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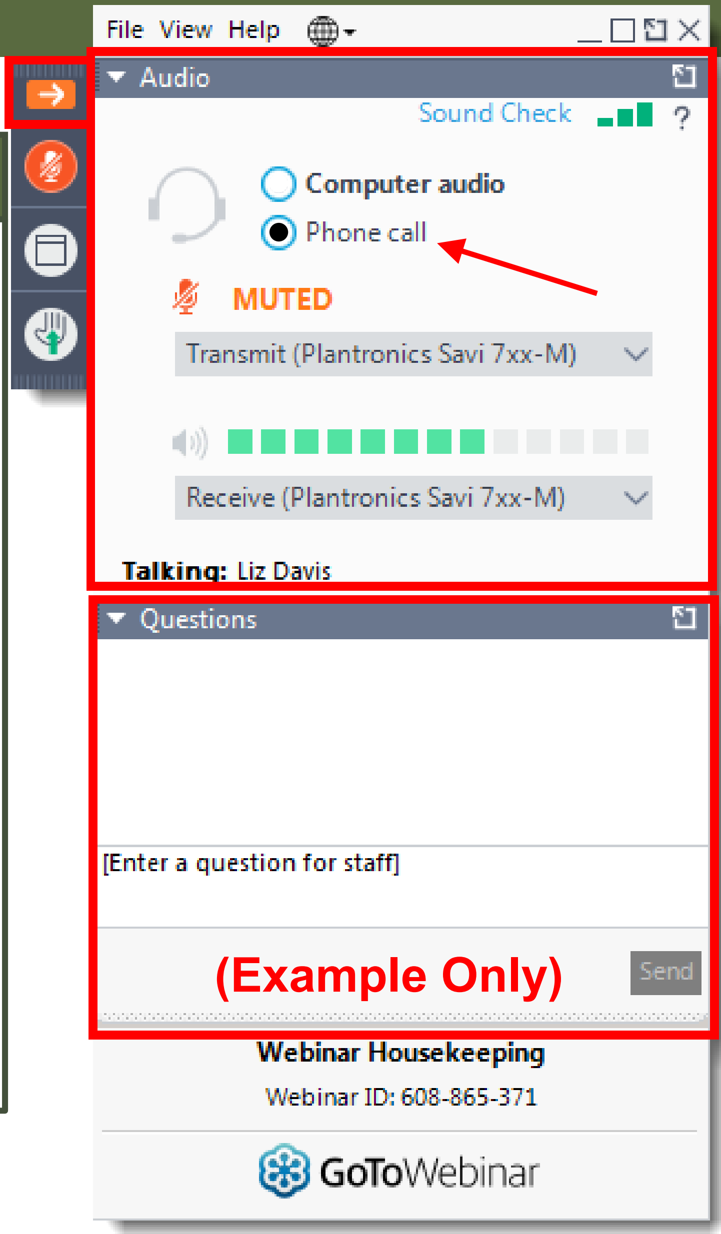


The Spatial Watershed Iterative Loading (SWIL) Model Calibration

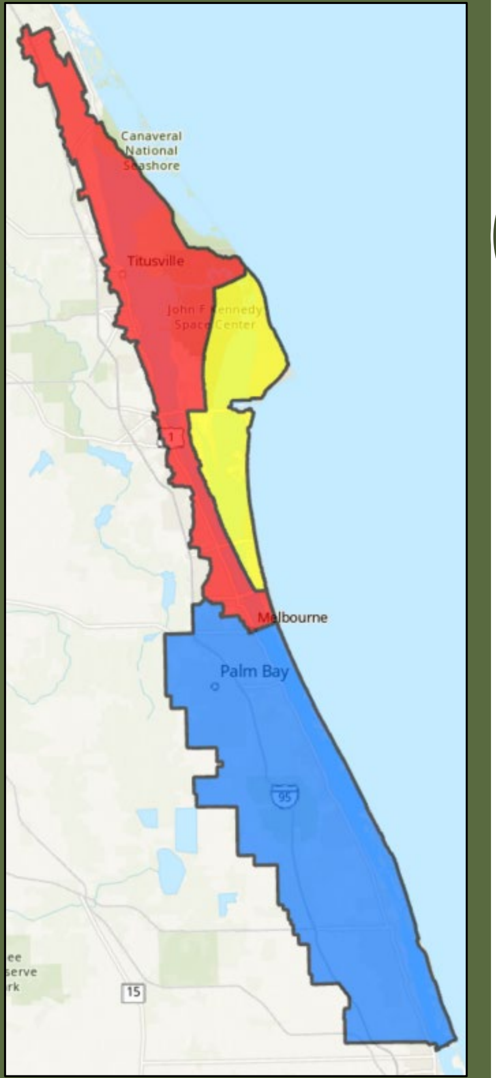
Presenter Stacy Cecil
Division of Environmental Assessment and Restoration
Basin Management Action Plan Coordination
Florida Department of Environmental Protection

Virtual Webinar | March 23, 2023

Agenda

- Opening Remarks
- Background on the Spatial Watershed Iterative Loading (SWIL) Model
- Overview of SWIL Calibration and Optimization
- Next Steps
- Questions

Indian River Lagoon Basin Management Action Plan Modeling



- **2007** Impaired Waters Listing
- **2009** TMDL Adopted
- **2013** BMAP Adopted
- **2021** BMAP Updated

- Total Maximum Daily Loads(TMDL) and 2013 BMAP allocations established with the Pollutant Load Screening Model (PLSM).
  - PLSM timeframe between 1990 and 2000.
  - Nutrient TMDLs set to restore seagrass deep edge habitat.
- 2021 BMAP allocations established with SWIL version 4.0 and TMDL percent reduction targets.
  - SWIL 4.0 timeframe between 2004 and 2015.
- Stakeholder input for updating the allocation model → SWIL 5.0.

SWIL 5.0 Input Summary 2010 - 2020

Rainfall

Land Cover and Use

Soils

Evapotranspiration

Basic Stormwater Treatments (ponds)

Event Mean Concentrations (EMCs)

NORTH IRL, BANANA RIVER LAGOON, AND CENTRAL IRL STAKEHOLDER BMAP MEETING

SWIL MODEL REDEVELOPMENT - PROGRESS MADE TO DATE

APPLIED ECOLOGY INC

MARCH 23, 2023

PRESENTATION OUTLINE

- Summary of Effort Completed, Ongoing, and Upcoming
- Model Input Review
- Purpose of Model Calibration
- Calibration Basins Selection and Changes
- Optimization Workflow and Post-Calibration Results for Hydrology
  - ET
  - Direct Runoff (DRO)
  - Subsurface Flow
- Optimization Workflow for Water Quality
  - Initial Process

SUMMARY OF EFFORTS

Not Performed

- **Task 3** (Incorporate Treatment Disposal to Subsurface Flow Module - OPT)
- **Task 4** (BMP Retrofit Layer Development - OPT)
- **Task 8** (Allocation Watershed Model Run)
- **Task 9** (Natural Background Run – OPT)
- **Task 10** (LET Automation (OPT)
- **Task 11** (Training and User Support)

In Progress

- **Task 5** (SWIL Model Code Update and Run)
- **Task 7** (Water Quality Calibration)

Complete

- **Task 1** (Runoff Component Data Evaluation)
- **Task 2** (Subsurface Flow Component Data Evaluation)
- **Task 6** (Hydrological Calibration)

SWIL 5.0 MODEL INPUTS - REVIEW

- Land Use Land Cover (LULC)
- Soil Hydrological Data
- Precipitation
- Stormwater Treatments (ERPs)
- Evapotranspiration (ET)
- Direct Runoff Coefficients (ROCs) – based on land use and soil type
- Direct Runoff Event Mean Concentrations (EMCs) – based on land use
- Subsurface Flow Event Mean Concentrations (EMCs) – natural versus developed based on groundwater data

WHY CALIBRATE A MODEL?

- Purpose of Calibration is to minimize the error between model outputs and observed data
  - Improve goodness of fit
  - User specifies constraints (has to fit within general knowledge of hydrology and water quality)
  - Used general purpose optimization tool: MS Excel Solver, evolutionary method
- Selection of calibration basins
  - Basins have to have reliable long-term (10 years+ of modelled period) measured data
  - Stream flow data (for hydrological calibration)
  - Water quality data (water quality calibration)
  - Ideally representative of the diversity of the watershed (land use, soils, etc.)

