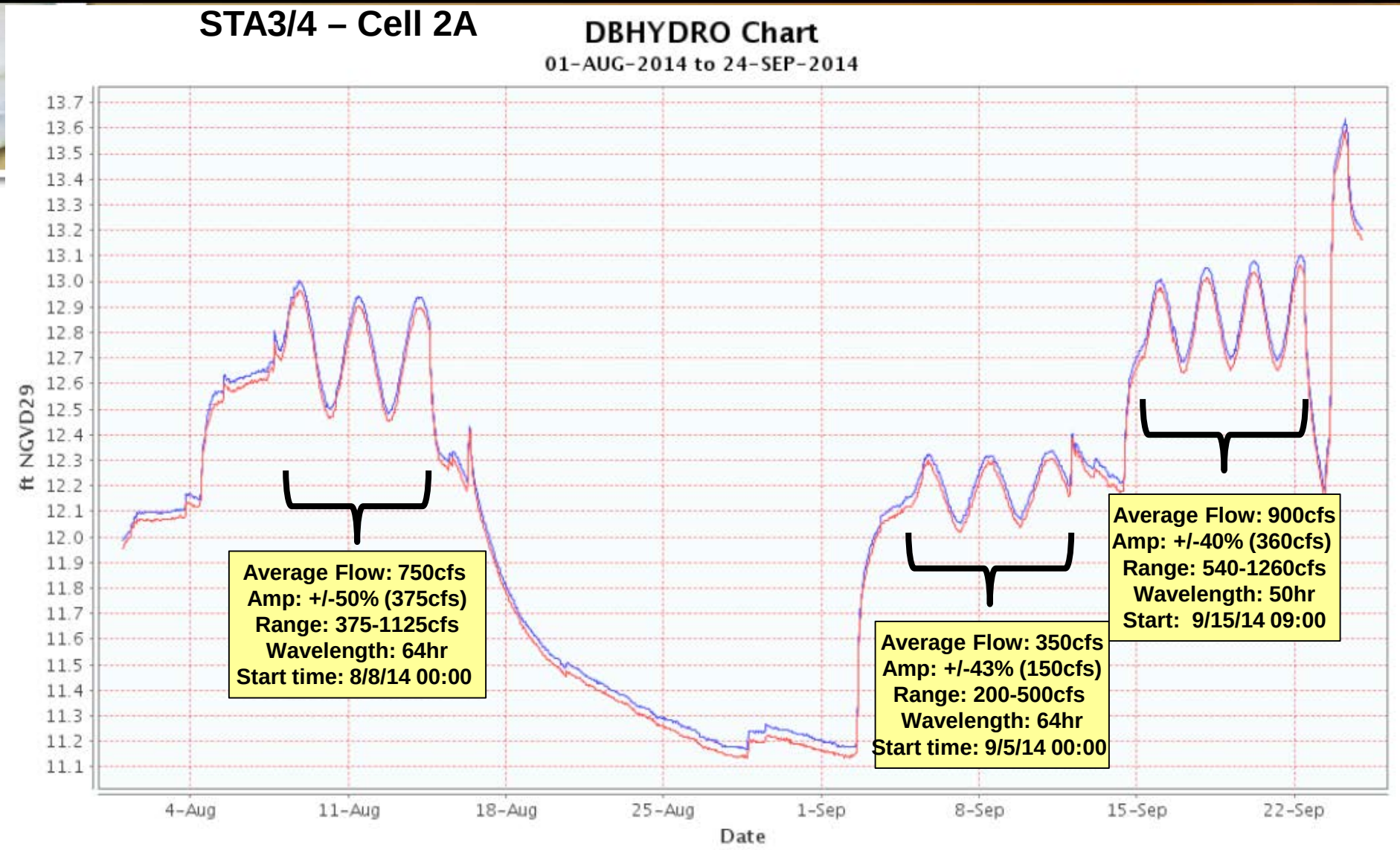
Parameter	Wave 1	Wave 2	Wave 3
Period (Hrs)	50	75	110
Base	900 cfs	650 cfs	200 cfs
Amplitude	270 cfs	300 cfs	100 cfs
Begining day Q	Nov 13, 2012	Nov 28, 2012	Jan 14, 2013
Begining time Q	11:00AM	8:00 AM	09:00 AM
First Q peak day	Nov 13, 2012	Nov 20, 2012	Jan 15, 2013
First Q peak time	11:30PM	21:00 PM	13:30 PM
Ending day	Nov 17, 2012	Dec 4, 2012	Jan 29, 2012
Ending time	13:15PM	16:00 PM	10:00 AM

