Modeling Restoration Alternatives for Water Conveyances on Jekyll Island
Final Report

Jekyll Island, Georgia

September 2017

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Prepared for

The Jekyll Island Authority

by

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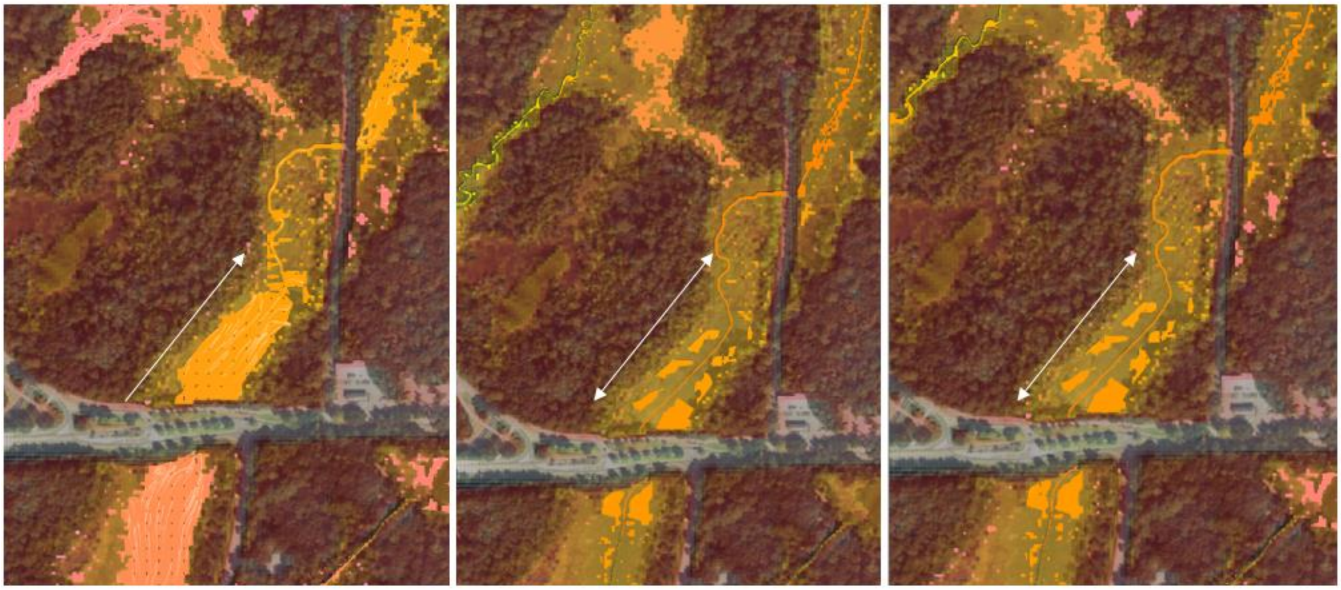

A3b Inflow (13 May 1100) A3b Outflow 8 hours later (13 May 1900) A3b Outflow10 hours later (13 May 2100)

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1.0 INTRODUCTION

Jekyll Island is one barrier island of four that make up the Golden Isles off the southeast coast of Georgia in Glynn County. The island is located five miles east of Brunswick and only 25-miles north of the Florida-Georgia border.

Jekyll Island was named and settled by British colonists in the 18th century, purchased by an elite club and patronized to prominent figures in the 19th century, and then purchased by the State of Georgia for initial use as a state park in the 20th century. Thereafter, the state created the Jekyll Island Authority (JIA) with the task of developing and managing the island. Subsequent construction resulted in hydrologic alteration and fragmentation of the original First Creek tidal system, which is no longer depicted on maps. Figure 1.1 illustrates the island location and study extent.

The Jekyll Island Authority contracted Taylor Engineering (Taylor) to perform hydrodynamic modeling of the First Creek tidal system to analyze hydraulic and limited water quality response to tidal fluctuations in terms of stage, flow, velocity, and inundation duration. JIA is interested in strategic design alternatives that support a restorative response for the water quality and ecosystem at large. Specifically, JIA tasked Taylor with modeling current conditions and up to (3) restoration alternatives under verified tide and current data for an extended period (weeks, a month, or several months) to identify sustainable, cost-effective, and hydraulically efficient restoration options. This report documents the methodologies used for evaluation of the drainage system, results of the evaluation, estimated construction costs for each alternative, and recommendations.

The Jekyll Island community has a population of 1000 residents and brings in more than 900,000 vehicles of tourists a year by the Georgia State Route 520, or Ben Fortson Pkwy, that connects the island to the mainland. Reviewing the connecting infrastructure within the island, Beachview Drive loops through the entire island, making the northern and southern reaches of the island accessible to residents and visitors.

This report is organized as follows. Section 2.0 of this report presents the data used to develop a hydrodynamic model of existing conditions and proposed alternatives. Section 3.0 presents a discussion of water quality improvements with respect to the alternatives. Section 4.0 presents a construction opinion of probable cost for each alternative and Section 5.0 presents a discussion of results and recommendations.

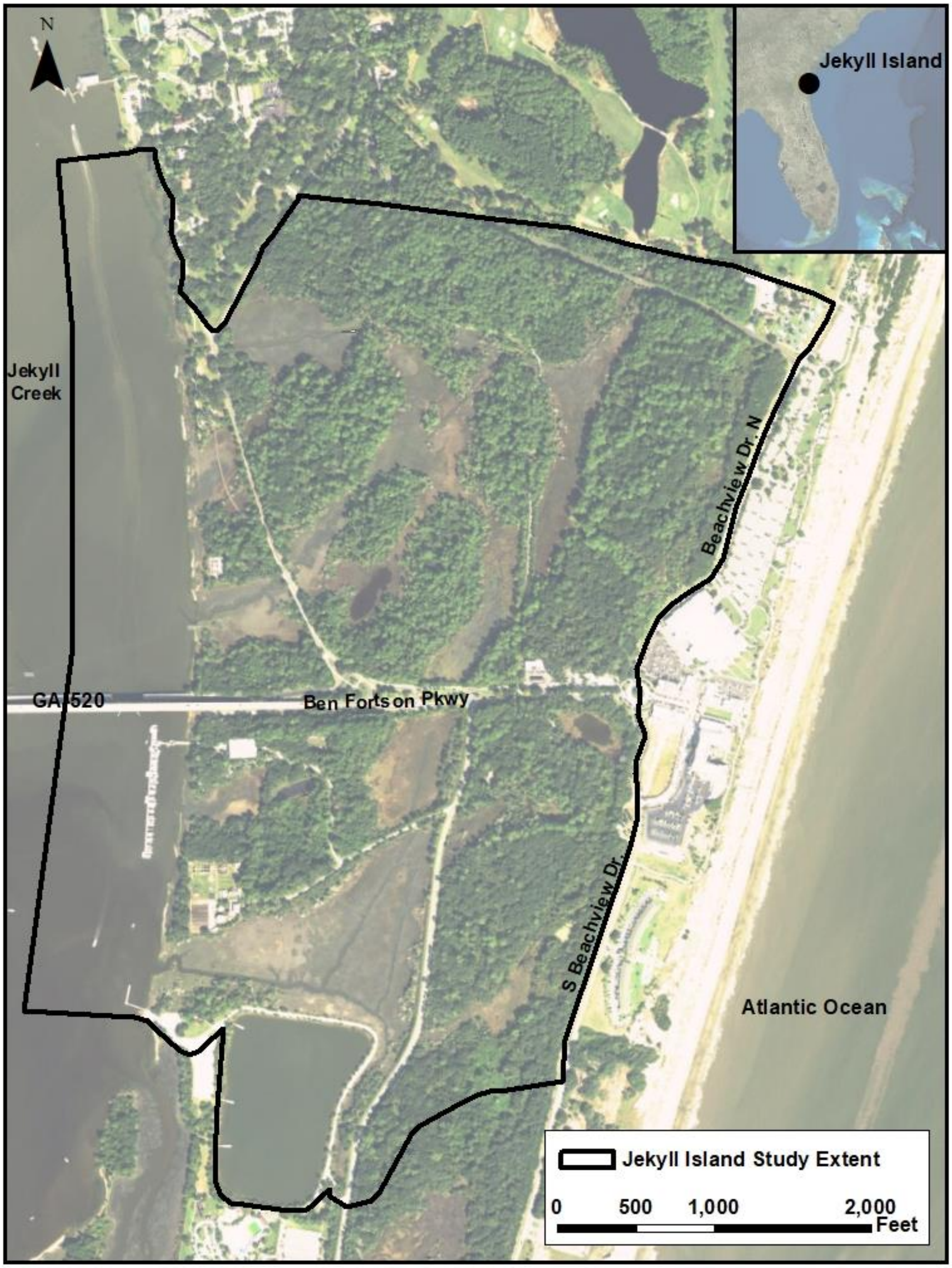


Figure 1.1 Jekyll Island Location Map and Study Extent

2.0 HYDRODYNAMIC MODEL, DEVELOPMENT, AND RESULTS

For this study, the Hydrologic Engineering Center River Analysis System (HEC-RAS) version 5.0.3 software package, supported by the U.S. Army Corps of Engineers (USACE), provides a time-dependent, two-dimensional (2D) model to simulate the flow regime due to input tide and current. The 2D hydrodynamic model provides engineers a means to evaluate riverine, tidal, or storm surge circulation in and around areas such as inlets, rivers, and marshes. The data required for computations are the geometric and flow data. The geometric data are important for the water systems connectivity. If recorded gage data are available, a hydrograph of either discharge or water surface elevation versus time may be applied as the flow input or boundary condition, which propagates from the edge of the 2D domain.

Hydrodynamic models simulate flow by solving the fluid dynamic governing equations for the physical processes at any given geographic location under specific water level and flow boundary conditions, and consider channel shape, depth, and bed roughness.

By establishing a hydrodynamic model based on site-specific flow conditions and geometry characteristics, an engineer can simulate, analyze, and compare the existing conditions and the proposed project conditions for potentially beneficial or negative impacts. Taylor Engineering setup models of the marsh areas of interest for the existing conditions and (3) alternative scenarios that simulate tide events, as discussed in Section 1.0, with HEC-RAS.

The following subsections will discuss the development of flow boundary conditions, site-specific geometric inputs, and results for the HEC-RAS models for existing conditions and (3) alternative scenarios.

2.1 Tidal and Surge Boundary Conditions

Boundary conditions for the HEC-RAS models include the dynamic stage hydrograph for the Jekyll Creek intracostal water way (ICWW); rainfall is not incorporated. Taylor established the stage boundary after comparing and selecting representative tide and current data from nearby tide gages available from NOAA, USGS, and JIA (Figure 2.1). After examining the data, we selected the USGS tide gage at the neighboring St. Simon Island station (#02226180) for verification with the on-site JIA gage due to the proximity, common period, and short time steps. The JIA tide gages are located within and adjacent to the Fortson Pond marsh. Regardless of the lower limit of the JIA gage in the marsh, the USGS and JIA flow data trends coincide, as seen in Figure 2.2.

For the boundary condition, the USGS St. Simon Island gage provides representative estimates of the ICWW tides for the project site. Figure 2.3 illustrates the ICWW tides boundary condition that are applied to the 2D project models. Applying the selected USGS data to the model and comparing the results to the JIA gage data ensure that the input data are reasonable. Taylor selected the time frame for the input stage hydrograph as 4/20/17 to 5/21/17 in order to include tidal fluctuation with both neap and spring tides. We expected that the variation in the range of flow periods would produce different results in the study area, which was the case. The entire timeframe ensures that typical monthly tidal conditions are properly modeled.

In the future, a HEC-RAS user could modify the input boundary condition to represent a select storm event or surge to study the results within the study area. Modifying the boundary condition for this model would be easier than applying a storm event, as the hydrology is not completed for the hydrodynamic model.