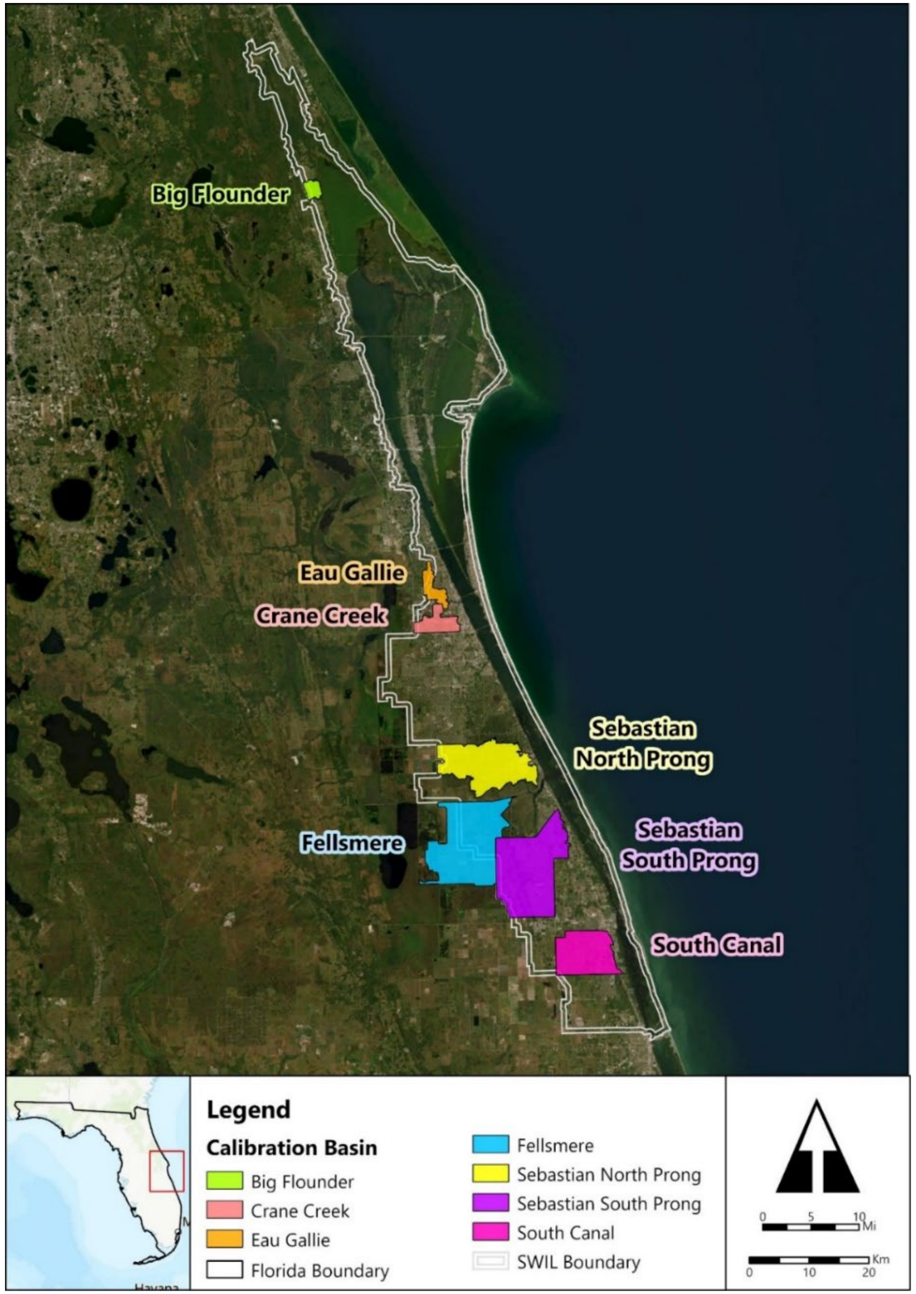
HOW TO DETERMINE A GOOD FIT?

- Percent Bias (PBIAS)
  - Accuracy of model
  - 0.0% means the model neither over or underestimates
  - Goal for SWIL 5.0 is to be within -25% to +25%
- Nash-Sutcliffe Efficiency (NSE)
  - Precision of model
  - -1 to 1
    - -1 means the average of observed data is a better predictor than the model
    - +1 means that the model perfectly predicts the observed data
  - Goal for SWIL 5.0 is to be above 0.5

Metric	Low Bound	Goal	High Bound
PBIAS	-25%	0.0%	+25%
NSE	0.5	1	1

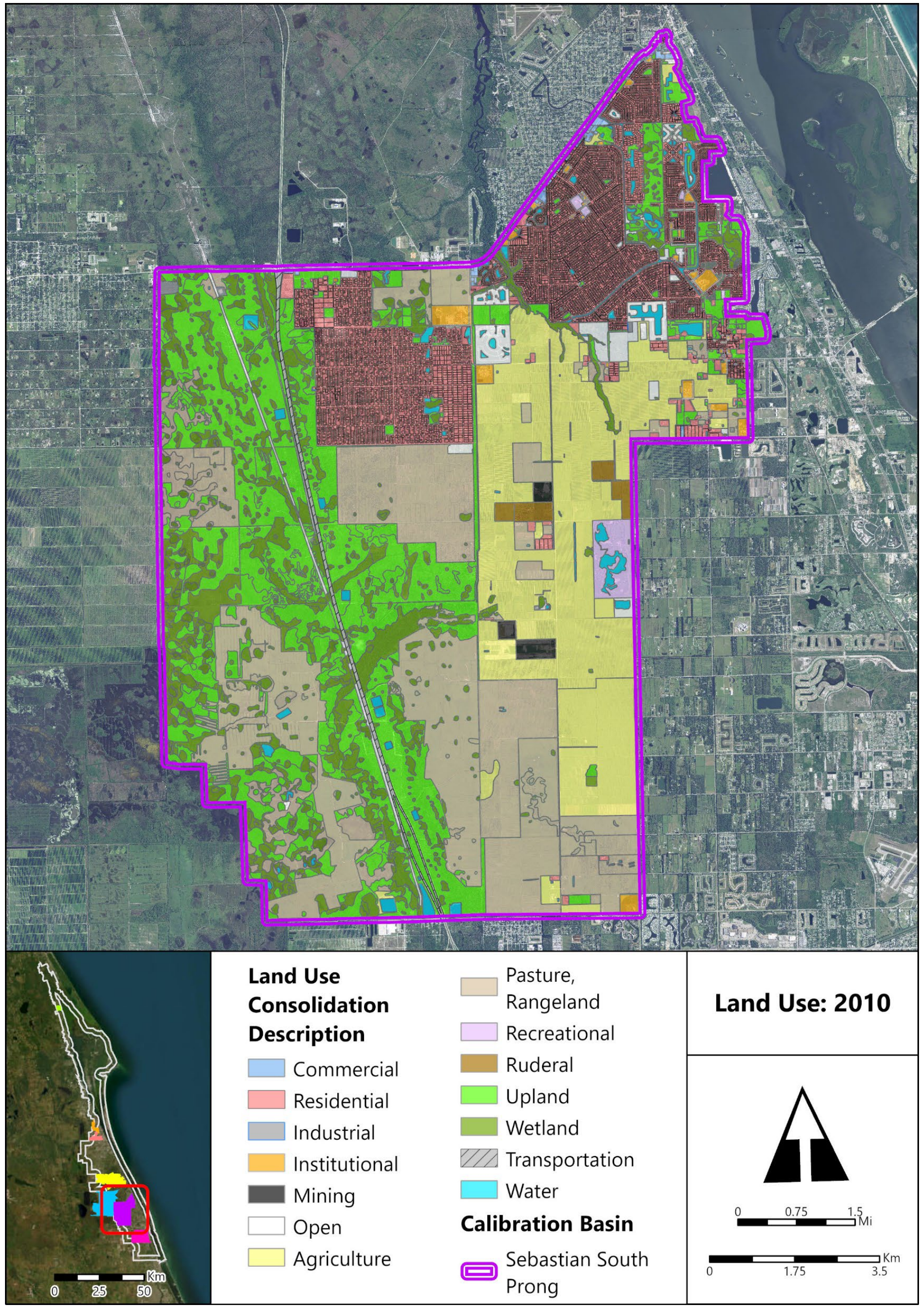
SWIL 5.0 CALIBRATION BASINS

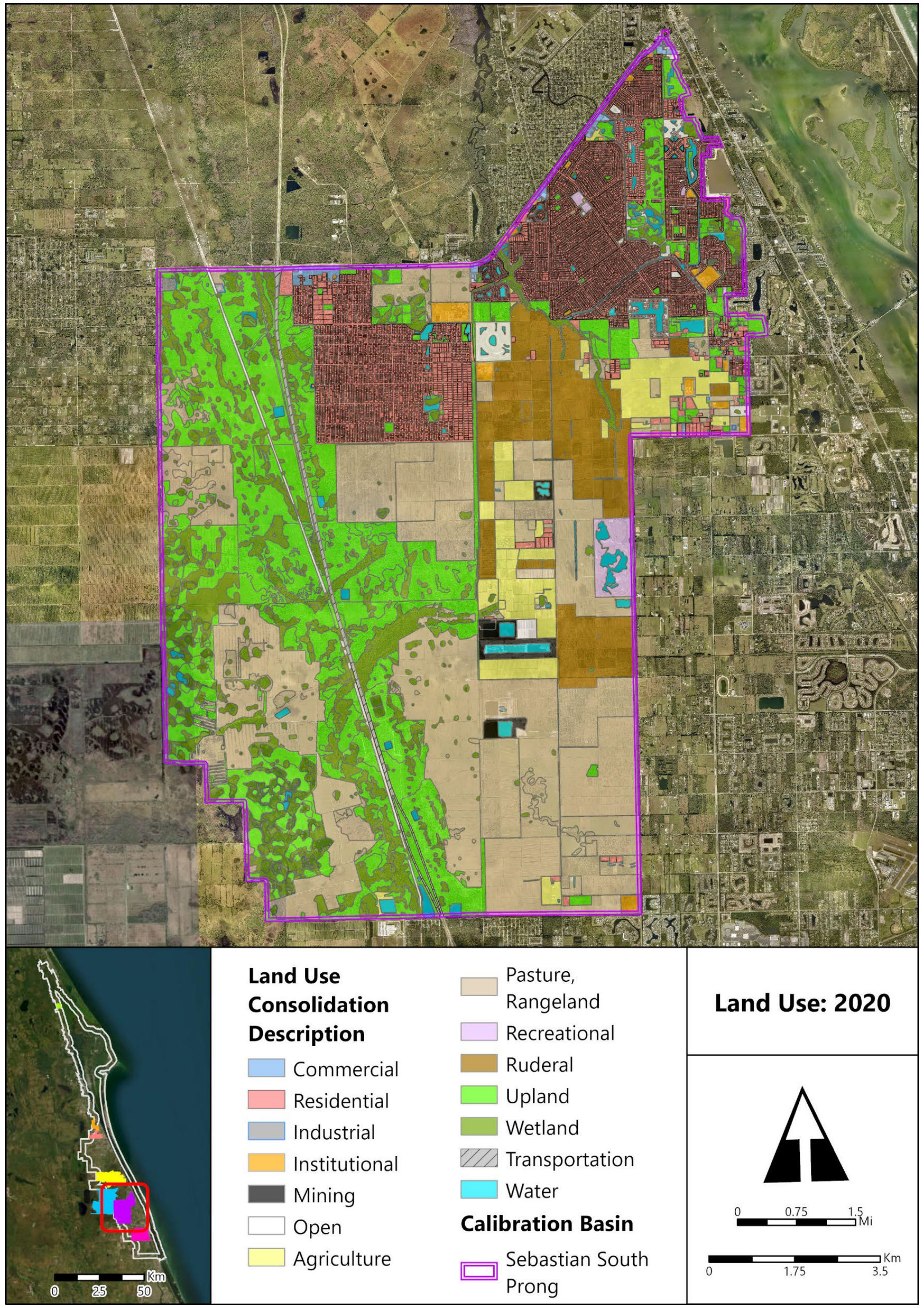
- Original SWIL Calibration Basins
  - Crane Creek
  - Hickory Street – Not active 2010-2020
  - Sebastian North Prong
  - Sebastian South Prong
  - Fellsmere
- SWIL 5.0 (Additional Basins)
  - Big Flounder – water quality calibration only
  - Eau Gallie
  - Vero Beach South Canal