Operational waves designed to produce different depth regimes, but still propagate through the entire facility

Real-time operations updated every 15 minutes to operate gates or pumps to mimic the desired wave pattern.

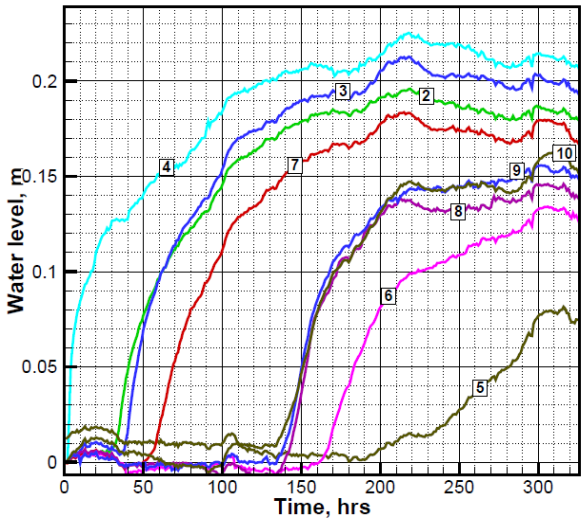


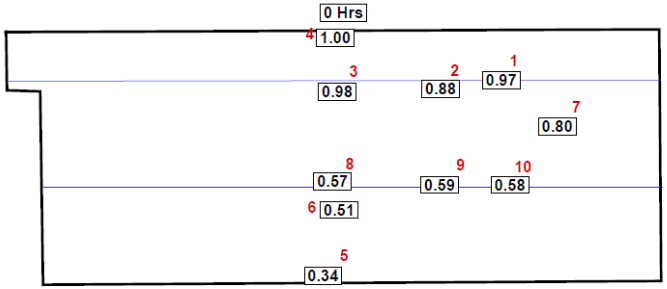
STA3/4 – Cell 2A

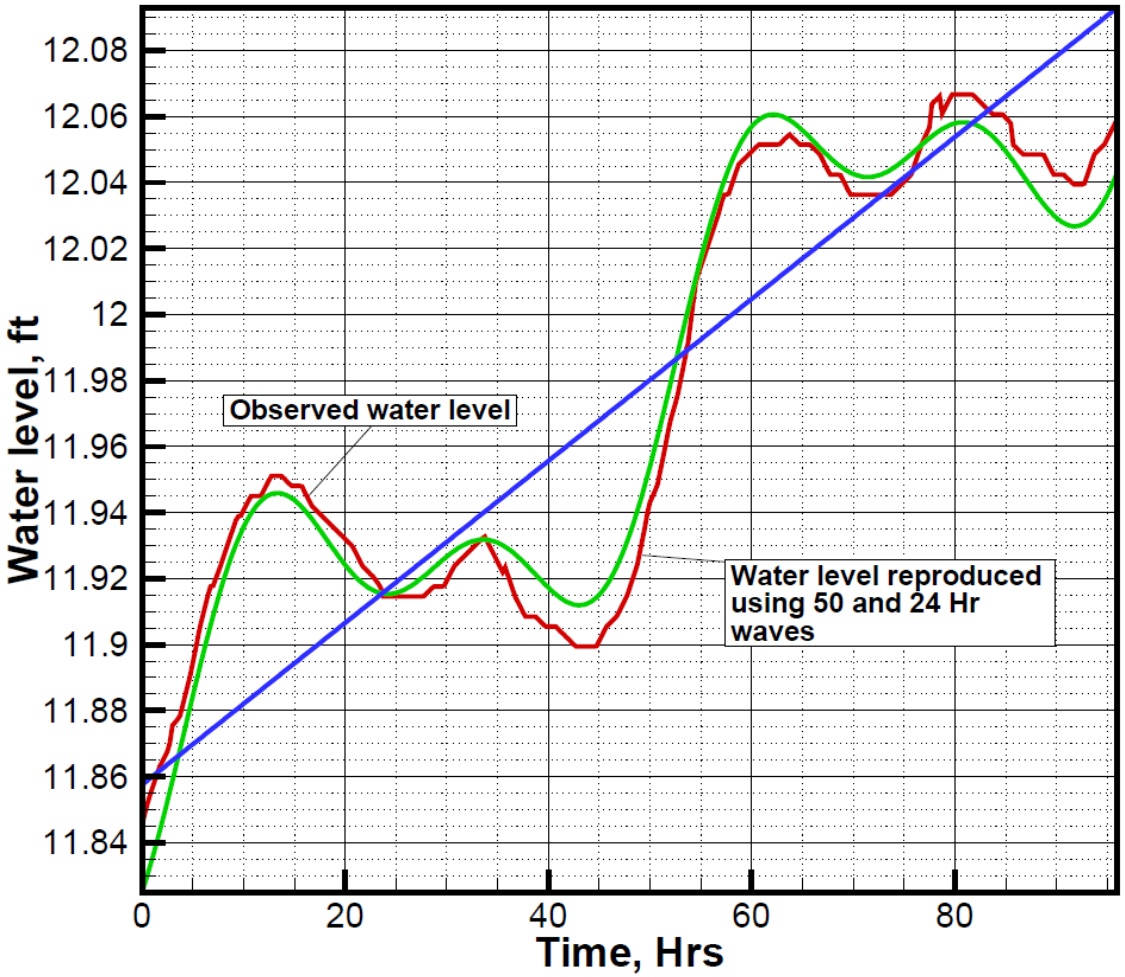


DBKey	Station	Agency	Data Type	Unit	Statistic	Frequency	Strata	Gate/Pump#
T9938	G377B_T	WMD	STG	ft NGVD29	INST	BK	0	N/A
T9940	G377D_T	WMD	STG	ft NGVD29	INST	BK	0	N/A