Figure 2.1 Available Tide Gages near the Study Location

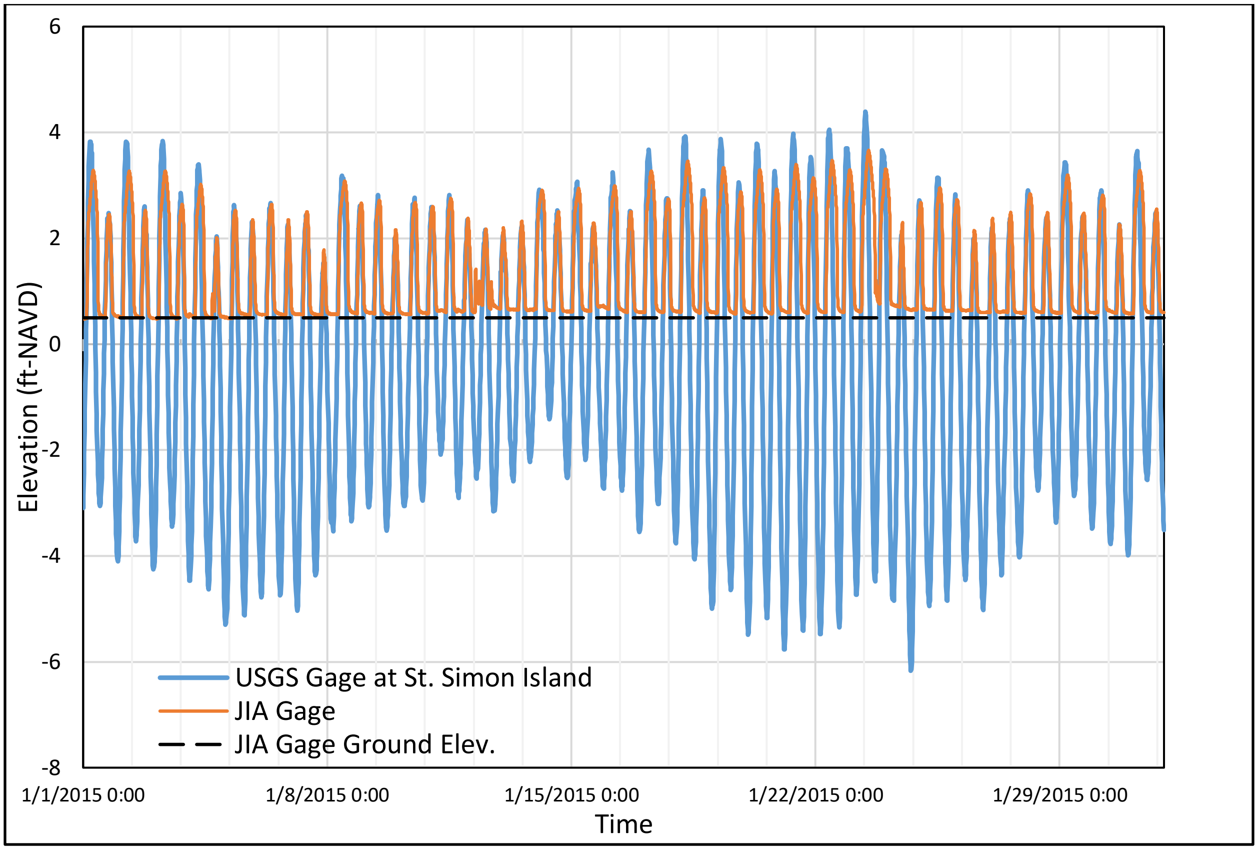


Figure 2.2 Tide Gage Data Comparison

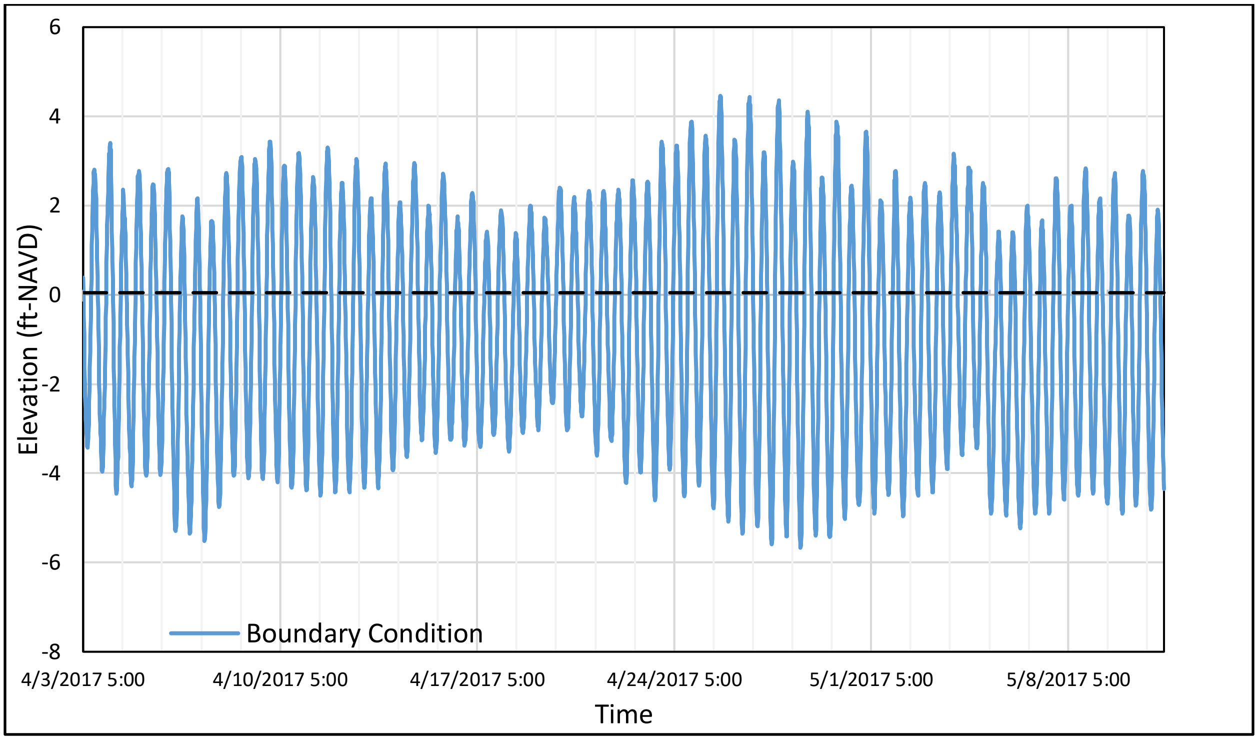


Figure 2.3 ICWW Tides Boundary Conditions for One Month Starting April 3, 2017

2.2 Existing Condition Hydrodynamic Model

The purpose of developing an existing condition (EC) hydraulic model for Jekyll Island is to route the current flow through the existing culverts, channels, and marsh. Taylor used the EC model geometry to establish a baseline for comparing the impact of proposed alternatives. While HEC-RAS is a combined 1D and 2D hydrodynamic model, we have set up the model entirely in 2D, to include the use of 2D area connections at culverts and the small North Marsh Bridge. The 2D model covers the entire project area as presented in Section 2.1.

HEC-RAS represents the ground surface, waterways, and roadways within the project area with a finite volume flexible mesh. Taylor built the HEC-RAS mesh based on an underlying existing condition Digital Elevation Model (DEM) which extends from the ICWW east to Beachview Drive, at an elevation greater than 7.0 ft. and parallel to the Atlantic coast. During the study, Taylor used the best available LiDAR data, which is the FEMA dataset previously used in flood insurance studies, in addition to aerial photography and JIA survey data of all culvert invert elevations to provide a DEM with a detailed culvert network. Figure 2.5 illustrates the existing condition DEM and Figure 2.6 illustrates an underlying aerial image and the extent of the 2-D HEC-RAS mesh.

Specifically, Taylor incorporates (11) culverts and the small North Marsh Bridge in the model based on survey data provided by JIA and site inspection. We coded all culverts into the model as 2D area connections, which connect the culvert openings to cells in the 2D mesh. HEC-RAS computes flow through each culvert from the upstream mesh element to the downstream element or vice versa. Figure 2.7 illustrates the culverts' locations and inverts incorporated into the DEM.

Appendix A illustrates HEC-RAS computed floodplains at the maximum (which is not at a single time), a low tide period, and a spring tide period for modeled events. The floodplains at additional time periods are included to provide a snapshot of the flow interaction in the system. In addition, we extracted HEC-RAS computed water level hydrographs at three-point locations within the model domain, in Figure 2.9. Appendix B illustrates the water level hydrographs for the modeled events. Appendix C illustrates plots of all flow duration curves. Table 2.1 displays the minimum and maximum computed water levels at the identified sample points in Fortson Pond in Figure 2.9. It should be noted that the maximum water levels are included as standard results data, but alone is not the best measure for improvement as the minimum water surface is expected to decrease more with flushing.