CALIBRATION BASINS: LAND USE CHANGES

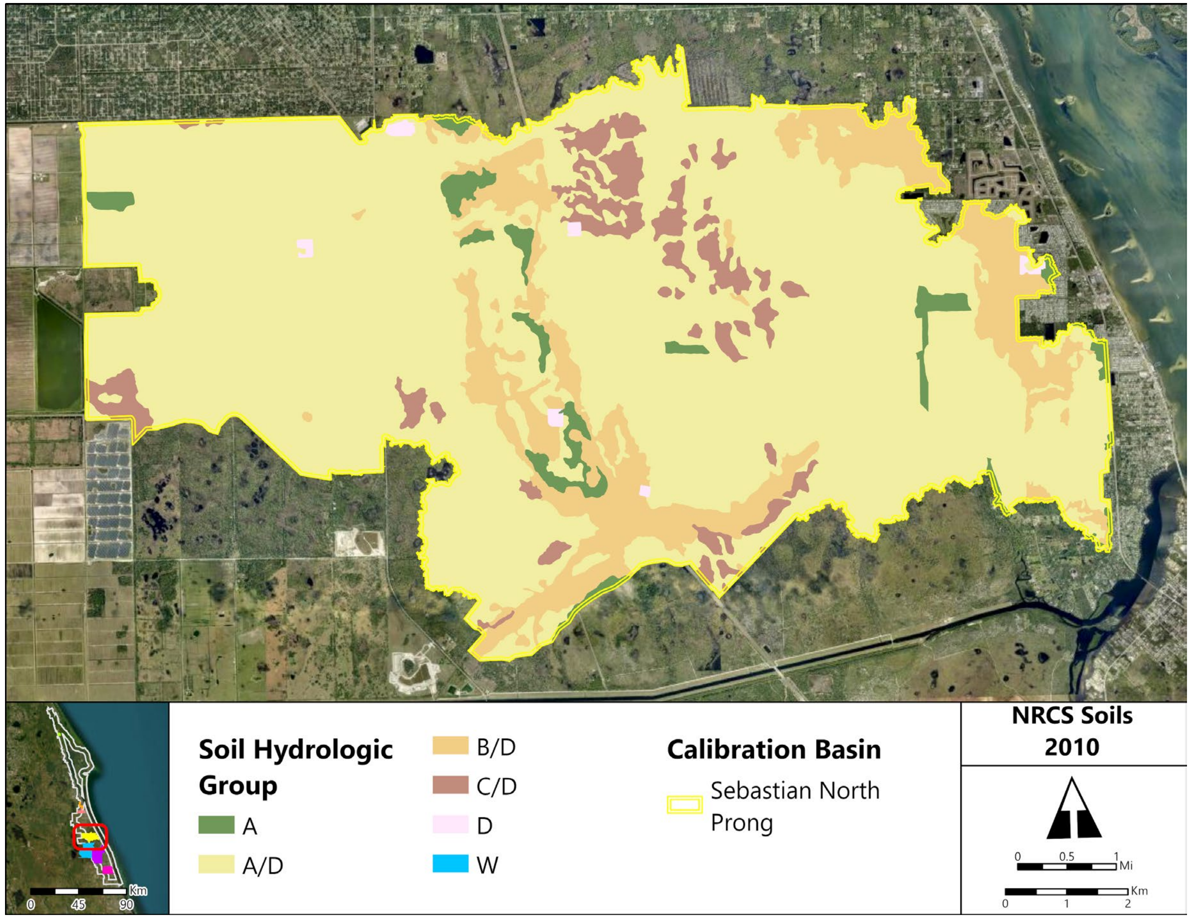
LAND USE	Crane Creek		SNP		SSP		Fellsmere Canal	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
Medium-Density Residential	29.0	16.8	4.0	0.3	6.0	12.7	5.0	1.7
High-Density Residential	6.0	12.0	3.0	2.7	0.0	0.6	0.0	0.3
Commercial	14.0	19.5	0.0	0.1	0.0	0.5	0.0	0.3
Wetlands / Wet Flatwoods	7.0	5.3	14.0	27.2	43.0	16.4	14.0	8.4
Citrus	1.0	0.3	13.0	4.1	21.0	2.6	48.0	45.7

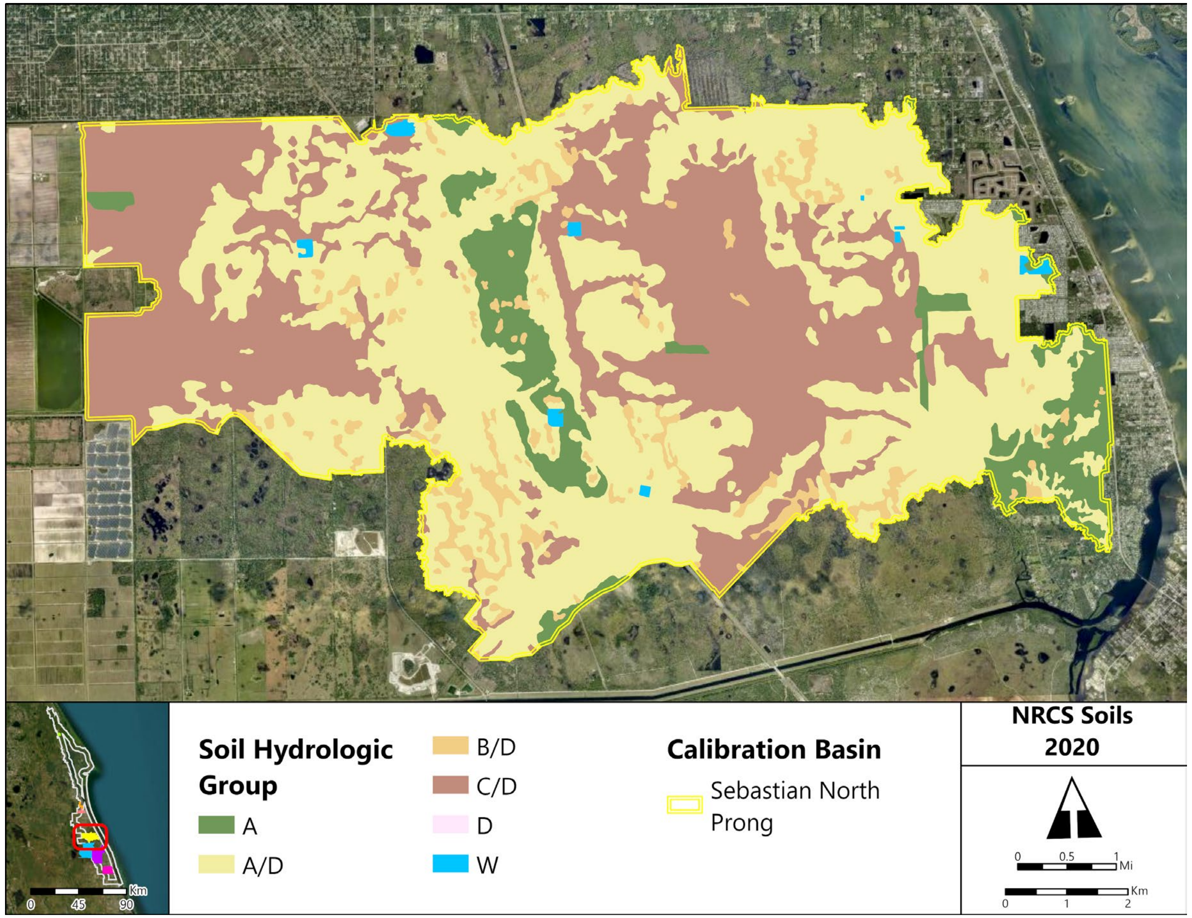

Land Use Consolidation Description
Commercial
Residential
Industrial
Institutional
Mining
Open
Agriculture
Pasture, Rangeland
Recreational
Ruderal
Upland
Wetland
Transportation
Water
Calibration Basin
Sebastian South Prong
Land Use: 2010
0 0.75 1.5 Mi
0 1.75 3.5 Km
0 25 50 Km


Land Use Consolidation Description
Commercial
Residential
Industrial
Institutional
Mining
Open
Agriculture
Pasture, Rangeland
Recreational
Ruderal
Upland
Wetland
Transportation
Water
Calibration Basin
Sebastian South Prong
Land Use: 2020
0 0.75 1.5 Mi
0 1.75 3.5 Km
0 25 50 Km