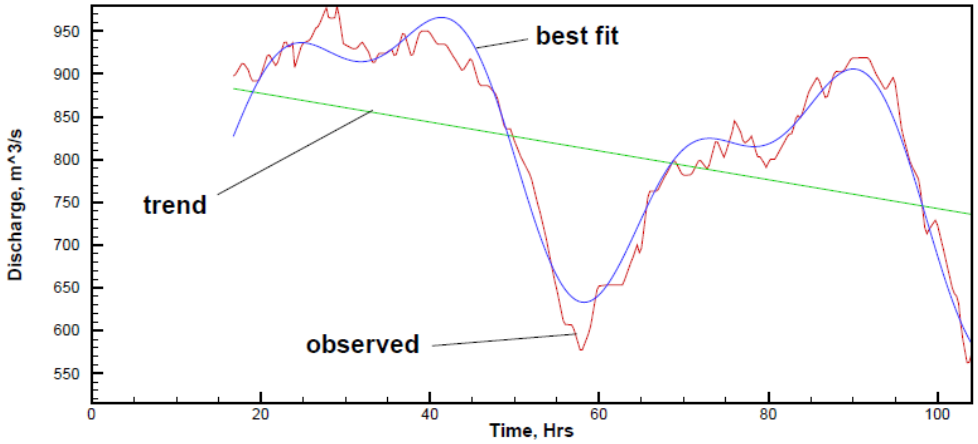
Responses in Stage

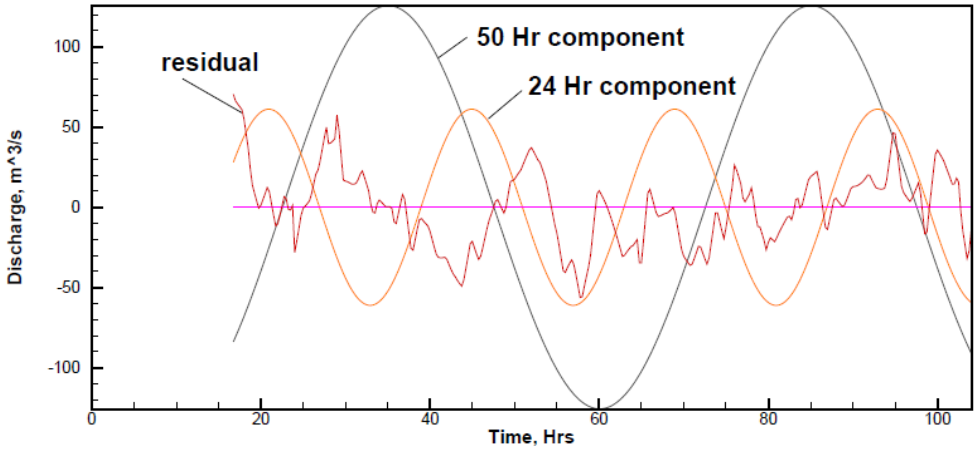






The Good News – We Can Find Our Signal!





Example Outcomes

Expressed as a multi-zone power function:

$$Q_0 = 900 \text{ cfs}, d \approx 0.41 \text{ m}: \quad Q = B\frac{1}{0.995}d^{0.856}s_f^{0.49} \quad (29)$$

$$Q_0 = 650 \text{ cfs}, d \approx 0.26 \text{ m}: \quad Q = B\frac{1}{0.192}d^{1.426}s_f^{0.58} \quad (30)$$

$$Q_0 = 200 \text{ cfs}, d \approx 0.10 \text{ m}: \quad Q = B\frac{1}{0.026}d^{0.951}s_f^{0.88} \quad (31)$$