Figure 2.5 Existing Condition Digital Elevation Model

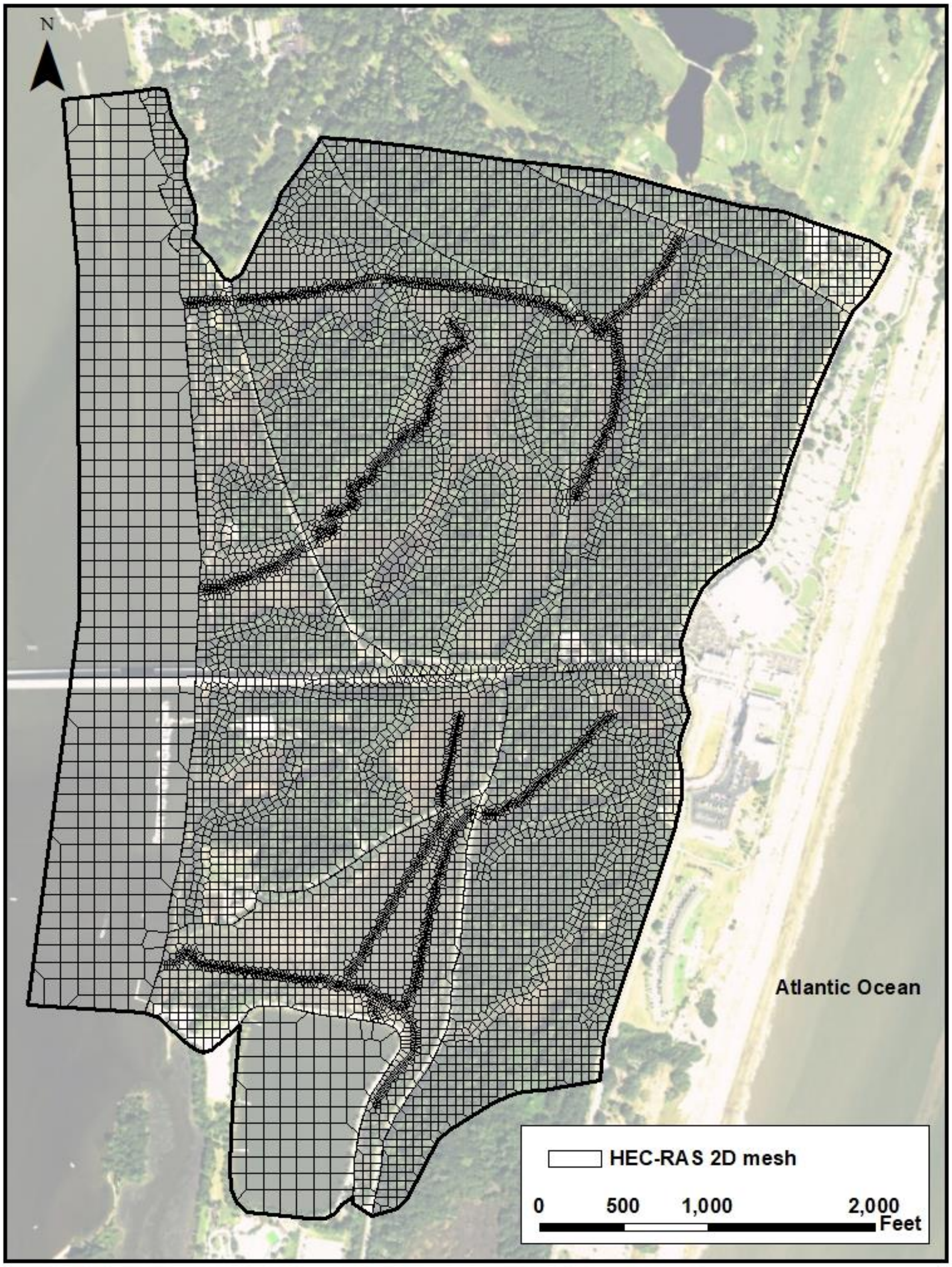


Figure 2.6 HEC-RAS 2D Mesh Extent

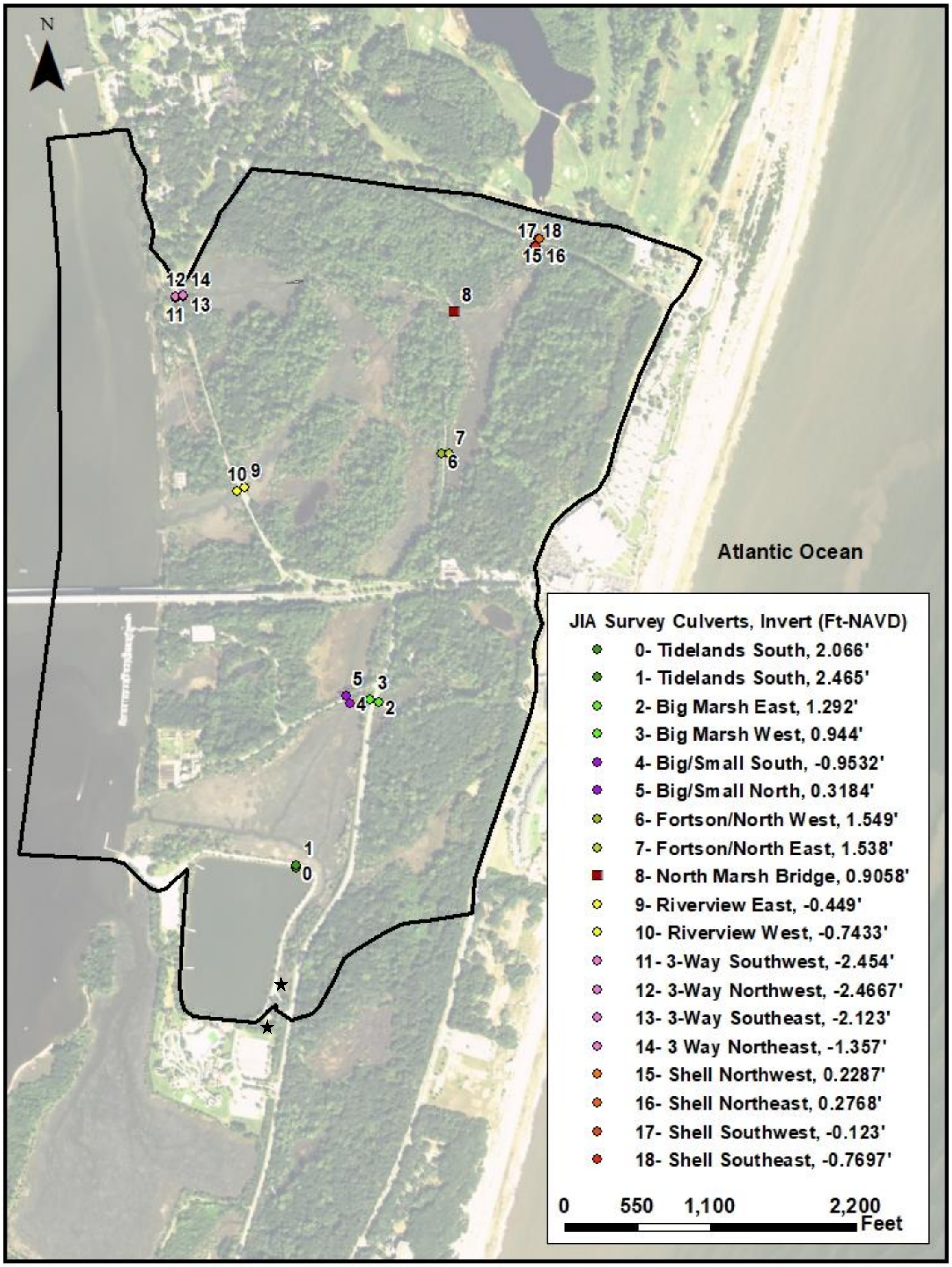


Figure 2.7 Extent of Modeled Ditches and Culverts

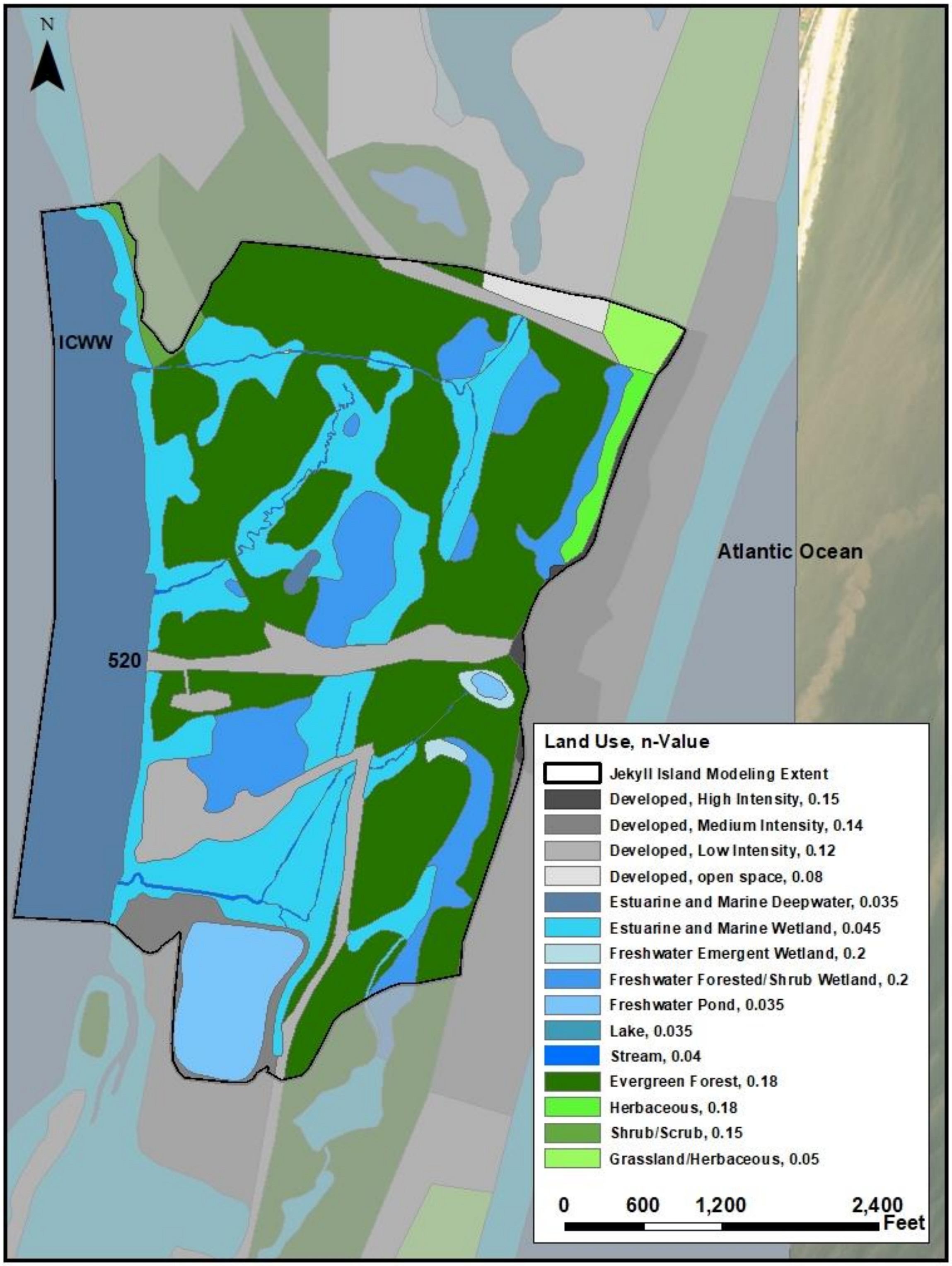


Figure 2.8 Land Use and Manning's n-values

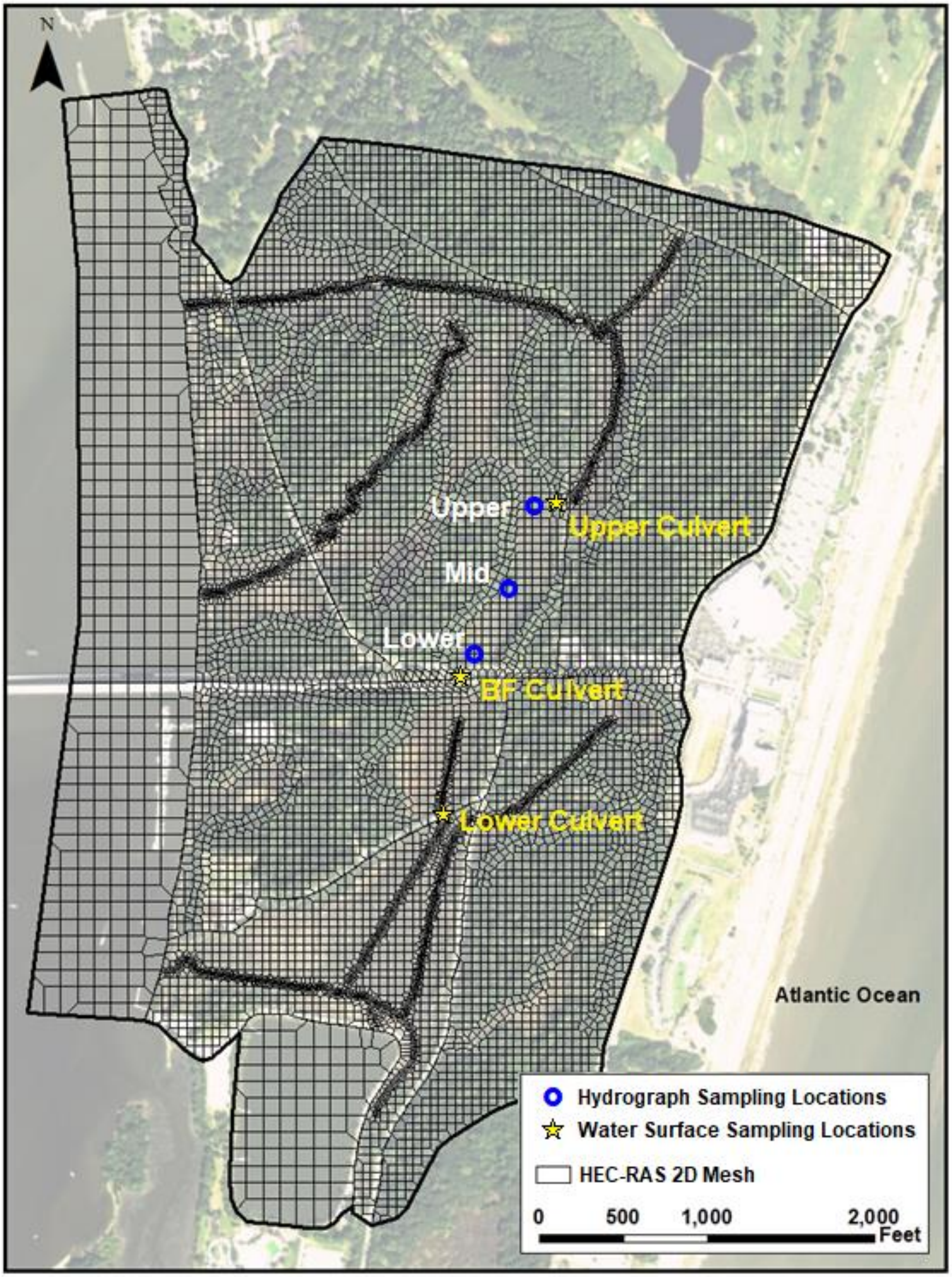


Figure 2.9 Hydrograph and Water Surface Elevation Sampling Locations around Fortson Pond

Table 2.1 Existing Conditions Minimum and Maximum Computed Water Level by Sample Point in Fortson Pond (Ft-NAVD)

EC Sample Point	Min	Max
Upper	1.88	3.55
Mid	1.97	3.52
Lower	2.35	3.52

2.3 Summary of Alternatives

The objective of each alternatives is to increase the amount of tidal exchange between the wetlands in the interconnected systems. The control points for the flow paths are the existing culverts and channels within the system that impede tidal flow. Hydrodynamic modeling allows us to model alternatives to the existing conditions and compare changes in flow patterns. We believe the best ways to compare alternatives is to compare the changes in flow through culverts and water surface stage in the marsh using duration curves.

Duration or percent exceedance curves illustrate the percent of time a certain flow or stage is equaled or exceeded. The curves from the modeling results will contain both positive and negative flow that coincide with the flow and ebb. Results will be oriented so that positive flow is inflow to Fortson Pond and negative flow is outflow of the pond. Using these duration curves, we can compare if an alternative is effective at increasing the flow rate into or out of a tidal pond system and how effective it is in comparison to existing conditions and other alternatives. Table 2.2 presents a summary of each alternative that is discussed in the following sections.

Table 2.2 Summary of Alternatives

<table>
<tr><th>Name</th><th>Summary</th></tr>
<tr><td colspan="2">Alternative-1 includes clearing rubble under the wooden North Marsh Bridge and optimizing the Upper Culvert as detailed.</td></tr>
<tr><td>Alternative-1 (A1)</td><td>Clear rubble and optimize Upper Culvert with
(1) 39 inch-equivalent elliptical culvert</td></tr>
<tr><td>A1 Comparison</td><td>Clear rubble and optimize Upper Culvert with
(2) x 24-inch circular culverts</td></tr>
<tr><td colspan="2">Alternative-2 includes optimizing culvert(s) under the Ben Fortson Parkway as detailed.</td></tr>
<tr><td>Alternative-2 (A2)</td><td>Use (2) x 48-inch circular culverts</td></tr>
<tr><td>A2 Comparison</td><td>Use (1) 4.0 x 6.0 ft. box culvert
*included for comparison with A2; not used in A3.</td></tr>
<tr><td colspan="2">Alternative-3 is a combination of A2 and A1 options as detailed.</td></tr>
<tr><td>Alternative-3 (A3)</td><td>Combination of A2 and A1 (elliptical)</td></tr>
<tr><td>A3 Comparison</td><td>Combination of A2 and A1 Comparison (double circular)</td></tr>
</table>

2.4 Alternative-1 North Marsh Bridge Cleanout and Upper Culvert

Taylor Engineering constructed the Alternative-1 (A1) model geometry to simulate a scenario in which the rubble under the North Marsh Bridge is removed for a smoother stream profile. The objective of this scenario is to increase flow from north of Fortson Pond by optimizing areas of constriction without dredging the marsh. Therefore, Taylor developed the A1 geometry by altering the depth of the bridge 2D area connection to match that of the stream profile, an opportunity observed and measured during a site visit. Additionally, we lowered the small Upper Culvert connecting Fortson Pond to North Marsh to the observed channel bottom and increased the capacity with (1) 39.0 in.-equivalent horizontal-ellipse culvert as Alternative-1 (A1) to optimize flow. We would like to note that several culvert configurations were investigated, such as a large 48-inch option, before selecting the more reasonable A1 optimization. One of the preliminary alternatives, the Alternative-1 Comparison with (2) 24-inch culverts, will be displayed in the results for comparison purposes. Figure 2.10 illustrates the location of the A1 design features in addition to flow path arrows. The A1 models use the same 2D mesh, DEM, and tidal boundary conditions as the existing conditions model. This section will summarize the difference in the 2D area connection model geometry for the stream profile at the North Marsh Bridge and at the Upper Culvert.

Figure 2.11 illustrates a comparison of the 2D area connection for the channel at the North Marsh Bridge. Under A1 conditions, inflow and outflow to the North Marsh and Fortson Pond increases ± 1.5 cfs for more than 70% of the simulation period. This occurs because the aligned channel conveys more flow in both directions with the tide. Once the tide has peaked, the water flows out of the marsh area. A1 with an ellipse culvert area of 8.56 sq. ft. conveys more flow to the north than the A1 comparison with a total culvert flow area of 6.28 sq. ft. The A1 ellipse culvert allows for an increased inflow rate and extends the outflow percent exceedance (Figure 2.12).

Appendix A illustrates HEC-RAS computed floodplains at the maximum (which is not at a single time), a low tide period, and a spring tide period for modeled events. We have included the floodplains at additional time periods to provide a snapshot of the flow interaction in the system. In addition, we extracted HEC-RAS computed water level hydrographs at three-point locations within the model domain, in Figure 2.9. The hydrographs display the most curve variance during higher tide events, May 10-18 of the simulation period. Appendix B illustrates the water level hydrographs for the modeled events. Appendix C illustrates plots of all flow duration curves. Figure 2.12 displays the percent exceedance and Table 2.3 compares the maximum computed water levels at each identified point in Figure 2.9.