CALIBRATION BASINS: SOILS

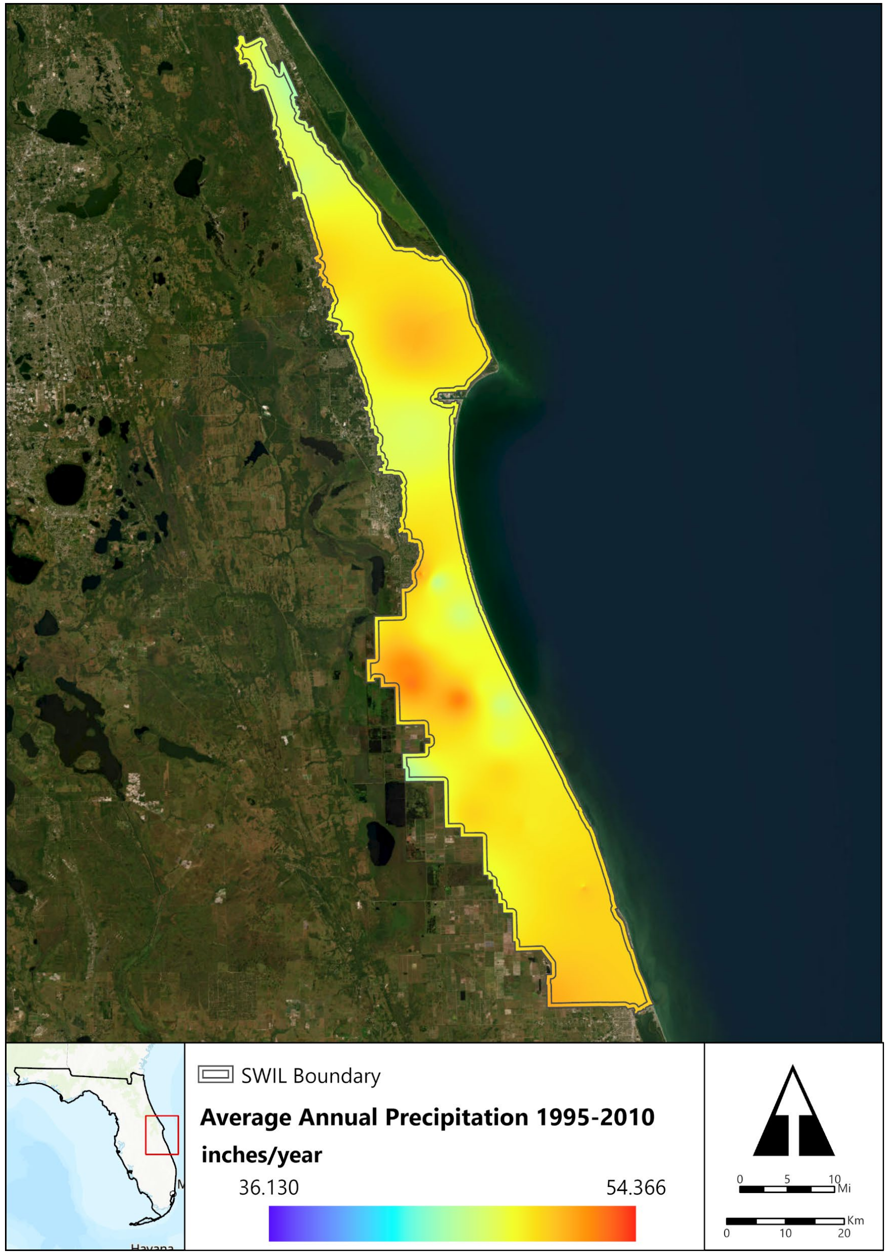
Soil Hydrologic Group	Crane Creek		SNP		SSP		Fellsmere Canal	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
A	8.8	23.5	3.1	8.0	4.3	4.2	1.9	1.9
A/D	50.0	66.6	76.0	50.5	37.0	45.9	33.0	37.5
B	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B/D	40.0	4.5	15.0	4.9	7.0	31.1	3.0	36.5
C/D	0.4	4.3	6.0	36.2	51.0	17.9	62.0	24.0
D	0.1	0.0	0.2	0.0	0.3	0.0	0.1	0.0

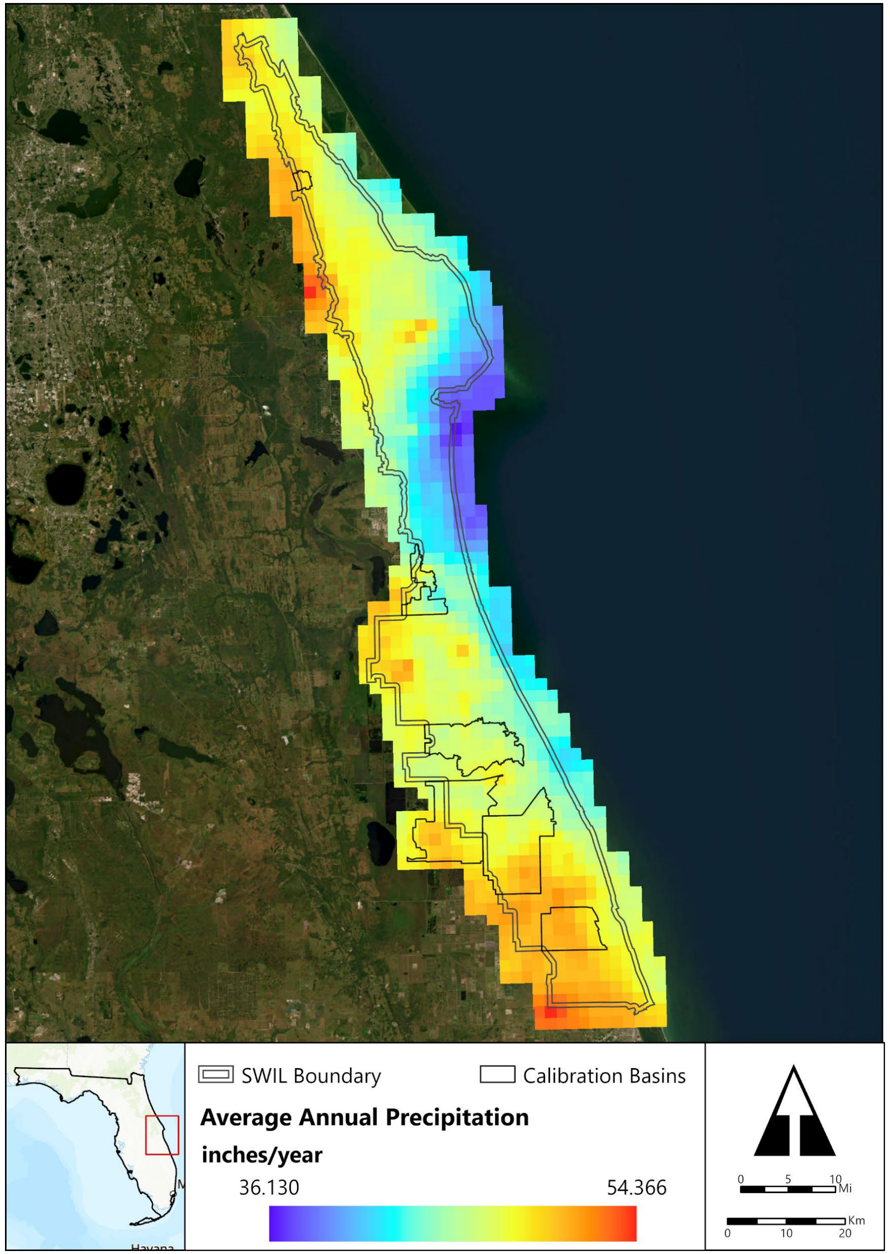

Soil Hydrologic Group
A
A/D
B/D
C/D
D
W
Calibration Basin
Sebastian North Prong
NRCS Soils 2010
0 0.5 1 Mi
0 1 2 Km
0 45 90 Km


Soil Hydrologic Group
A
A/D
B/D
C/D
D
W
Calibration Basin
Sebastian North Prong
NRCS Soils 2020
0 0.5 1 Mi
0 1 2 Km
0 45 90 Km