If you want only one equation

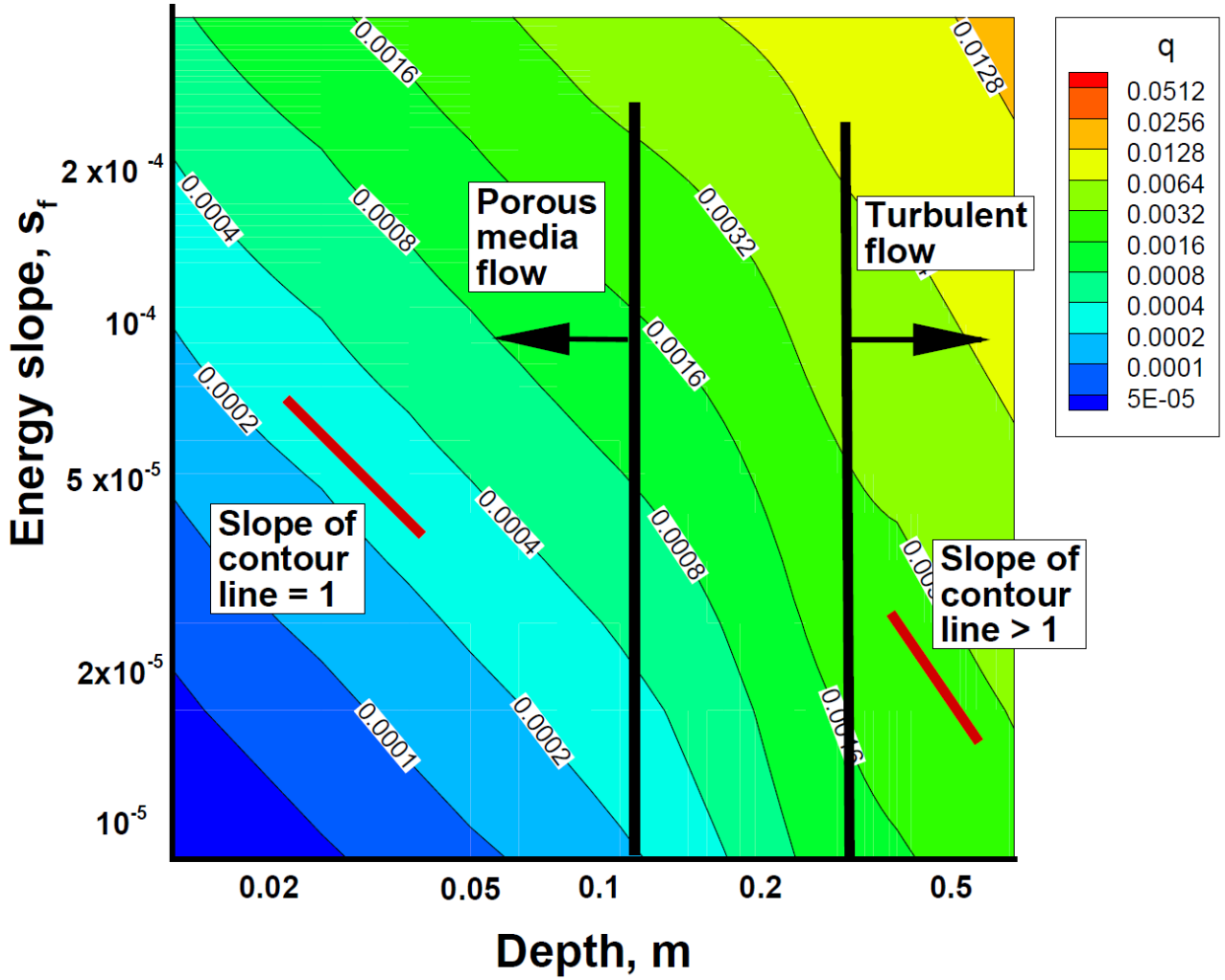
$$Q = B\frac{1}{0.3887}d^{0.95052}s_0^{0.58388}$$

There are Simpler Versions Too

Expressed in simpler functions (with associated error):

Resistance Equation	Depth Period	≈ 0.41 m 50 hrs.	≈ 0.26 m 65 hrs.	≈ 0.10 m 110 hrs.
$Q = B\frac{1}{0.388}h^{0.951}s_f^{0.583}$	Discharge	2.3%	5.3%	7.6%
	Wave speed	10.2%	9.0%	11.4%
	Amplitude ratio	13.4%	25.9%	3.7%
$Q = B\frac{1}{0.00933}hs_f$	Discharge	8.1%	15.8%	18.2%
	Wave speed	35.6%	10.2%	5.2%
	Amplitude ratio	31.2%	19.2%	9.8%
$Q = B\frac{1}{0.768}hs_f^{0.5}$	Discharge	6.4%	8.9%	6.6%
	Wave speed	4.7%	14.0%	15.6%
	Amplitude ratio	12.8%	25.4%	8.2%
$Q = B\frac{1}{0.386}h^{1.666}s_f^{0.5}$ (Manning's eq.)	Discharge	15.8%	22.8%	53.8%
	Wave speed	15.3%	17.4%	42.7%
	Amplitude ratio	57.1%	9.1%	16.7%