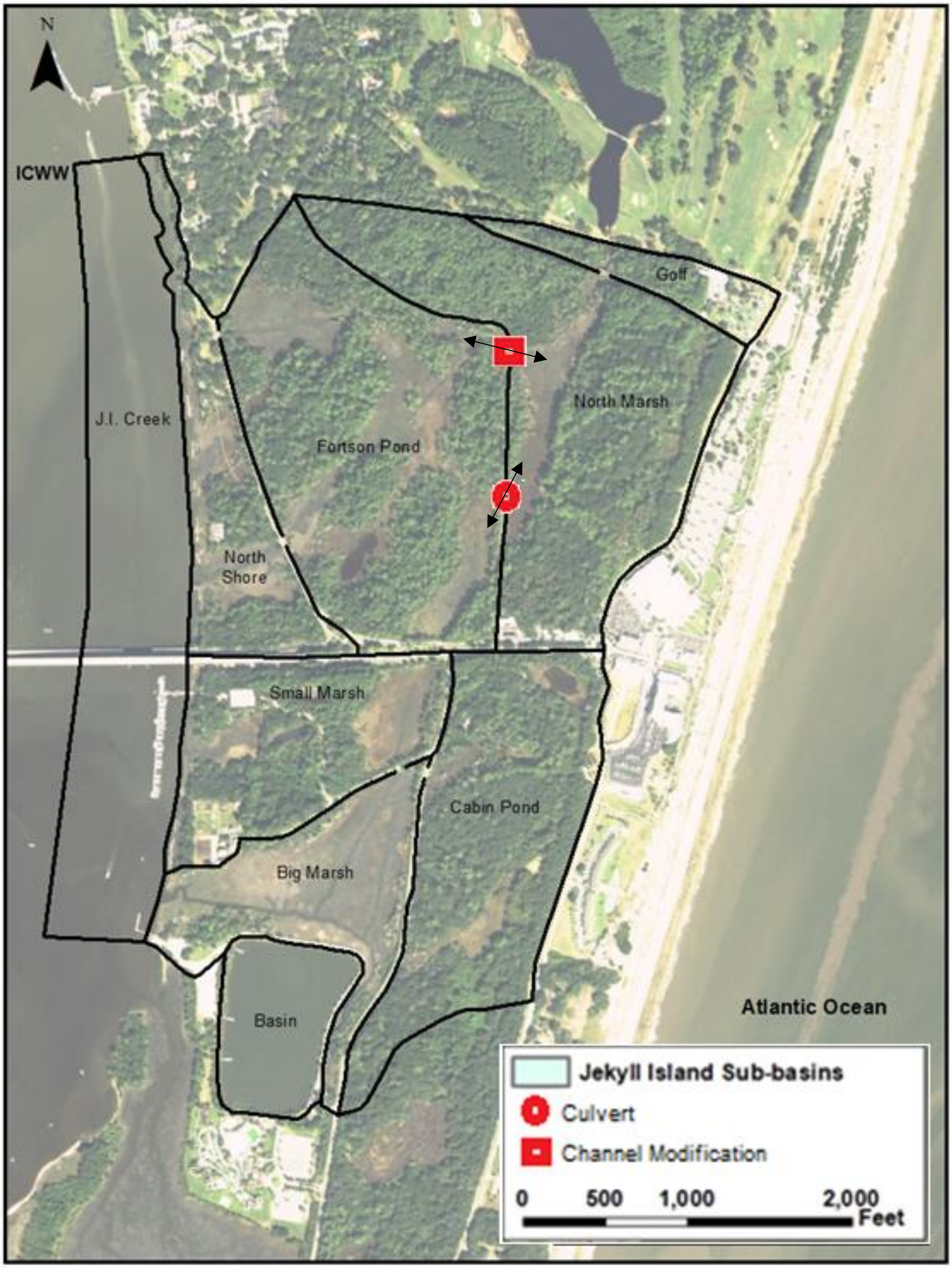


Figure 2.10 Alternative-1 Design Location

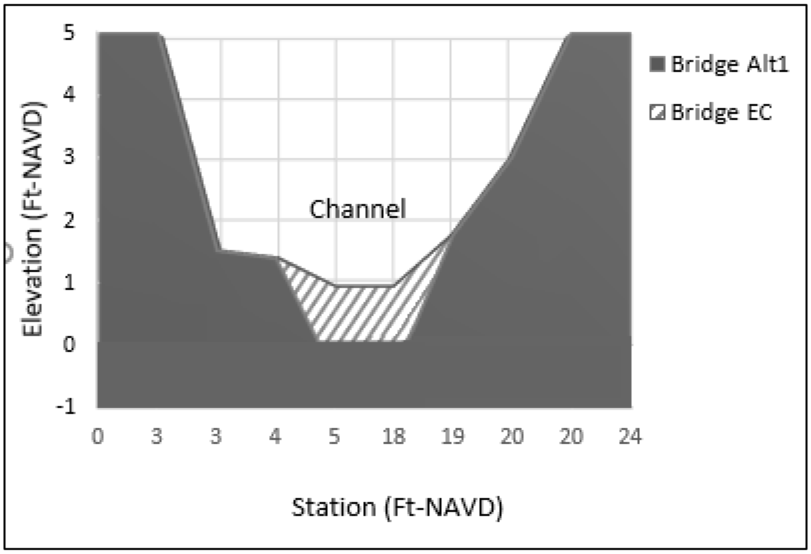


Figure 2.11 2D Area Connection Comparison Between Existing Conditions and Alternative-1

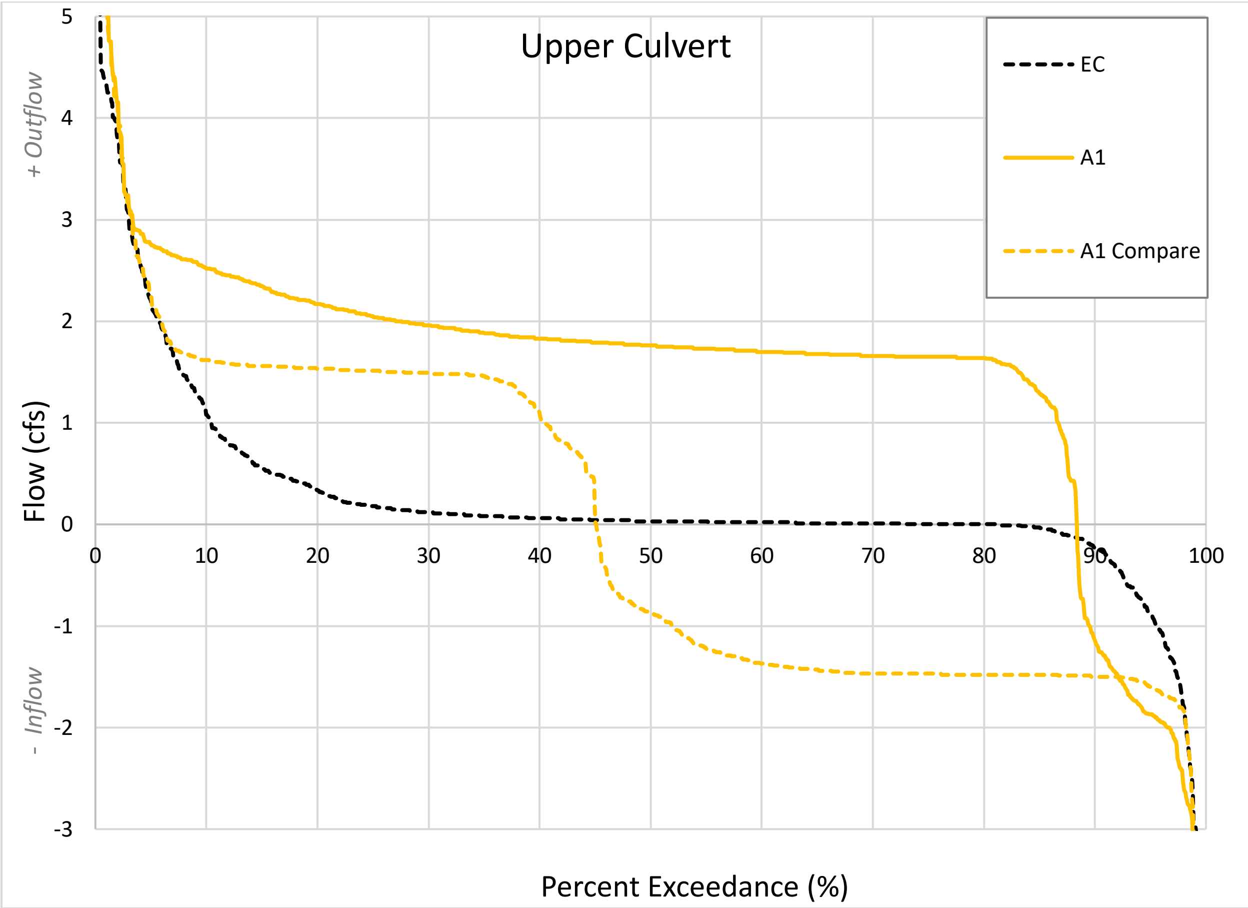


Figure 2.12 Percent Exceedance Between Alternative-1 and Existing Conditions at the Upper Culvert

Table 2.3 Comparison of Alternative-1 Maximum Computed Water Levels (Ft-NAVD)

Point	Maximum				
	EC	A1	Δ	A1 Comp.	Δ
Upper	3.55	3.55	0	3.54	-0.01
Mid	3.52	3.5	-0.02	3.51	-0.02
Lower	3.52	3.5	-0.02	3.51	-0.02
	Minimum				
Upper	1.88	1.94	0.06	1.94	0.06
Mid	1.97	1.97	0.00	1.97	0.00
Lower	2.35	2.35	0.00	2.35	0.00

2.5 Alternative 2 New Ben Fortson Culvert

Taylor and JIA formulated the Alternative 2 (A2) concept to optimize culverts beneath Ben Fortson Parkway, utilizing circular pipes. Figure 2.13 illustrates the A2 design features in addition to arrows indicating the flow path. We assessed a range of sizes and configurations for the culvert(s) beneath Ben Fortson Parkway, from (3) 24" RCP to (1) 4.0' x 6.0' box culvert with inverts established at the estimated marsh bottom. The final A2 design is (2) 48" concrete culverts with inverts lowered to the bottom of the marsh at 2.0' upstream and 1.95' downstream. The pipe size is accommodated by the limited road height, but is large enough that it should not be easily blocked by debris, which is the concern with smaller culverts. A box culvert is included in results as the A2 Comparison for performance evaluation with the A2 double circular culverts.

Comparison of A2 model results to EC and A1 model results indicates a positive effect in terms of conveyance and flushing at the lower portion of Fortson Pond. Figure 2.13 indicates the increased flow direction through Fortson Pond. A2 increases outflow from Fortson Pond at the Upper Culvert (Figure 2.14), but decreases inflow due to the new flow source beneath Ben Fortson Parkway. Figure 2.15 is a flow hydrograph of new flow from the Ben Fortson Culverts. During the spring tide, the flow range reaches an outflow of 12 cfs and an inflow around 25 cfs, which is much higher than that of the Upper Culvert in Figure 2.14. For the Ben Fortson Culverts hydrograph, the outflow does not match the inflow because once in the Fortson Pond, the water also outflows to the north.

A2 outperforms EC and A1 with an increased water level range, with a maximum level about three inches higher and a minimum level nearly five inches lower than that of EC (Table 2.4). The increased water surface range supports tidal flushing, which is expected to enhance the study area hydrologically and ecologically. As expected, the A2 comparison follows the same trend, but reduces the inundation duration further as the bottom conveyance area of the box culvert is greater than that of the combined circular culverts.

The added culverts effectively exchange flow and drain within and adjacent to Fortson Pond. The Lower Culvert connecting the Small Marsh to the Big Marsh (Figure 2.9) also experiences increased flushing. As seen in Figure 2.16, the percent exceedance of both the outflow and the inflow increase by up to five percent of the month-long simulation time without modifications to the Lower Culvert. The increase suggests that enhancements continue downstream of the Ben Fortson Culverts improvement to Small Marsh.

Appendix A illustrates HEC-RAS computed floodplains at the maximum (which is not at a single time), a low tide period, and a spring tide period for modeled events. The floodplains at additional time periods are included to provide a snapshot of the flow interaction in the system. In addition, we extracted HEC-RAS computed water level hydrographs at three-point locations within the model domain, in Figure 2.9. Appendix B illustrates the water level hydrographs for the modeled events. Appendix C illustrates plots of all flow duration curves.