CALIBRATION BASINS: PRECIPITATION

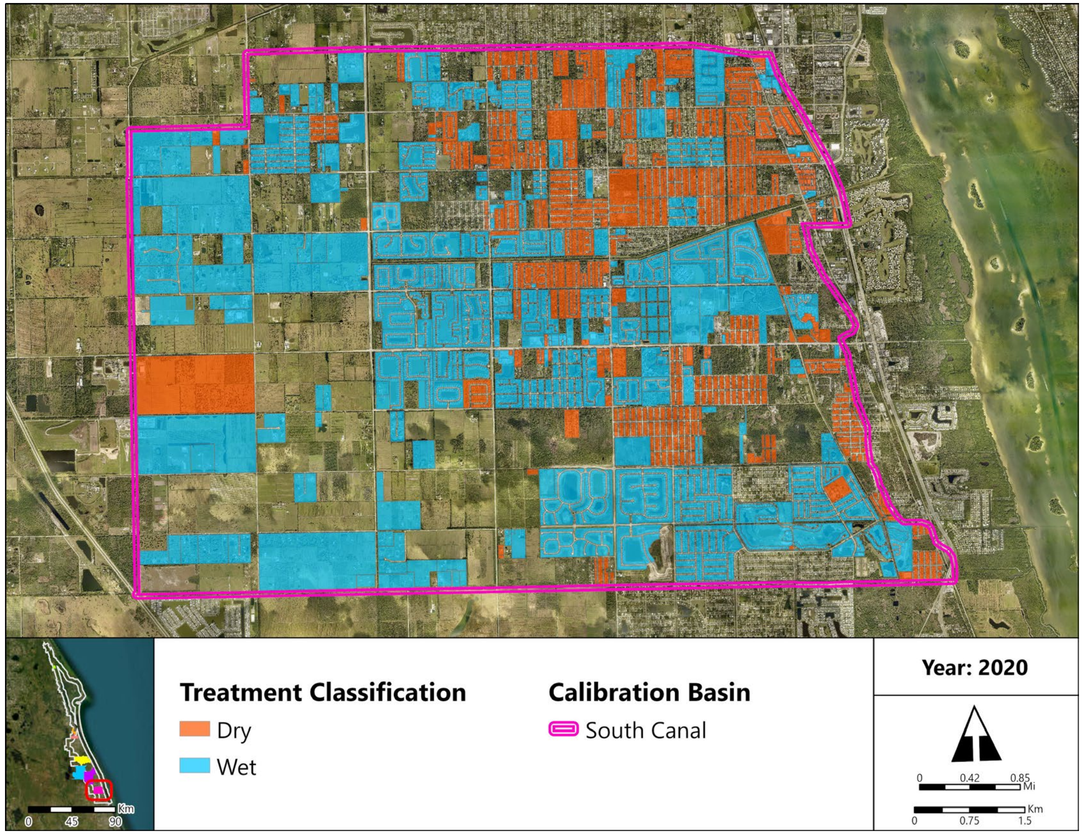
Month	SWIL 4.0 (1995-2010)	SWIL 5.0 (2010-2020)
January	2.26	2.68
February	2.13	1.72
March	3.40	1.82
April	2.16	2.40
May	3.09	4.50
June	7.05	6.39
July	6.35	5.82
August	7.09	5.85
September	7.65	6.79
October	4.86	4.69
November	2.32	2.60
December	2.48	1.97
Annual Mean	50.38	46.46


SWIL Boundary
Average Annual Precipitation 1995-2010
inches/year
36.130
54.366


SWIL Boundary
Calibration Basins
Average Annual Precipitation
inches/year
36.130
54.366

CALIBRATION BASINS: TREATMENTS

Basin	Dry (%)		Wet (%)		Total (%)	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
Crane Creek	10.30	24.30	4.60	21.60	14.90	45.90
SNP	2.70	0.10	2.20	21.90	4.80	22.00
SSP	1.40	3.90	2.50	12.60	3.90	16.50
Fellsmere Canal	3.50	2.90	0.20	13.10	3.70	16.00



HYDROLOGICAL CALIBRATION PROCESS

APPLIED ECOLOGY INC

OPTIMIZATION WORKFLOW FOR HYDROLOGY

ET

ET is the first model input to be optimized using land use/land cover and ET against the USGS measured total stream discharge

DRO

Direct Runoff (DRO) is the second model input to be optimized using ROC, Treatments, and Precipitation against the USGS DRO discharge (segregated using Web-based Hydrograph Analysis Tool or WHAT)

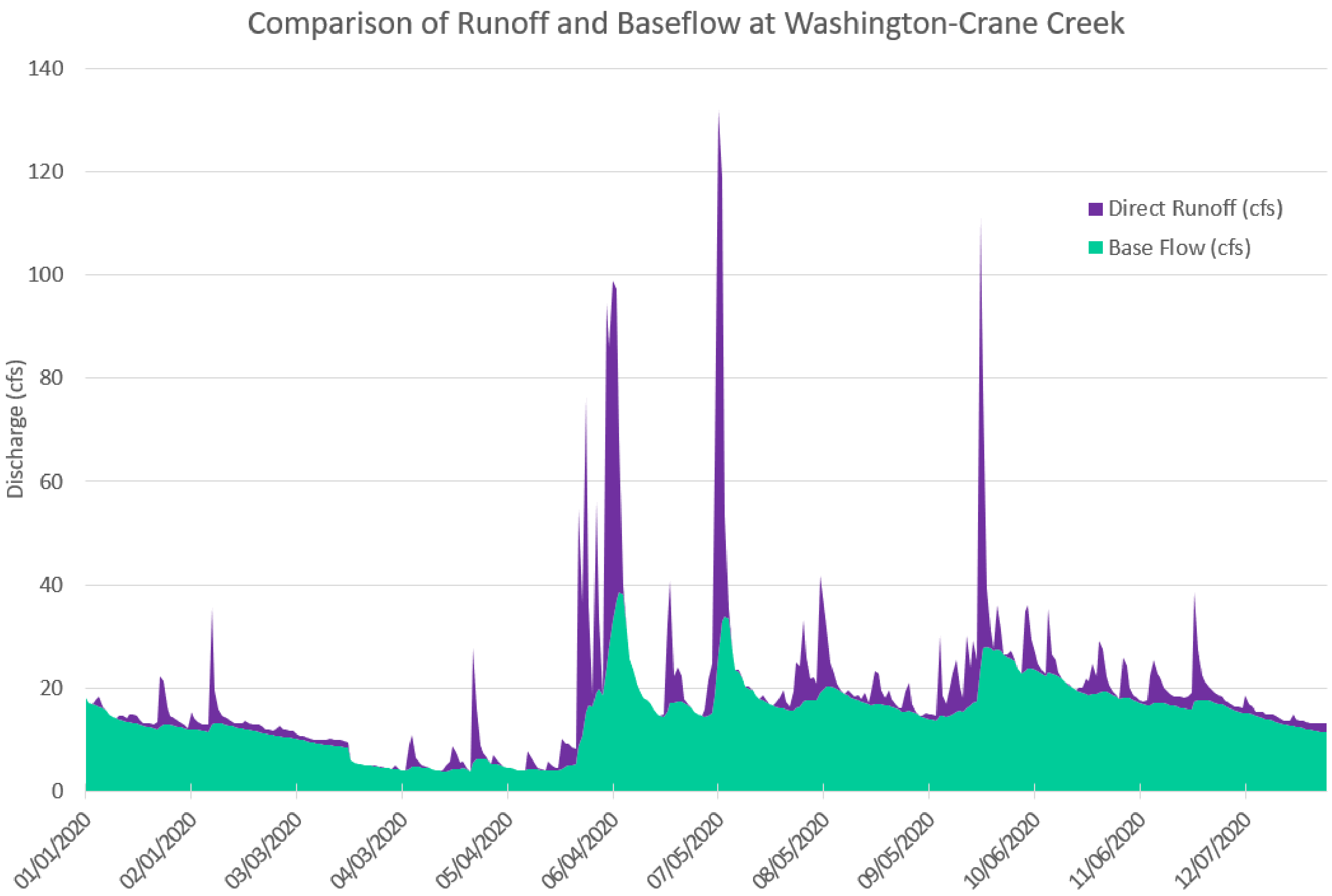
Subsurface

Subsurface flow is the last model input to be optimized using ET, DRO, and the estimated starting groundwater volume and subsurface discharge WHAT estimated USGS subsurface discharge

DIRECT RUNOFF VS. SUBSURFACE FLOW

- To be able to compare hydrological conditions that correspond to mostly subsurface flow conditions versus direct runoff conditions, the measured streamflow data has to be segregated
- Web-based Hydrograph Analysis Tool (WHAT) system, developed at Purdue University (Lim and Engel, 2004) to determine subsurface flow from direct runoff
- Similar method used originally by Harper and baker (2016)
- Typical thresholds for subsurface flow: vary between 75-85%
  - Volume of subsurface flow threshold must be >75-85% or more of total streamflow to be considered a baseflow event
  - Any day with subsurface flow contributing <25% is considered Direct Runoff
  - Between 25% and 75% is considered a mixed sample
  - Water quality data sample dates that correspond to subsurface flow event dates were used in EMC selection