Another Way of Looking at the Outcomes



Example SIMULATION of Operational Filling Based on Analytical Results

STA3/4, Cell 3A simulation, verified with field data

STA3/4 simulated surge

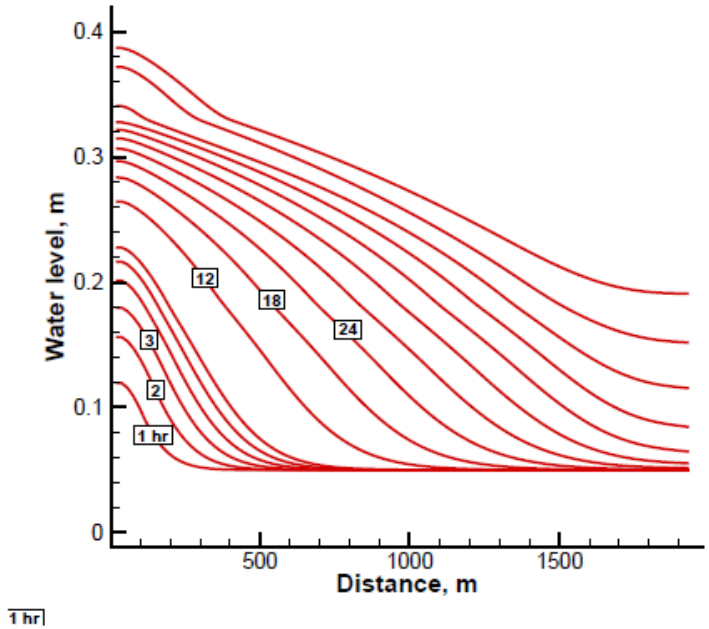


Figure C.11: Water level rise during the wave front movement with overland flow and groundwater-like flow