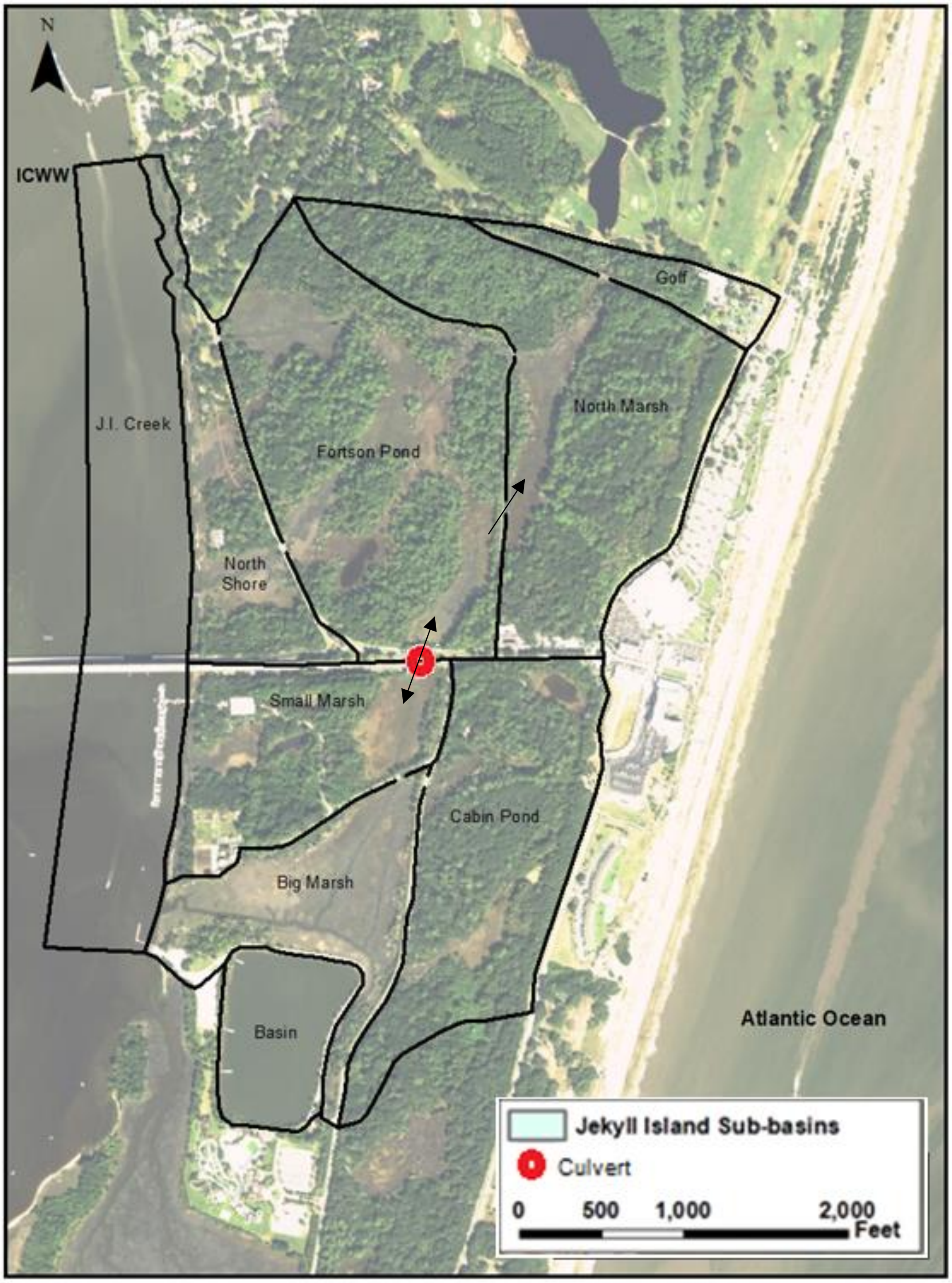


Figure 2.13 Alternative-2 Design Location

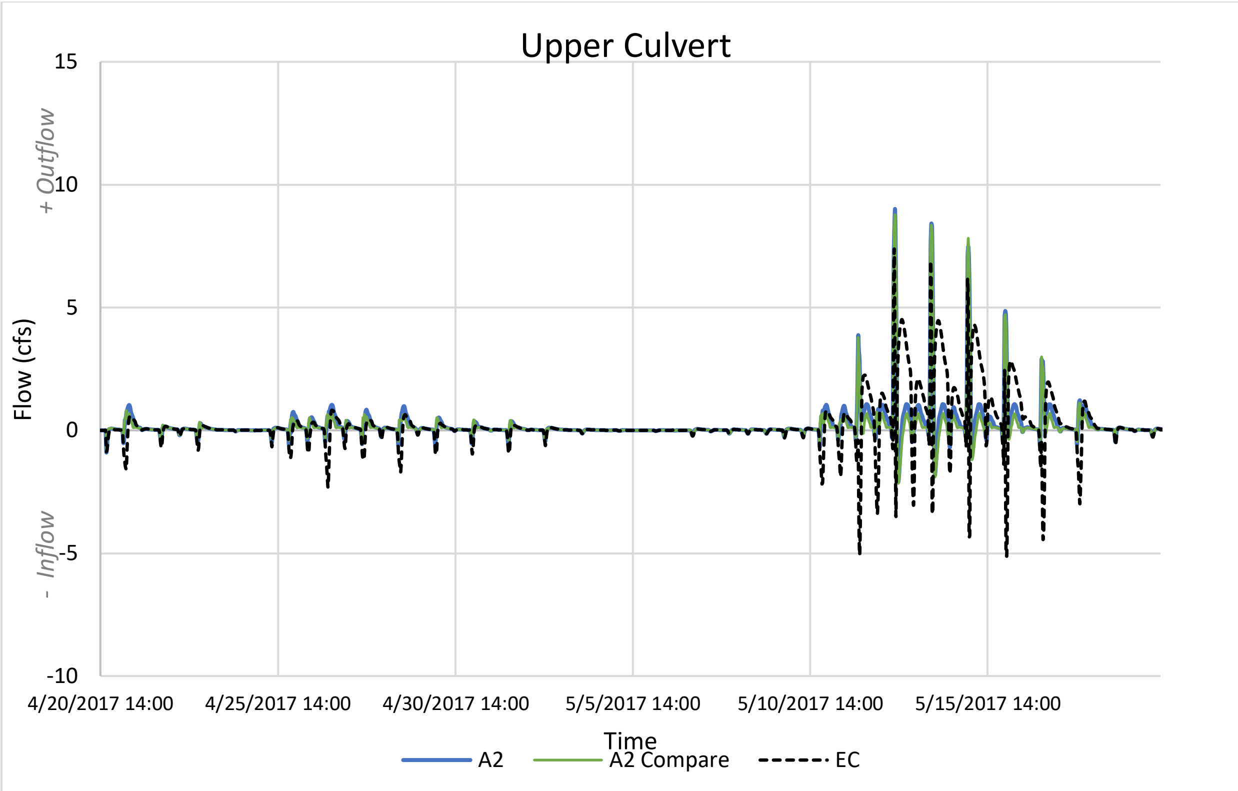


Figure 2.14 Alternative-2 Hydrograph at the Upper Culvert

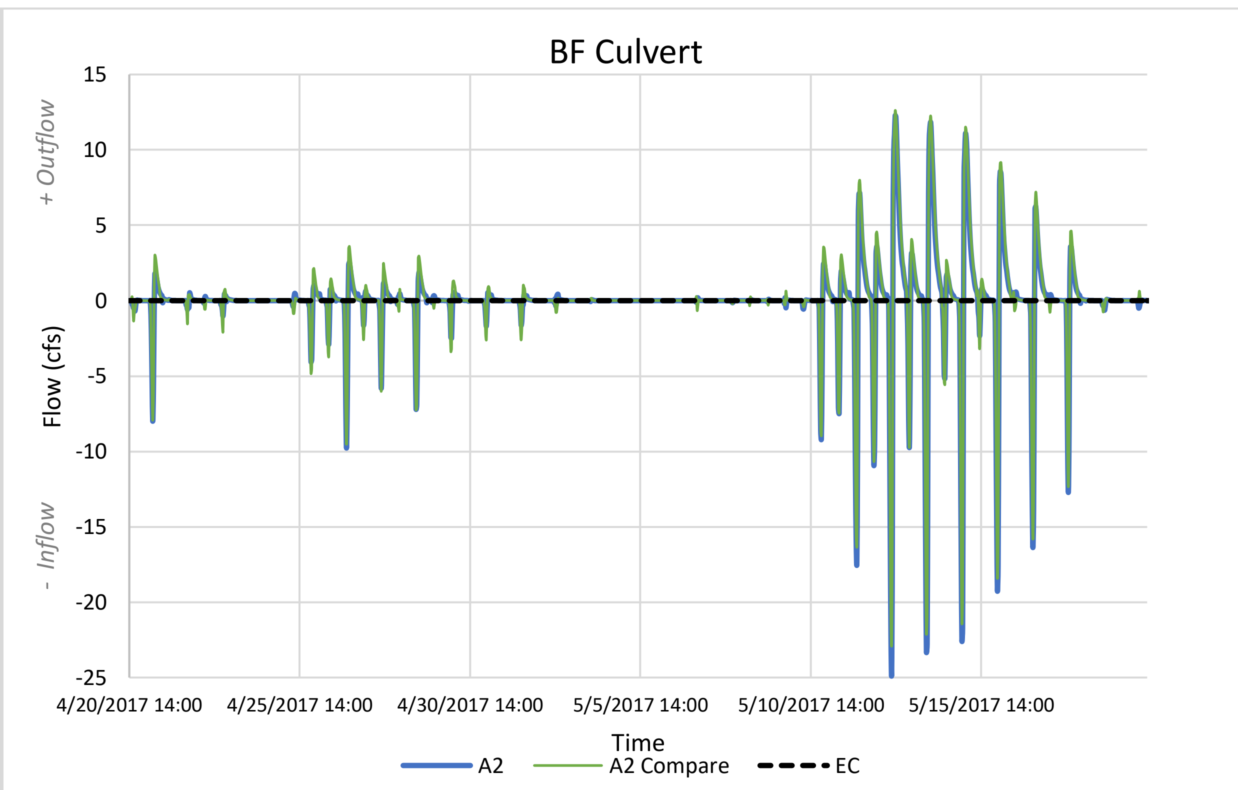


Figure 2.15 Alternative-2 Hydrograph at the Ben Fortson Culvert

Table 2.4 Comparison of Alternative-2 Minimum and Maximum Computed Water Levels at Fortson Pond (Ft-NAVD)

Point	Maximum				
	EC	A2	Δ	A2 Comp.	Δ
Upper	3.55	3.78	0.23	3.78	0.24
Mid	3.52	3.79	0.26	3.79	0.26
Lower	3.52	3.79	0.26	3.79	0.26
	Minimum				
Upper	1.88	1.88	0.00	1.88	0.00
Mid	1.97	1.89	-0.08	1.89	-0.08
Lower	2.35	1.95	-0.40	1.96	-0.39

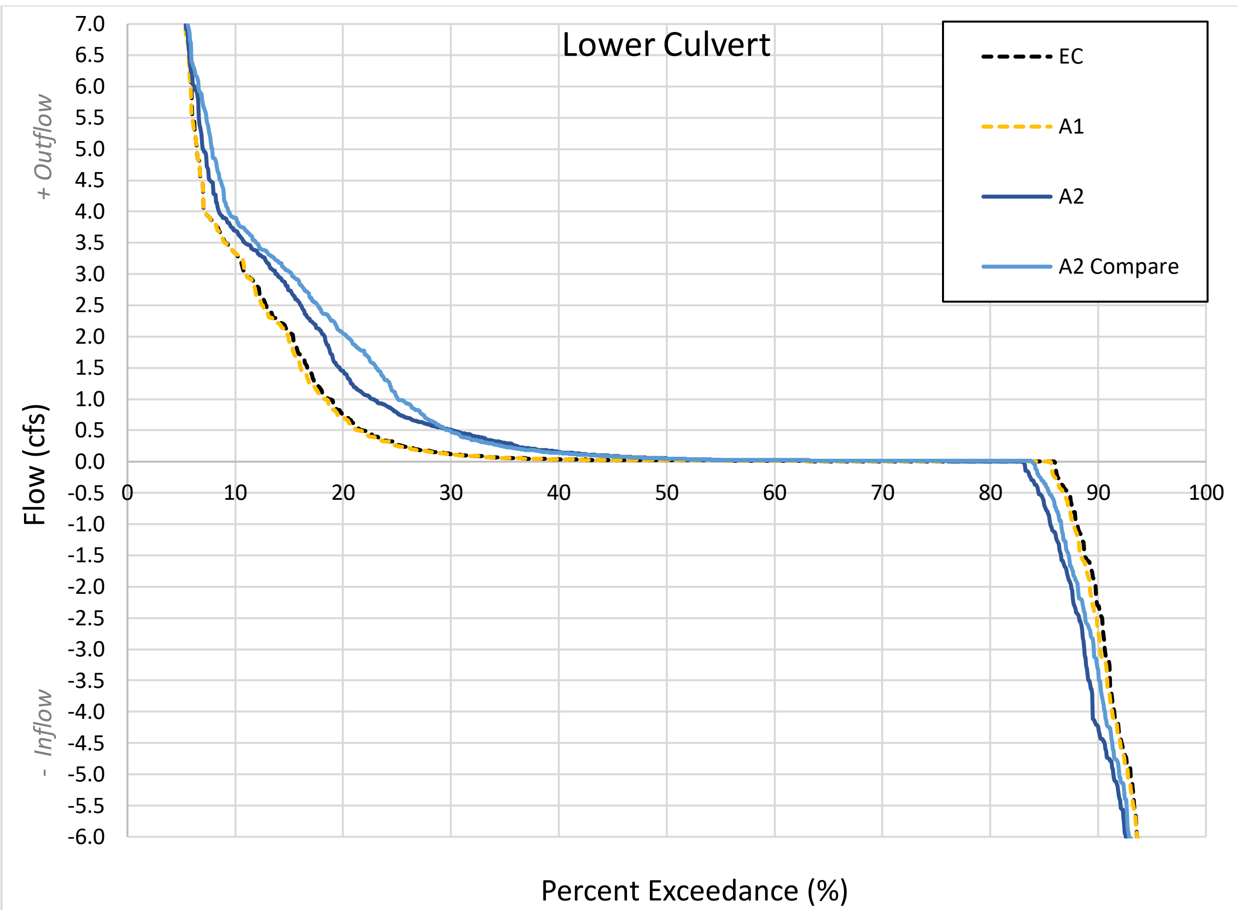


Figure 2.16 Percent Exceedance for Existing Conditions Alternative-1, and Alternative-2 at the Lower Culvert

2.6 Alternative-3 Combination of A1 and A2

Taylor and JIA formulated the Alternative-3 (A3) concept during a conference call on July 6, 2017. The team discussed combining the selected A1 and A2 to determine if the combination further enhances flow and drainage within and adjacent to Fortson Pond. Based on the discussion, JIA and Taylor decided that A3 will combine the A2 design features beneath Ben Fortson Parkway with the A1 optimizations (Figure 2.17). The selected A3 and the A3 comparison designs include:

A3: (2) 48” culverts from A2 with (1) 39”-equivalent horizontal-ellipse culvert from A1

A3 Comparison: (2) 48” culverts from A2 with (2) 24” circular culverts from A1 Comparison

While A1 outperformed the A1 Comparison (double circular culverts) configuration, Taylor modeled both options as A3 combinations to compare A3 to a similar option.

Figure 2.17 also displays arrows that indicate flow direction and location, corresponding to the culverts. Figure 2.18 illustrates the flow hydrograph at the Ben Fortson Culvert for A3. The existing condition is zero because there was no culvert previously. The flow exchange is highest through the new culvert during the spring tide. The culvert performs similarly to that in A2, increasing inflow to about 25 cfs and outflow to 12 cfs. The outflow also flows out of Fortson Pond to the north. Figure 2.19 presents the flow results at the Ben Fortson Parkway as percent exceedance for the entire 1-month simulation period and a 1-week period, which better represents conditions during the spring tide. The figure includes results from both timeframes to illustrate that flow will vary with the tidal cycle and increase during higher flow times. All graphed A2 and A3 results display similar flow through the new culvert, although, the A2 Comparison improves performance by increasing outflow and slightly increasing inflow, as expected with the box culvert.