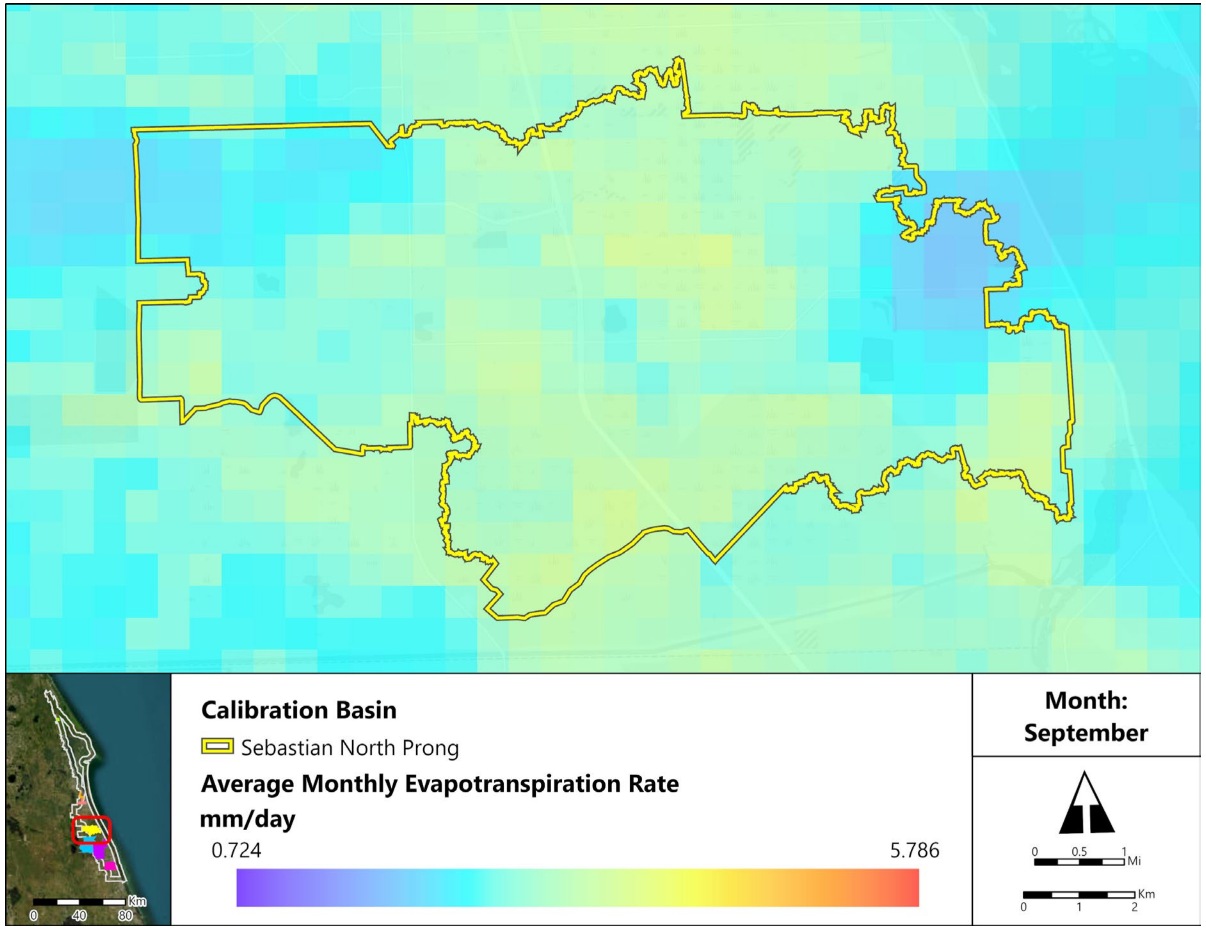
Harper, H.H. and Baker, D.M. 2016. Refining the Indian River Lagoon TMDL, Technical Memorandum Report: Assessment and Evaluation of Model Input Parameters. Final Report submitted to Brevard County Natural Resources.



SUBSURFACE FLOW AND RUNOFF COMPARISON AT CRANE CREEK IN 2020

OPTIMIZATION PROCESS – ET

- Follows prior method (Harper and Baker, 2016)
- Sum of 3 ET Sources
  - ET Undeveloped Pervious: MODIS ET
  - ET Developed Pervious: Bahiagrass ET
  - ET Impervious: Abstracted Rainfall



POST-CALIBRATION RESULTS - ET

Metric	Low Bound	Goal	High Bound
PBIAS	-25%	0.0%	+25%
NSE	0.5	1	1

ET Factor	Undeveloped Pervious ET	Developed Pervious ET	Impervious ET
SWIL 5.0 (u) – uncalibrated	1.02	0.7	0.6
SWIL 5.0 (c) calibrated	0.97	0.89	0.11

	Monthly Volume		Annual Volume	
	SWIL 5.0u	SWIL 5.0c	SWIL 5.0u	SWIL 5.0c
Average PBIAS	67%	29%	28%	-2%
Average Absolute PBIAS	67%	35%	28%	9%

OPTIMIZATION PROCESS – DRO

- Land Use Group Specific Weighting
  - SWIL 4.0: Wetlands only
- SWIL 5.0 (4 land use groups)
  1. Wetland
  2. Upland
  3. Developed
  4. Agriculture

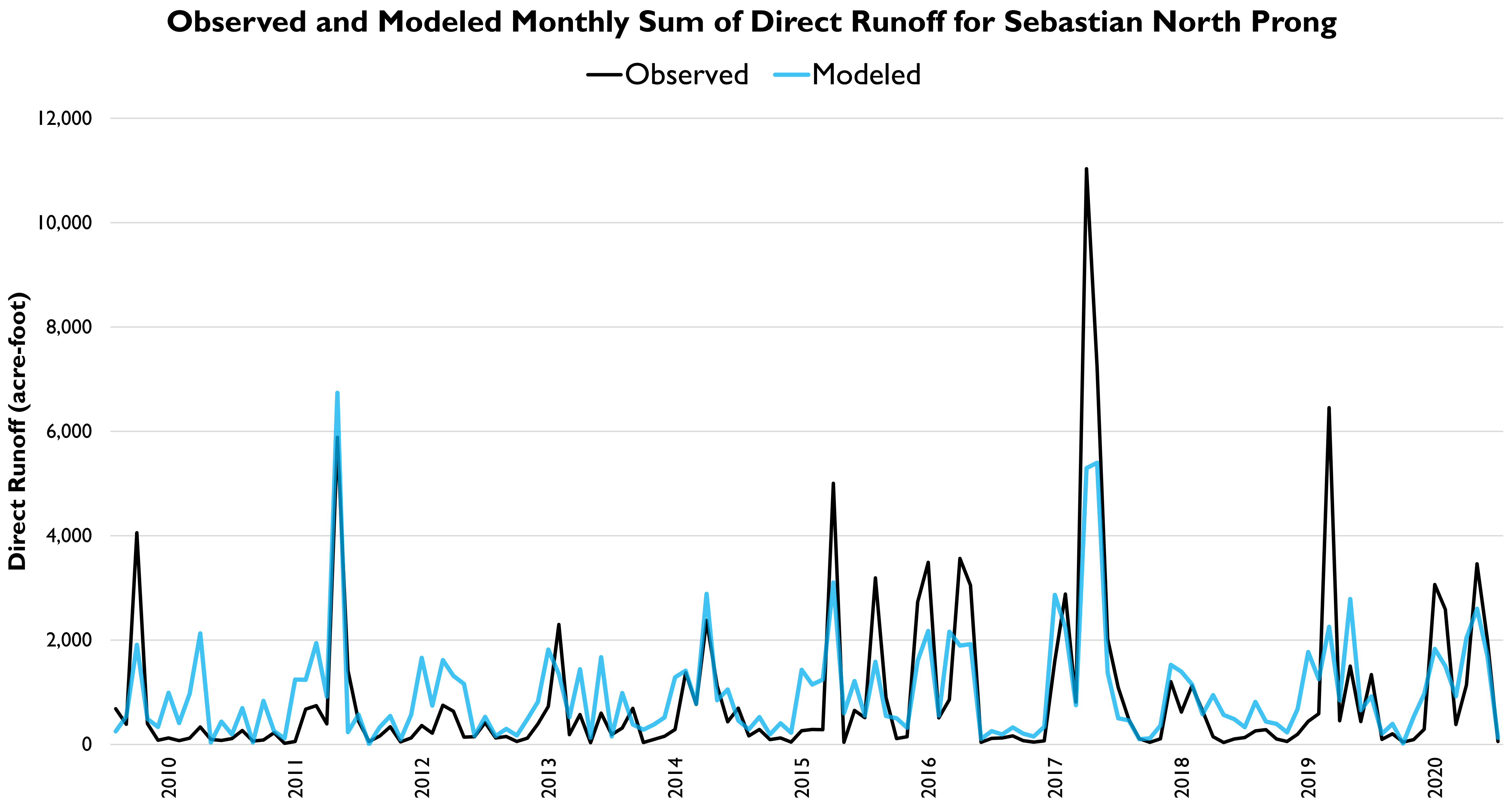
Wetland	Upland	Developed	Agriculture
Hydric Hammock	Dry Prairie	Commercial	Other Agriculture
Wet Flatwoods	Mesic Flatwoods	High Density Residential	Citrus
Wet Prairies	Mining	Industrial	Improved Pasture
Wetland	Open	Institutional	Row Crops
	Ruderal	Low Density Residential	Rangeland
	Scrub	Medium Density Residential	Field Crop
	Upland Flatwoods	Recreational 1	
	Upland Mixed Forest	Recreational 2	
	Xeric Hammock	Transportation	
	Spoil Islands		

POST CALIBRATION RESULTS – DRO

Metric	Low Bound	Goal	High Bound
PBIAS	-25%	0.0%	+25%
NSE	0.5	1	1

Wetland	Upland	Developed	Agriculture
0.42	1.25	1.21	1.25

	PBIAS	Avg. Abs. PBIAS	NSE – Month	NSE – Annual
SWIL 5.0u	-2.00%*	18.00%*	0.67	0.41
SWIL 5.0c	-2.62%	4.05%	0.69	0.56



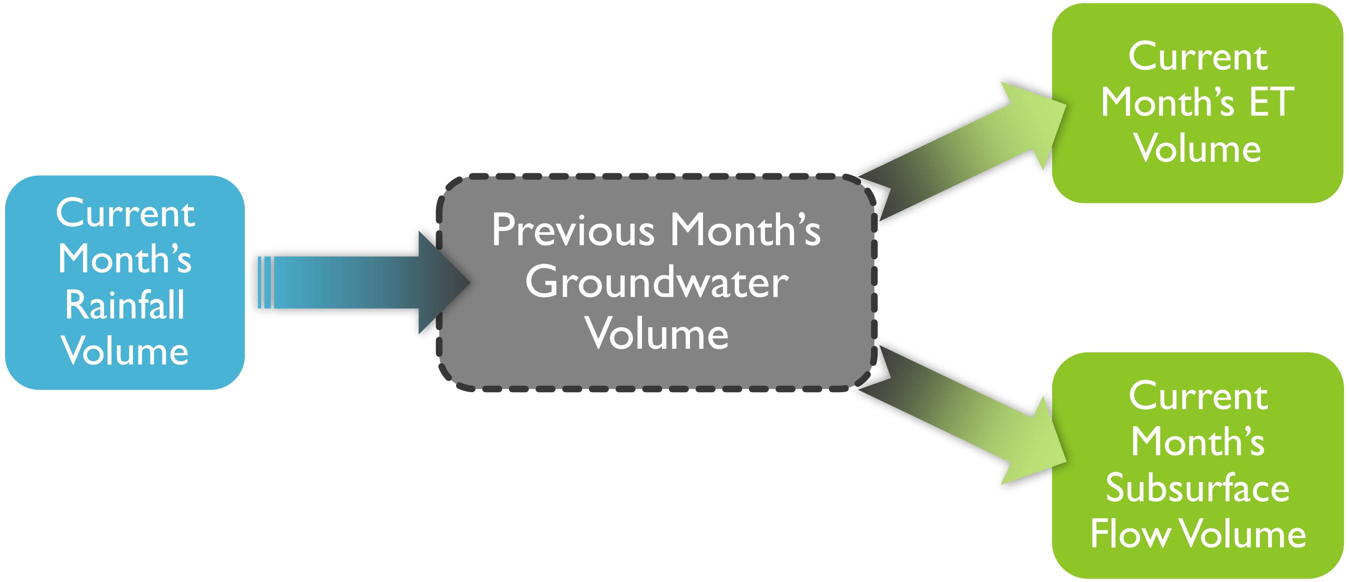
Observed and Modeled Monthly Sum of Direct Runoff for Sebastian North Prong
Observed
Modeled
Direct Runoff (acre-foot)
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