STA3/4 observed data logger data

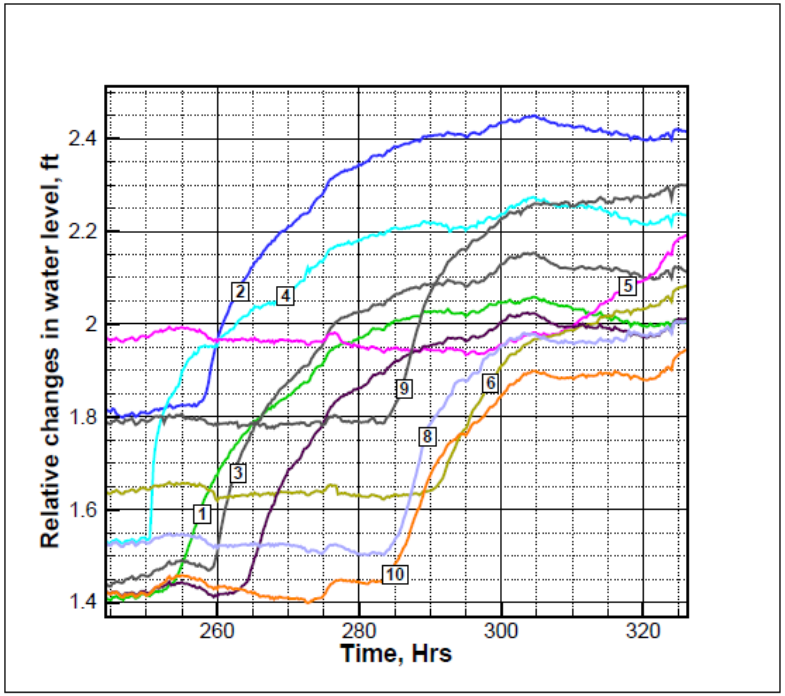
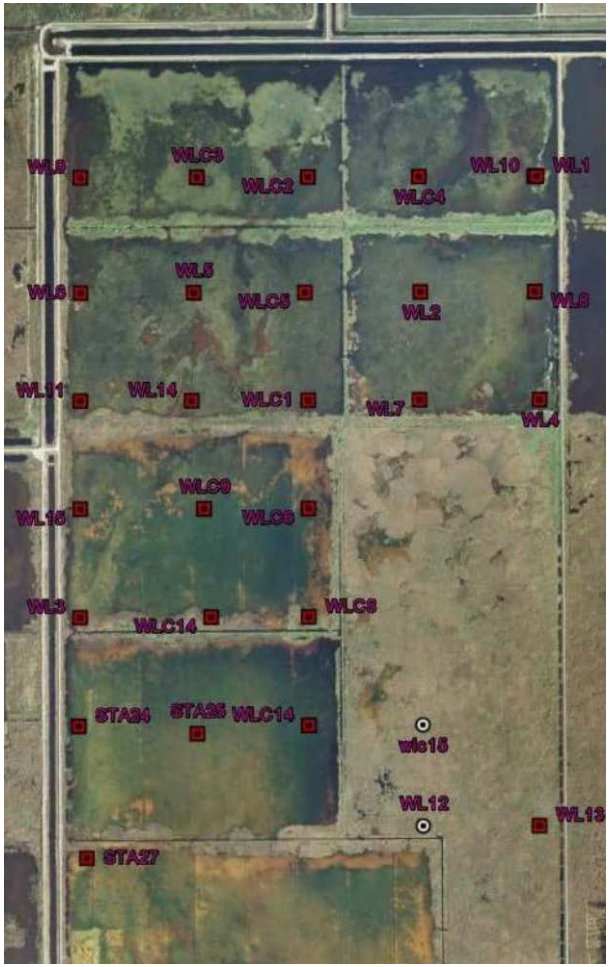
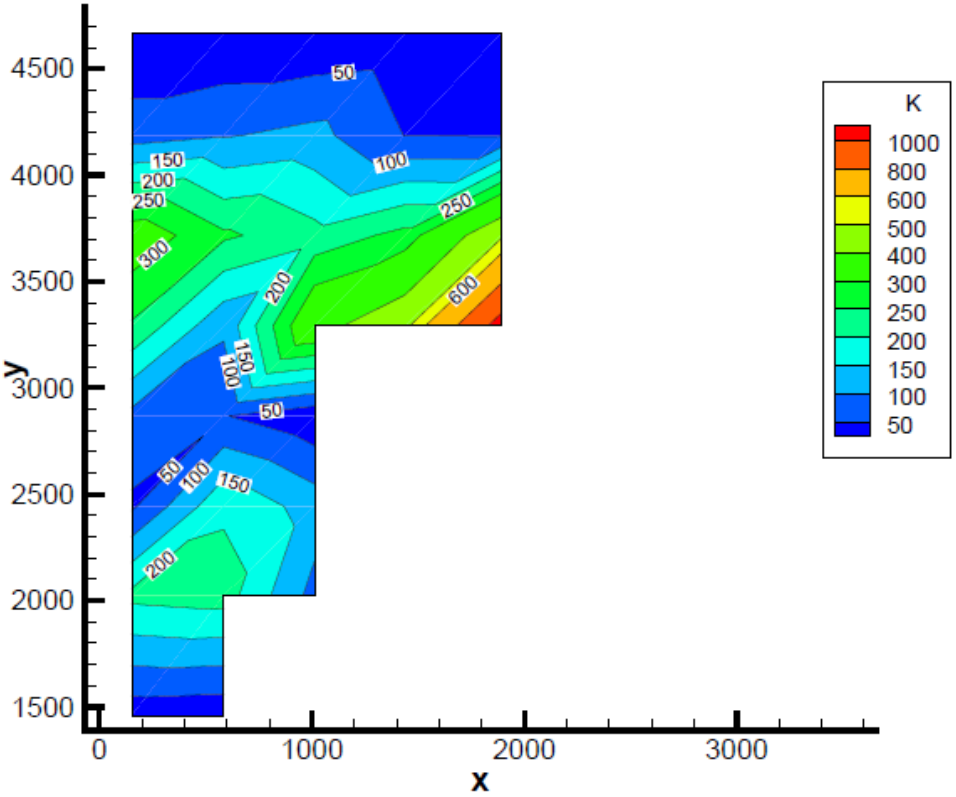


Figure B.3: Sketch showing the wave front for wave 3

An Example of Vegetation "Transmissivity" Mapping in STA2





Conclusions

- Wave testing as performed in the STAs of South Florida has demonstrated an ability to improve the understanding of physical systems in a low cost, yet robust manner.
- Similar testing has also been performed in the L31W and M-Canal waterways in South Florida with similar success.
- This novel approach to field experimentation has the potential for broad-scale applicability.

Thank You!