The percent exceedance for flow through the Upper Culvert (Figure 2.20) supports that the ellipse combination (A3) frequently conveys higher flow rates. The flow hydrograph for the Upper Culvert (Figure 2.21) illustrates a sustained increase in outflow for A3. Since A1 increases outflow and A2 increases inflow independently, especially during high-flow periods, the combined A3 supports flushing through Fortson Pond. Furthermore, the stage-duration for lower Fortson Pond (Figure 2.22), supports that flow through the culvert substantially decreases the stage for A3 combinations, indicating that the area can drain more for improved flushing.

Model results indicate that A3 most improves flushing with an increased water surface range and increased conveyance, especially during peak periods, in both culvert locations. The A3 Combination also improves flushing, although flow through the upper culvert increases to a lesser degree. The A3 results look similar to A2 results, except A3 has the benefit of further draining the lower Fortson Pond with a decreased water surface level (Figure 2.22). A3 increases the water level range, with a maximum level similar to that of A2 (nearly three inches higher), but the added benefit of a minimum level decreased across the marsh, up to nearly five inches lower than that of EC (Table 2.5).

Appendix A illustrates HEC-RAS computed floodplains at the maximum (which is not at a single time), a low flow period, and a high flow period for modeled events. In addition, we extracted HEC-RAS computed water level hydrographs at three-point locations within the model domain, in Figure 2.9. Appendix B illustrates the water level hydrographs for the modeled events. Appendix C illustrates plots of all flow duration curves.

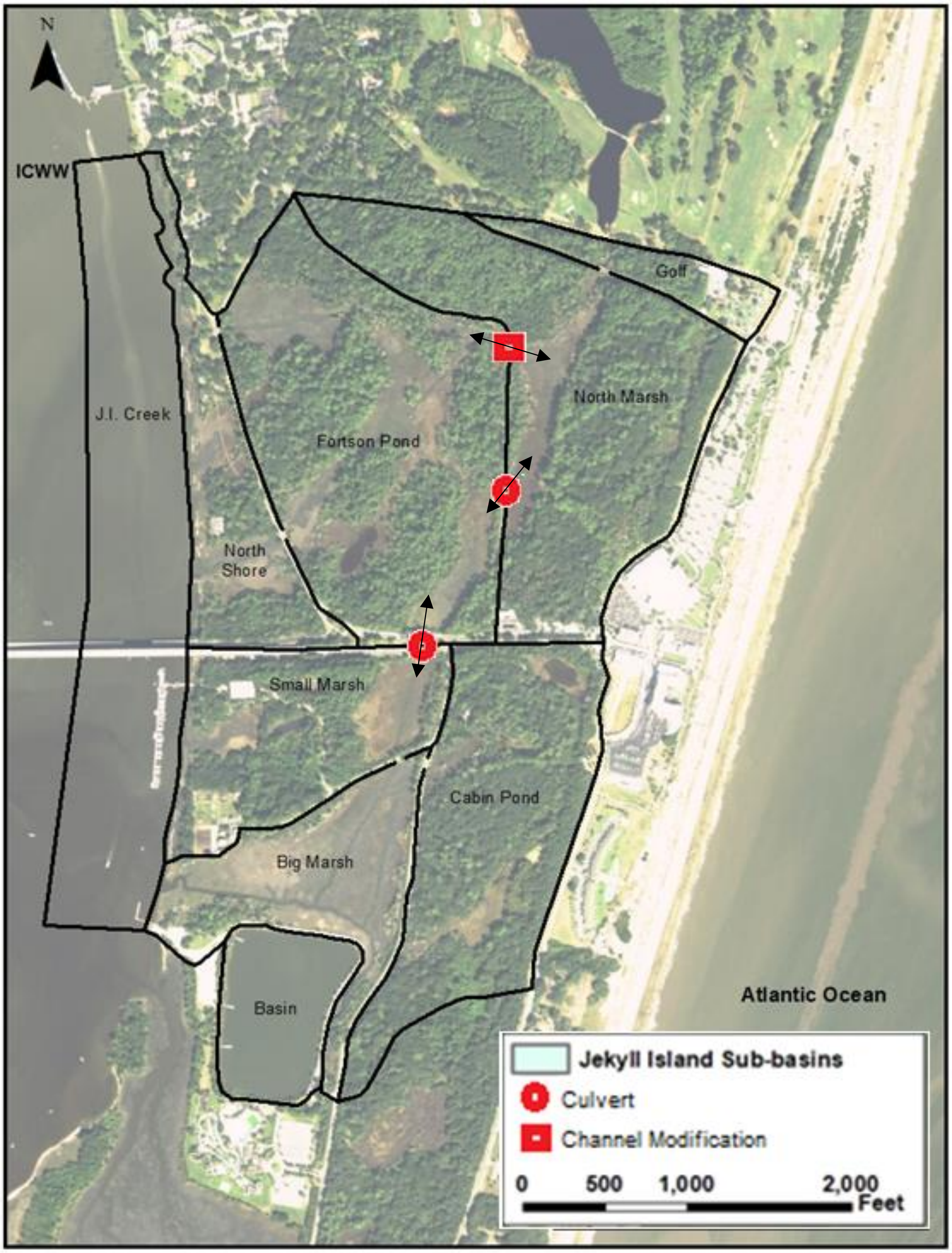


Figure 2.17 Alternative-3 Combination Design Locations

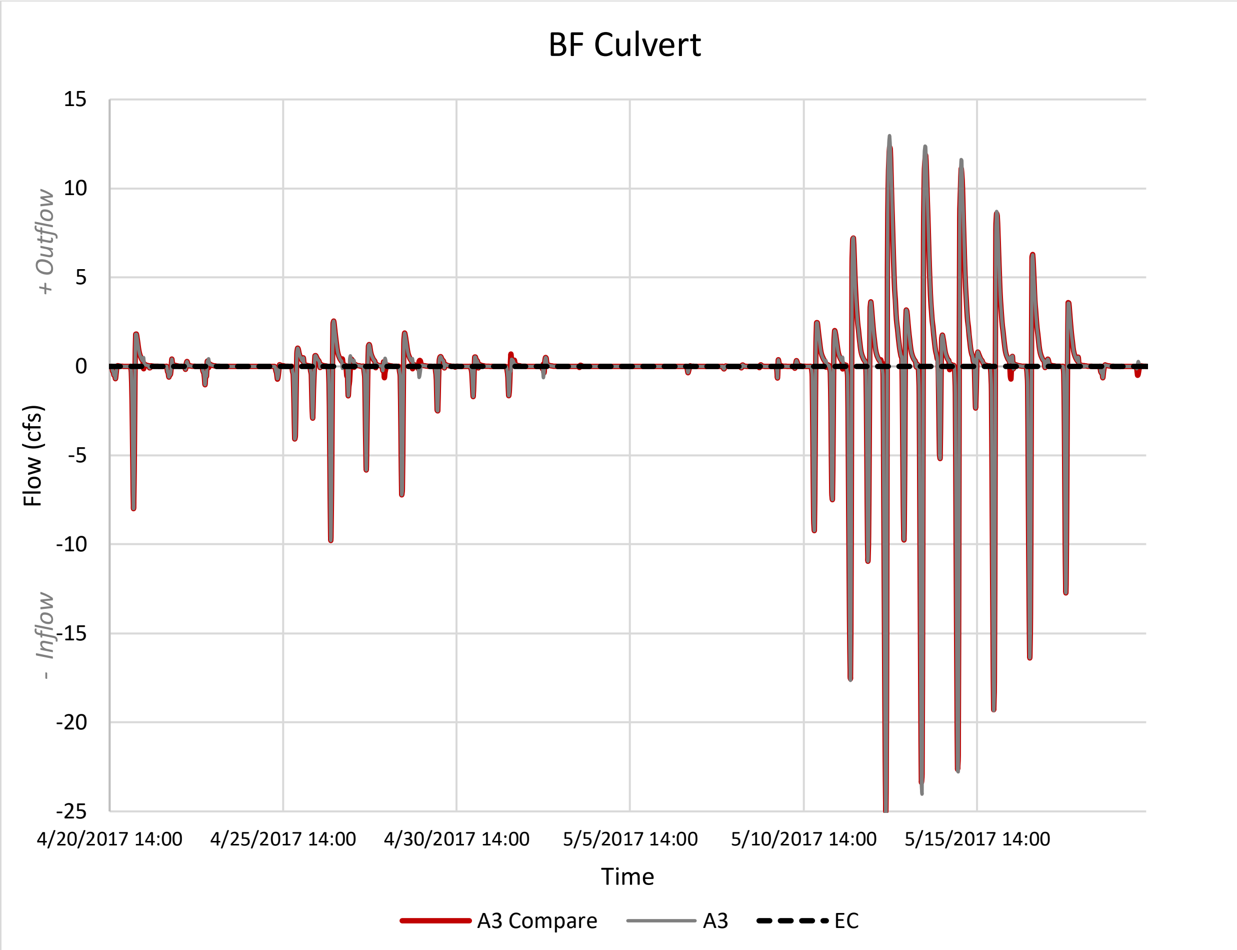


Figure 2.18 Alternative-3 Flow Hydrograph at the Ben Fortson Culvert

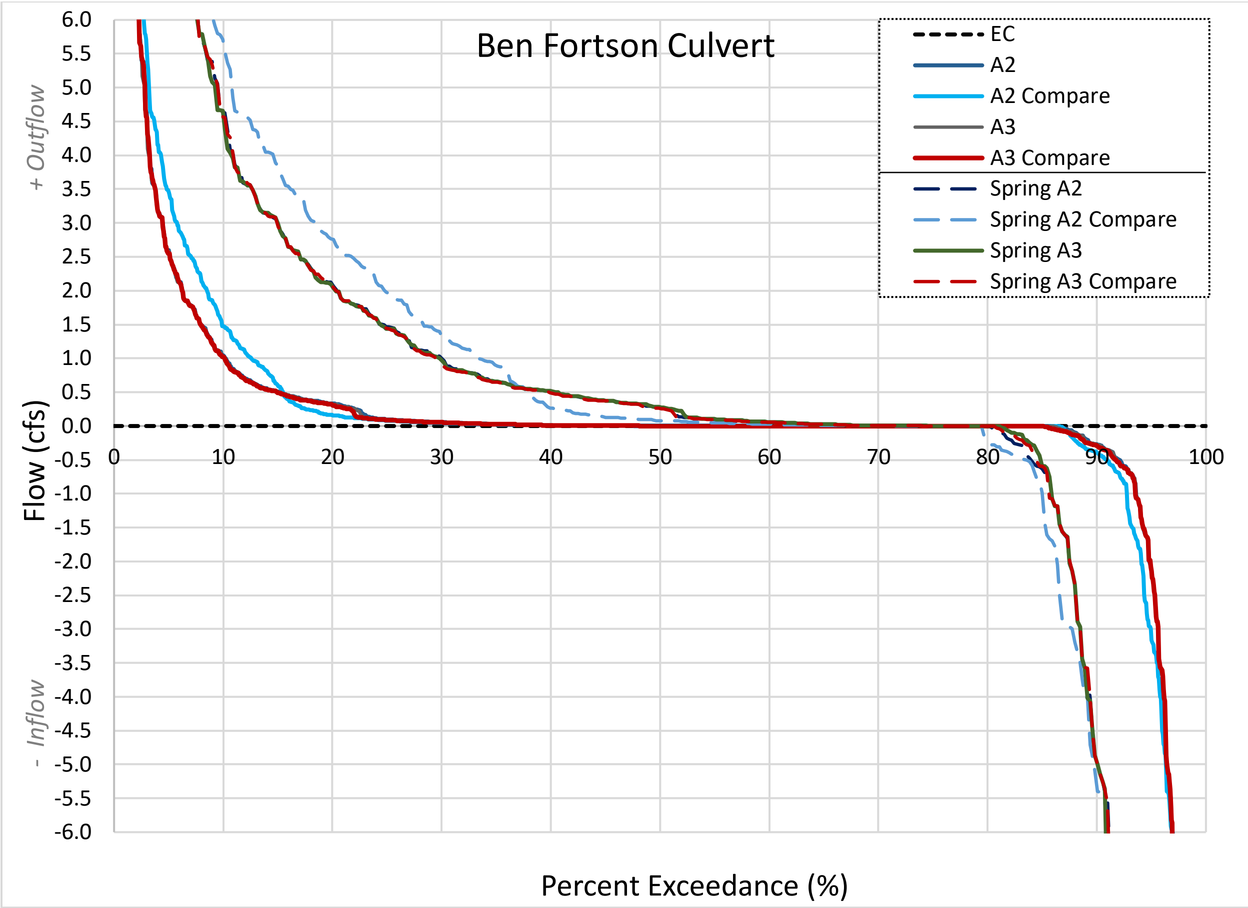


Figure 2.19 Percent Exceedance for the 1-month Simulation Period and a 1-week Spring Tide Period at the Ben Fortson Parkway Culvert