Metric	Low Bound	Goal	High Bound
PBIAS	-25%	0.0%	+25%
NSE	0.5	1	1

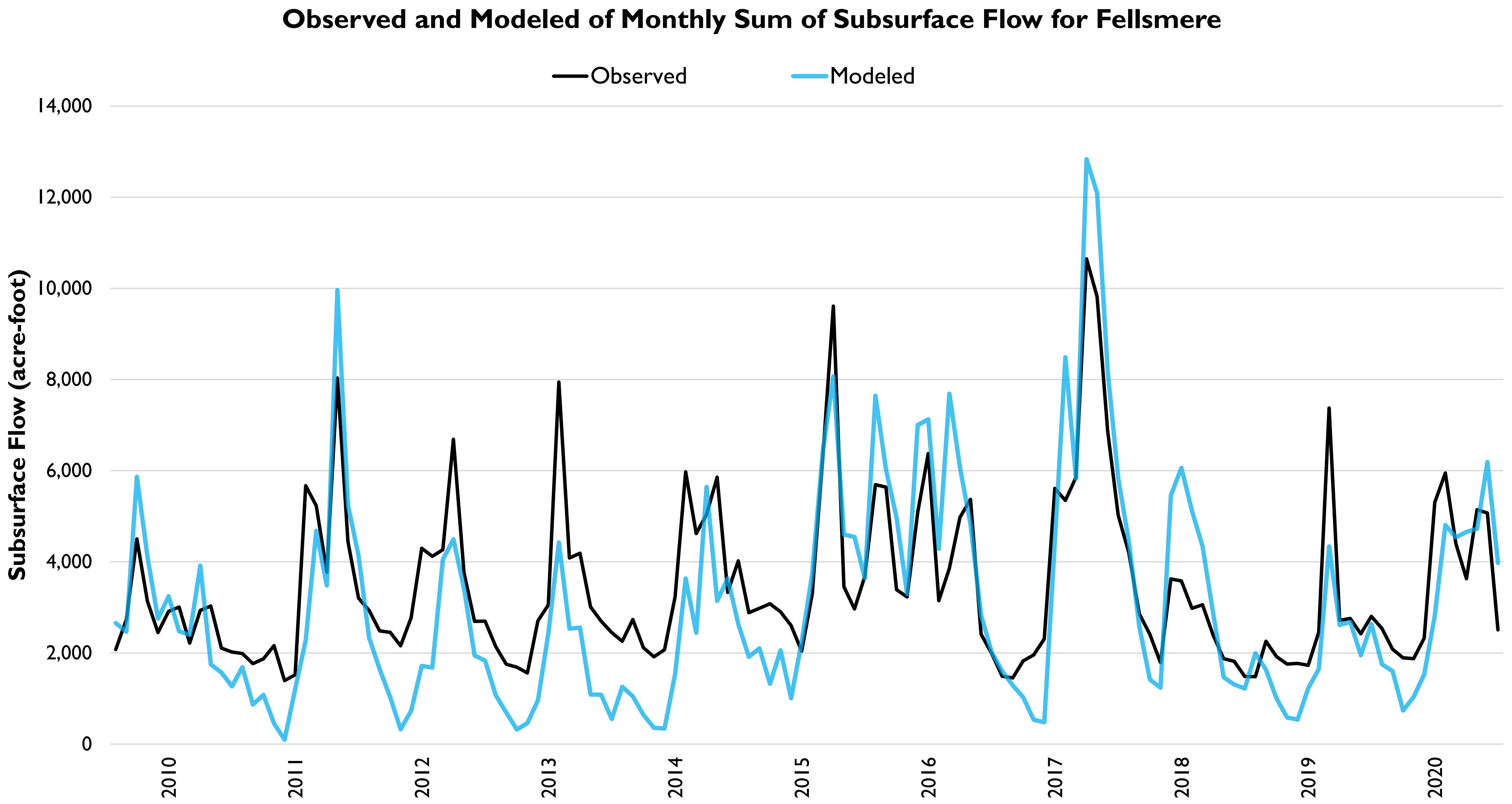
OPTIMIZATION PROCESS – SUBSURFACE FLOW

Subsurface Flow Lag Factor

- Varies between 0.0 to 1.0
- 0.0 represents no subsurface flow
- 1.0 represents all previous month's groundwater and current month's rainfall becoming subsurface flow



	Lag Factor	PBIAS	Average Abs. PBIAS	Monthly Volume NSE
SWIL 5.0u	**32.32%**	32.60%	34.29%	0.33
SWIL 5.0c	**42.75%**	-11.22%	11.22%	0.55

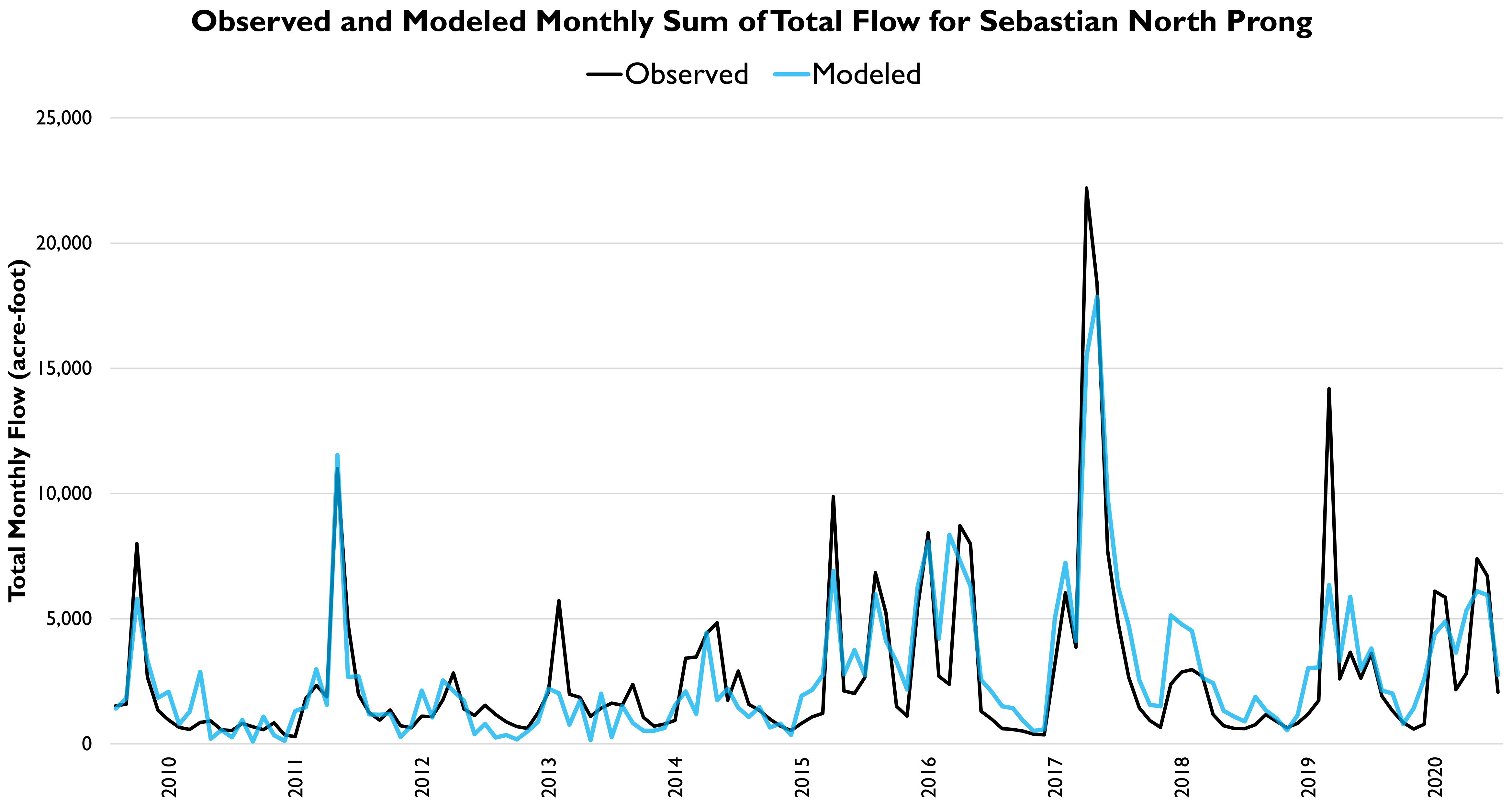


Observed and Modeled of Monthly Sum of Subsurface Flow for Fellsmere
Observed
Modeled
Subsurface Flow (acre-foot)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