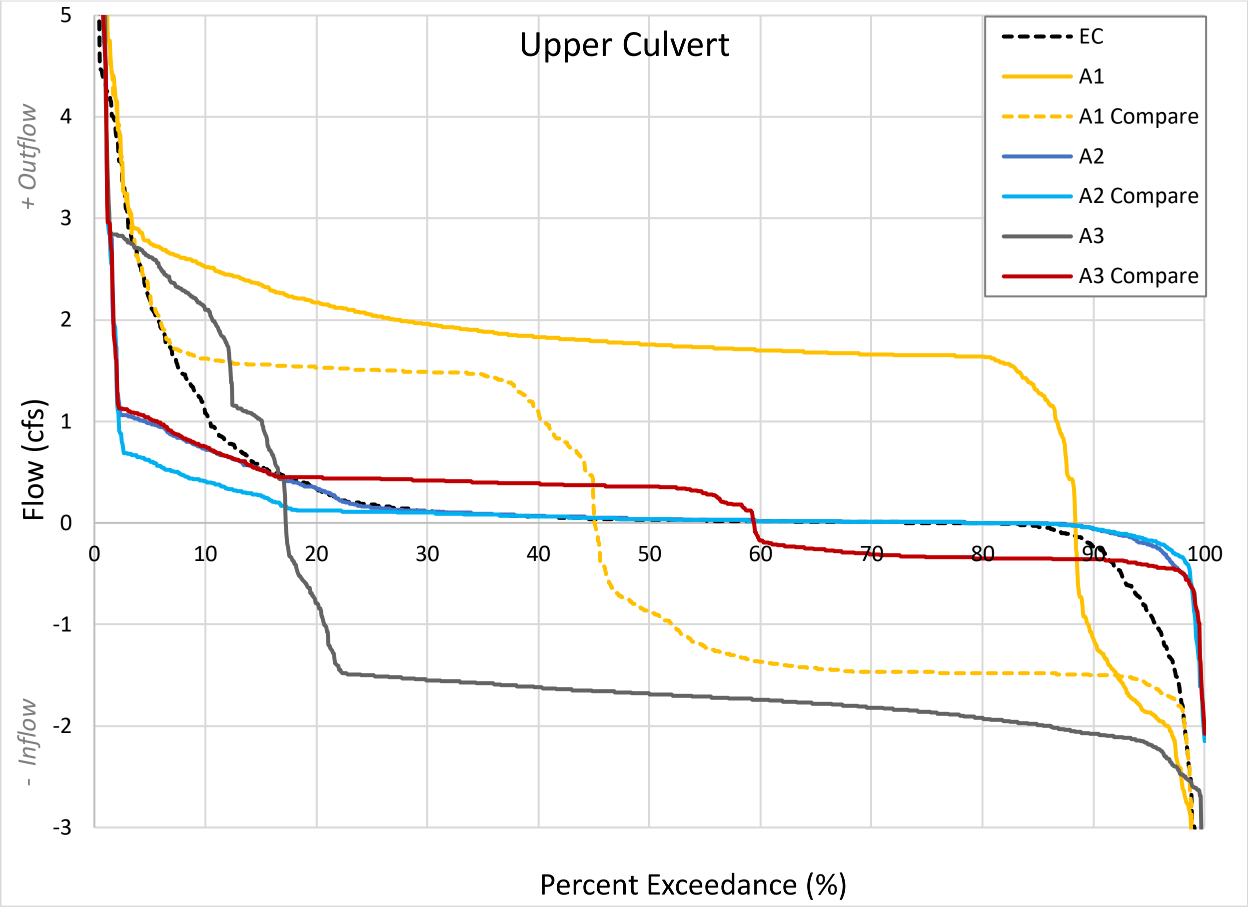


Figure 2.20 Percent Exceedance for the 1-month Simulation Period and a 1-week Spring Tide Period at the Upper Culvert

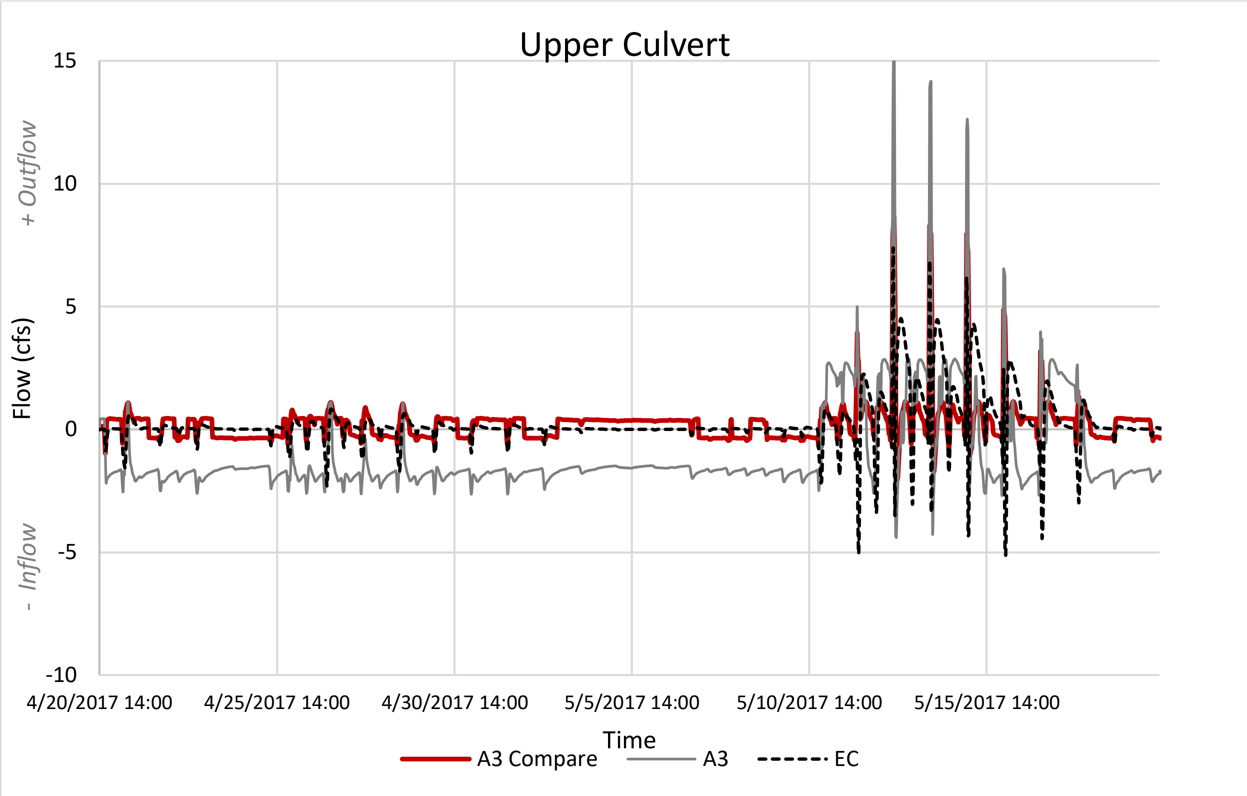


Figure 2.21 Alternative-3 Flow Hydrograph at the Upper Culvert

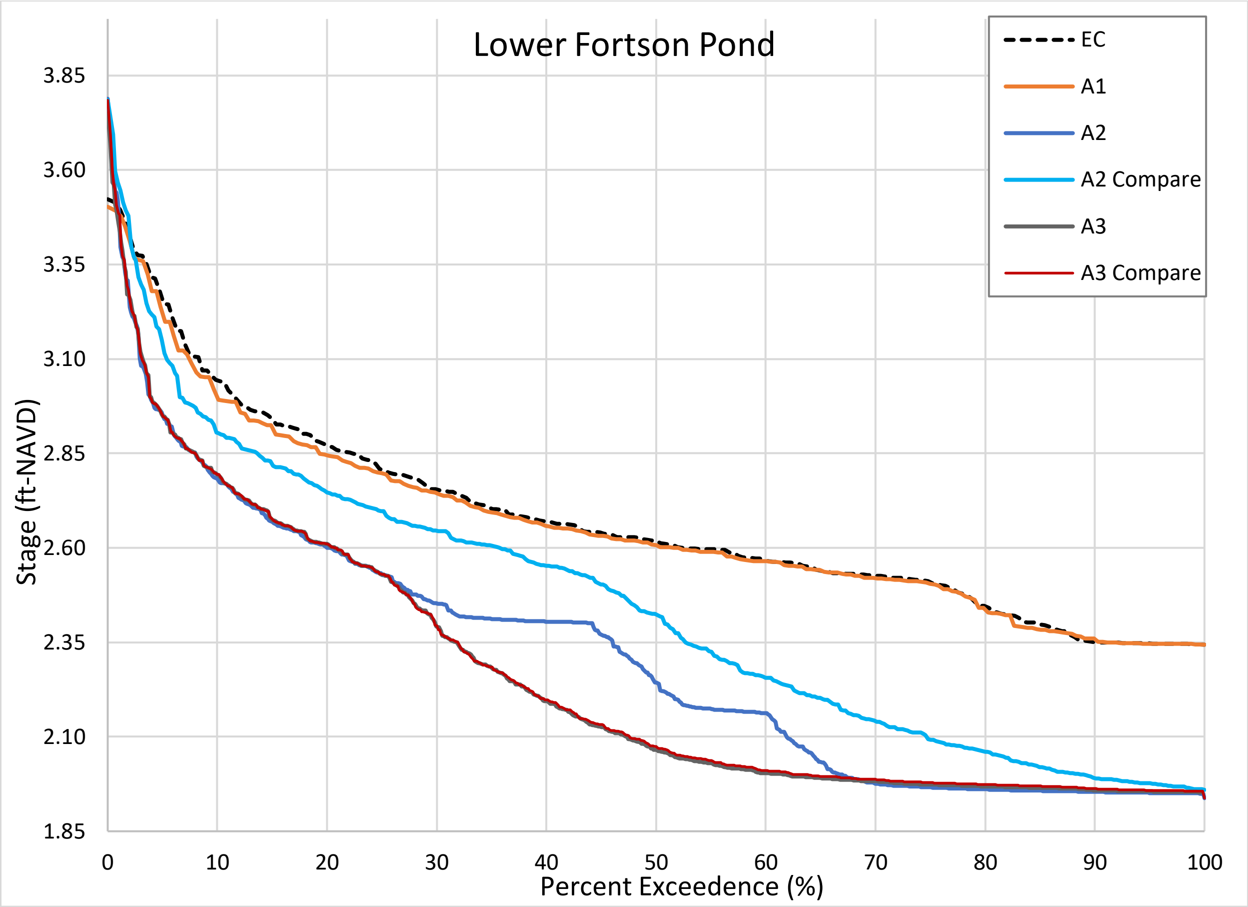


Figure 2.22 Percent Exceedance at the lower Fortson Pond

Table 2.5 Comparison of Alternative-3 Minimum and Maximum Computed Water Levels in Fortson Pond (Ft-NAVD)

Point	Maximum				
	EC	A3	Δ	A3 Comp.	Δ
Upper	3.55	3.74	0.20	3.78	0.23
Mid	3.52	3.75	0.23	3.79	0.26
Lower	3.52	3.75	0.23	3.79	0.26
	Minimum				
Upper	1.88	1.78	-0.10	1.85	-0.03
Mid	1.97	1.79	-0.19	1.85	-0.12
Lower	2.35	1.95	-0.39	1.96	-0.39

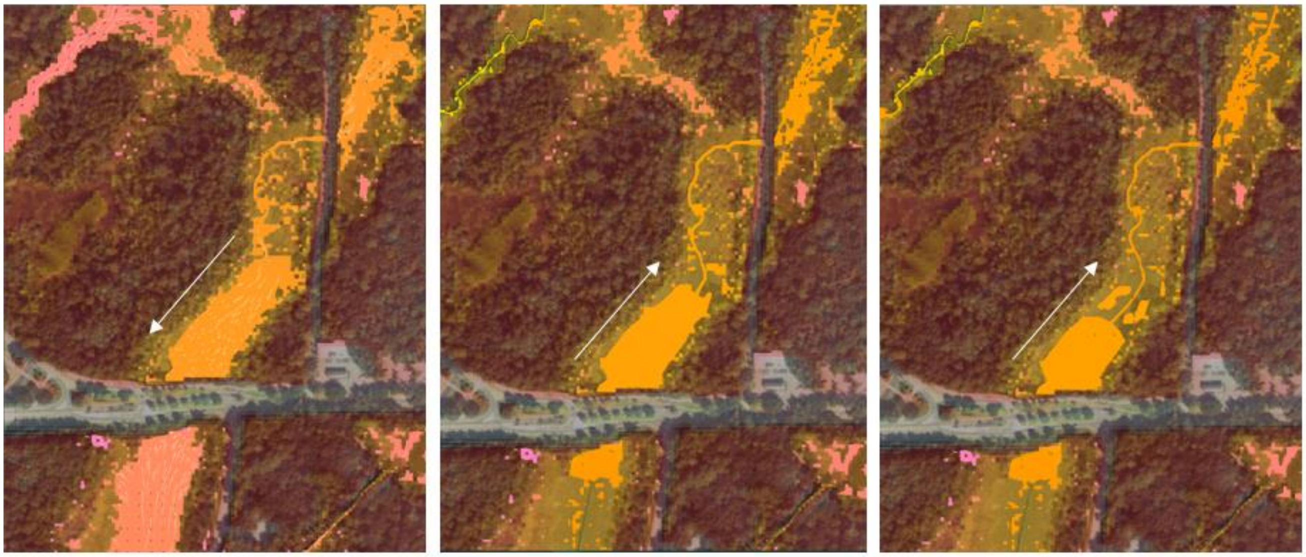
3.0 DISCUSSION OF WATER QUALITY AND HABITAT

Potential water quality benefits are quantified in terms of the flushing effect of each alternative by means of flow and stage durations. To be clear, the salinity is not directly modeled, but Taylor analyzed modeled flow durations and velocities within the marsh to identify areas of flow stagnation that would result in higher than normal salinities and/or water quality other constituents. Analyzing the flushing capabilities of the strategic design alternatives will justify the selected response to improve the water quality of the project area.

JIA has characterized Fortson Pond as eutrophic and hypereutropic (Jekyll Island Authority, 2016). Hypoxic conditions are prevalent in all but the most tidally influenced locations. Increasing tidal flushing and circulation could improve the health of the system for water quality, vegetation, and macroinvertebrate communities.