POST CALIBRATION RESULTS – TOTAL FLOW

	PBIAS	Average Abs. PBIAS	Monthly Volume NSE	Annual Volume NSE
SWIL 5.0u	-2.00%	18.00%	0.67	0.41
SWIL 5.0c	7.40%	8.31%	0.72	0.41

Metric	Low Bound	Goal	High Bound
PBIAS	-25%	0.0%	+25%
NSE	0.5	1	1


Observed and Modeled Monthly Sum of Total Flow for Sebastian North Prong
Observed
Modeled
Total Monthly Flow (acre-foot)
25,000
20,000
15,000
10,000
5,000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

WATER QUALITY CALIBRATION PROCESS

OPTIMIZATION WORKFLOW FOR WATER QUALITY

SJRWMD WQM

Acquire SJRWMD monthly surface water sampling data

USGS Hydrology

Acquire the corresponding USGS gauge monthly total discharge data

Mass of TN & TP

Estimate the **MASS LOAD** of TN and TP loading with the SJRWMD and USGS monthly data

OPTIMIZATION WORKFLOW FOR WATER QUALITY

Segregate DRO and Subsurface

Using the WHAT DRO and Subsurface flow estimations, identify SJRWMD sampling events that correspond with each state

Calibrate Subsurface

Calibrate the subsurface discharge TN and TP loadings

In Progress

Calibrate DRO/Total

Calibrate DRO TN and TP loadings by assuming the difference between Total and Subsurface loadings is equal to DRO loading.

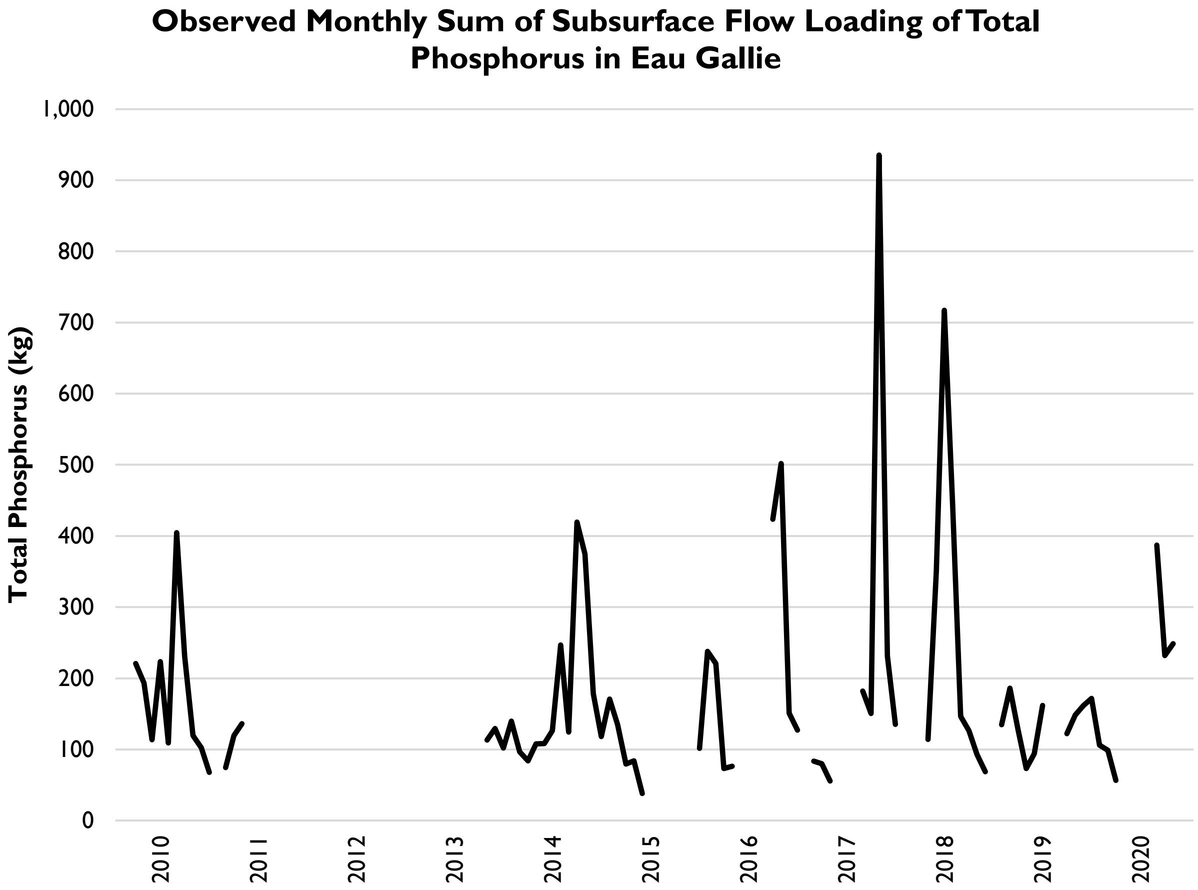
In Progress

WATER QUALITY CALIBRATION – EMC CHANGES

- Subsurface flow EMCs
  - SWIL 4.0: uniform EMCs
    - 0.886 mg/L TN and 0.112 mg/L TP
  - SWIL 5.0: 2 categories of EMCs (based on available well data)
    - Developed - 1.085 mg/L TN and 0.139 mg/L TP
    - Undeveloped - 0.349 mg/L TN and 0.132 mg/L TP
- DRO EMCs
  - Minimal changes for selected land uses
    - Agriculture
    - Transportation

WATER QUALITY CALIBRATION: CHALLENGES AND OPPORTUNITIES

- Surface Water Sampling Data in not continuous, unlike streamflow
  - Includes Gaps
  - 1-2X monthly data applied to monthly volume, not flow representative
- Subsurface Flow Conditions – represented by 59 to 84 Samples (basin dependent)
- Data QA improves dataset:
  - Removing certain flagged data
  - Examine any outliers/extreme events and removing these from calibration effort



Challenges to Calibration

- Fitting the simulated data to the measured data works generally well in terms of matching hydrological characteristics.

- While it is possible to optimize the model to measured water quality characteristics, fitting the optimized outcome to the model event mean concentrations (EMCs) does not match realistic expectations.

- Additional time to calibrate the model to the conditions of water quality is needed.

- Changes to the EMC inputs of the model may also be needed.

Event Mean Concentrations

Current EMCs			
Optimization Category	Consolidated Land Use	TN (mg/L)	TP (mg/L)
Developed	Low Density Residential	1.51	0.178
Developed	Medium Density Residential	1.873	0.301
Developed	High Density Residential	2.102	0.497
Developed	Commercial	1.635	0.214
Developed	Industrial	1.19	0.213
Developed	Transportation	1.4	0.17
Developed	Institutional	1.51	0.178
Undeveloped – Upland	Mining	1.18	0.15
Undeveloped – Upland	Open	1.15	0.055
Developed	Recreational 1	1.873	0.301
Undeveloped – Upland	Ruderal	1.32	0.347
Undeveloped – Upland	Scrub	1.16	0.096
Undeveloped – Upland	Spoil Islands	0.68	2.29
Developed	Recreational 2	1.51	0.178
Agricultural	Rangeland	1.25	0.075
Agricultural	Field Crops	2.917	0.792
Agricultural	Other Agriculture	2.45	0.344
Agricultural	Row Crops	3.36	0.44
Agricultural	Pasture	3.46	0.28
Agricultural	Citrus	2.05	0.17
Undeveloped – Upland	Mesic Flatwoods	1	0.034
Undeveloped – Upland	Dry Prairie	1.95	0.107
Undeveloped – Upland	Upland Flatwoods	1	0.034
Undeveloped – Upland	Upland Mixed Forest	0.68	2.29
Undeveloped – Upland	Xeric Hammock	1.32	2.82
Undeveloped – Wetland	Water	0	0
Undeveloped – Wetland	Hydric Hammock	1.07	0.026
Undeveloped – Wetland	Wet Flatwoods	1.18	0.015
Undeveloped – Wetland	Wet Prairies	0.78	0.009
Undeveloped – Wetland	Wetland	1.5	0.1

Literature Reviewed EMCs				
Optimization Category	HSPF Category	Consolidated Land Use	TN (mg/L)	TP (mg/L)
Developed	Low Density Residential	Low Density Residential	1.810	0.260
Developed	Medium Density Residential	Medium Density Residential	2.030	0.327
Developed	High Density Residential	High Density Residential	2.104	0.480
Developed	Industrial & Commercial	Commercial	1.8925	0.2625
Developed	Industrial & Commercial	Industrial	1.200	0.260
Developed	Industrial & Commercial	Transportation	1.4	0.17
Developed	Industrial & Commercial	Institutional	1.785	0.200
Developed	Extractive	Mining	1.18	0.15
Developed	Open & Barren Land	Recreational 1	1.873	0.301
Developed	General Agriculture - Golf Course	Recreational 2	1.700	0.299
Agricultural	Rangeland	Rangeland	1.25	0.075
Agricultural	General Agriculture	Field Crops	2.917	0.792
Agricultural	General Agriculture	Other Agriculture	2.45	0.344
Agricultural	General Agriculture	Row Crops	3.36	0.44
Agricultural	Pasture	Pasture	3.46	0.28
Agricultural	Agricultural Tree Crops	Citrus	2.05	0.17
Undeveloped	Forest	Forest	1.120	0.056
Undeveloped	Water	Water	0	0
Undeveloped	Wetlands	Wetlands	1.469	0.127

Next Steps

- Finish Calibration and Optimization.
- Allocation run of the model.
- Load estimation tool (LET) development.
- Natural background run of the model.

THANK YOU

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