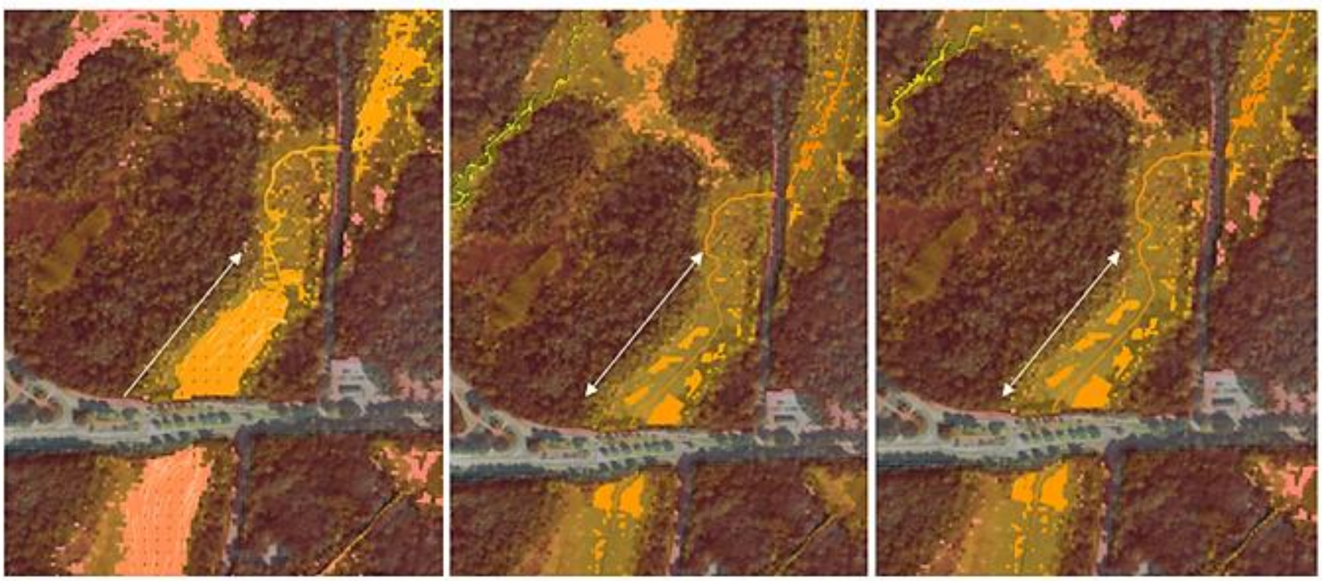
For simplicity, we will present comparisons of existing conditions (EC) and Alternative-3 — which has (2) x 48-inch circular culverts at Ben Fortson Parkway, improvements under the North Marsh Bridge, and a 39-inch equivalent elliptical culvert at the Upper Culvert.

Figure 3.1a presents the flow lines in Fortson Pond with existing conditions at three stage periods: peak inflow, after eight hours of outflow, and after ten hours of outflow. Longer flow lines in the flow area indicate higher velocities. Figure 3.1b shows the same time periods as the existing conditions images but with the Ben Fortson culvert from A3. The flow lines in Figure 3.1a show the stagnant water in the south end of Fortson Pond under existing conditions while Figure 3.1b shows longer flow lines indicating better flow velocities and flushing under A3 conditions. In the second case, the pond is filled from the south and outflows in both directions, rather than just to the north. Reasonably, opening Fortson Pond with A3 results in a much quicker drainage of the pond and a lower stage, which suggest favorable circumstances for flushing the accumulated material.



EC Inflow (13 May 1100) EC Outflow 8 hours later (13 May 1900) EC Outflow 10 hours later (13 May 2100)

Figure 3.1a Existing Conditions Flow Lines



A3 Inflow (13 May 1100) A3 Outflow 8 hours later (13 May 1900) A3 Outflow10 hours later (13 May 2100)

Figure 3.1b A3 Conditions Flow Lines

An important component of the health of a marshy ecosystem is the tidal range that it experiences. Looking at the Fortson Pond lower data point from model results, we can examine the change in the stage Percent Exceedance. Data from Figure 2.22 was distilled in Figure 3.2 to better compare the existing condition to A3.

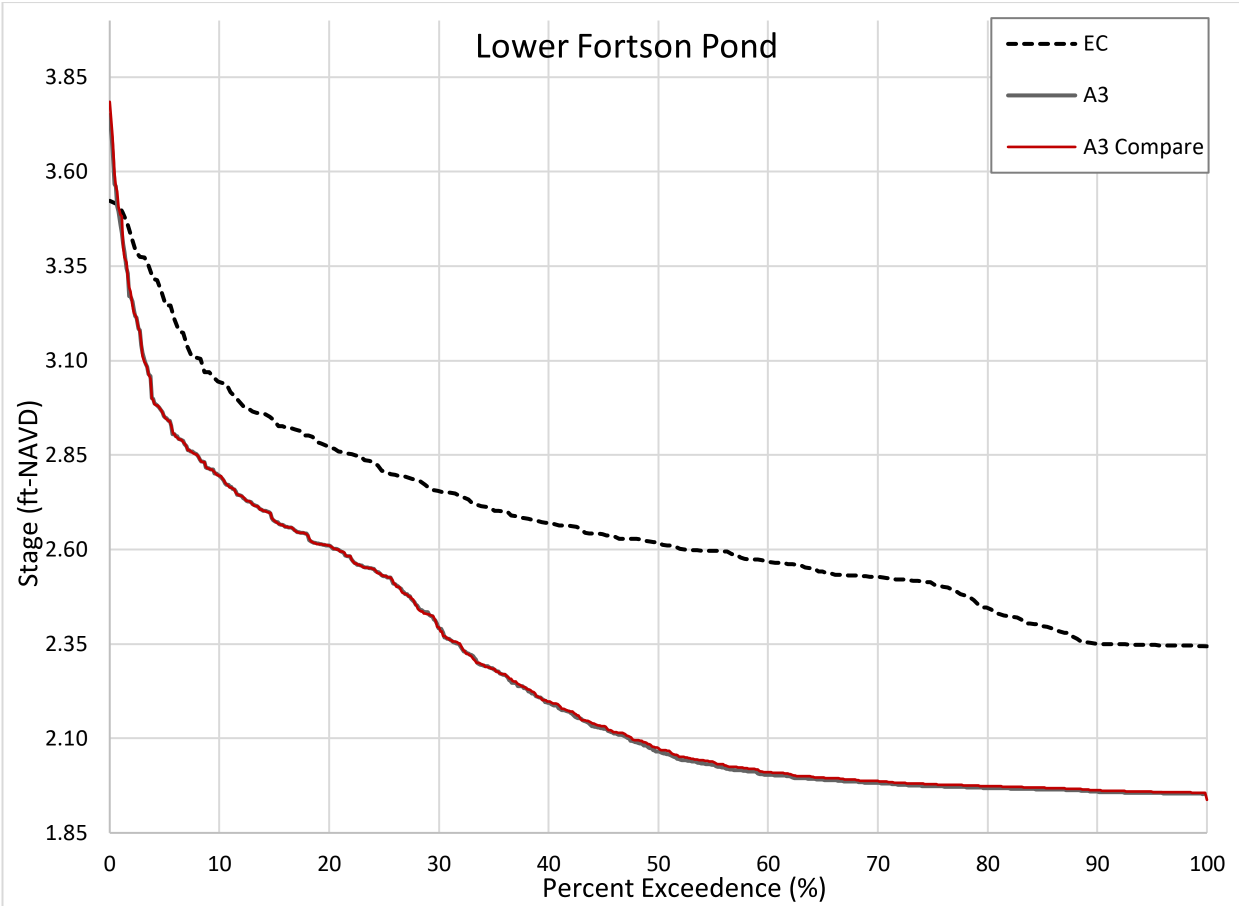


Figure 3.2 Lower Fortson Pond Stage Duration Curve for A3

The model results show a reduction of over 0.5 ft in the 50% exceedance stage, meaning the stage in Fortson Pond would experience a substantial lowering of the water level elevation. On the higher end, the Pond will experience higher water levels for less than 1% of the time, over existing conditions.

Table 2.5 showed that the peak water surface elevation in A3 conditions are about 0.25 higher than existing conditions. This means the water surface elevation achieves a larger range under A3. The model shows the Pond fills up on inflows and slowly drains over an extended period. The introduction of culverts under Fortson Parkway, as expected, enhances the drainage of the Pond and reduces the stagnant conditions that currently exist. This reduction in stage will create a greater intertidal habitat for vegetation and macroinvertebrates.

As mentioned previously, increased inflow and outflow through Fortson Pond will improve water quality. Greater flushing could also improve vegetative communities, resolve low dissolved oxygen conditions, and move accumulations of organic material. One way to examine the effects of A3 on Fortson Pond is to examine the flow hydrograph through the culvert under the Parkway. Previously Figure 2.19 showed the hydrograph, but Figure 3.3 shows the same data with other alternatives removed.

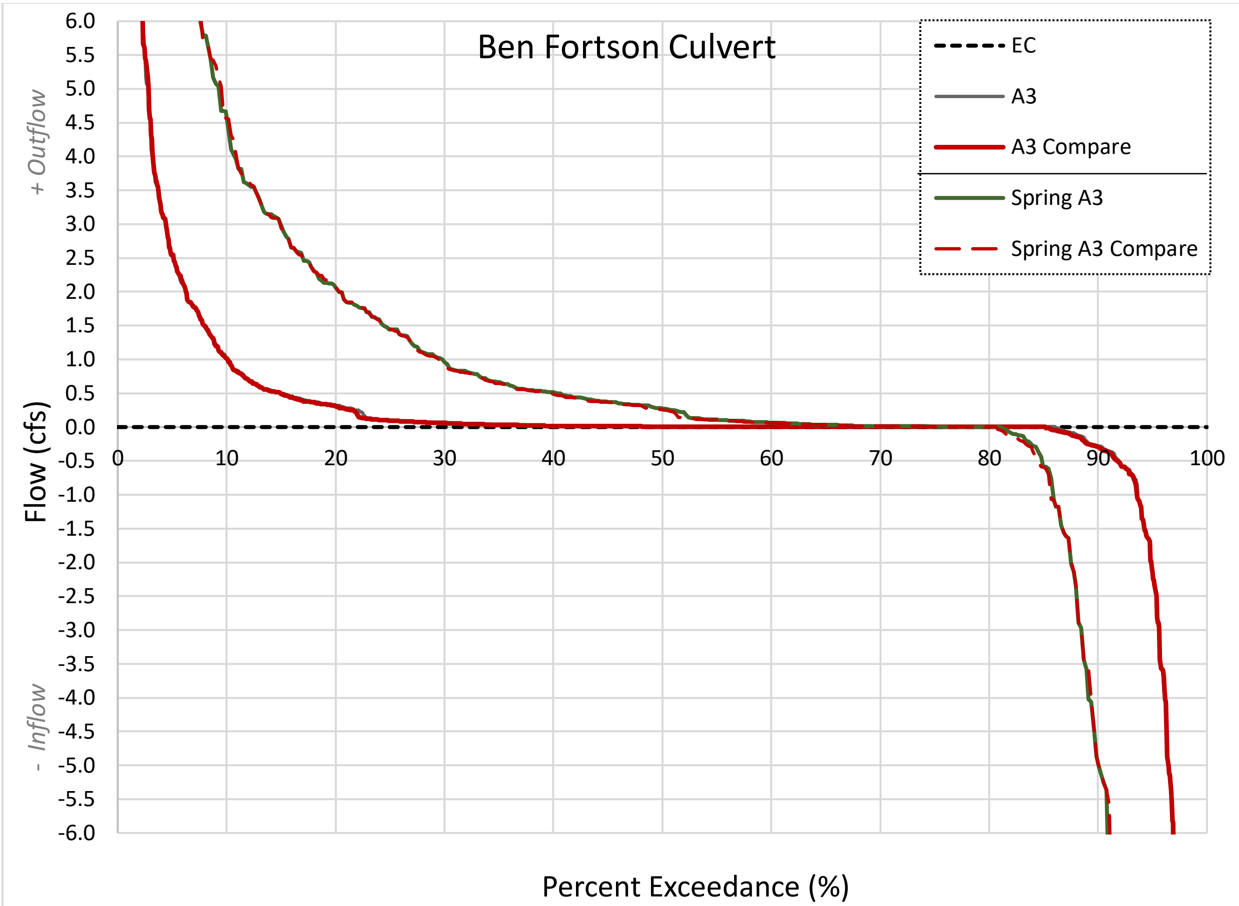


Figure 3.3 Ben Fortson Culvert Flow Duration Curve

Since there is no existing culvert, hydrodynamic modeling is a useful tool to examine potential flow exchanges and answer questions such as, "how much flow exchange could be expected with a new culvert?", "how often would there be exchange?", and "would there be a dominant flow direction?" Figure 3.3 presents the flow duration expected through a new culvert under the Parkway. This curve shows data from modeling an entire month of tidal exchange and a smaller time period showing only a spring tide. For the month-long simulation, we can see most of the time the flow is zero. But, about 20% of the time the flow will be predominantly outflow and/or inflow (below 20% and above 80%). The shapes of the duration curve indicate a difference in the inflow and outflow characteristics.

4.0 ALTERNATIVES COST ESTIMATES

To support the comparison of alternatives, we developed a construction opinion of probable cost for each alternative (Table 4.1). These estimates include limited general item fees such as contractor's bonds and insurance, taxes and fees, construction quality control testing, and pollution control; additional costs associated with enhancements was not included. For cost estimation, we assigned costs from the RSMeans Construction Cost Estimates values and best judgement.

Table 4.1 Construction Opinion of Probable Cost Comparison for Alternatives 1-3

Jekyll Island Construction Opinion of Probable Cost - Alternative 1						
		Description	Unit	Quantity	Unit Cost	Amount (rounded)
1.0	Earthwork and Materials					
		39"-Equivalent, Elliptical Culvert	LF	28	$ 272.00	$ 15,200.00
					Subtotal	$ 15,200.00
				Contingency	10%	$ 1,500.00
				Total Project Cost		**$ 2,000.00**

Jekyll Island Construction Opinion of Probable Cost - Alternative 2						
		Description	Unit	Quantity	Unit Cost	Amount (rounded)
1.0	Earthwork and Materials					
		Earthwork	CY	5970	$ 20.00	$ 119,400.00
		48" Circular Culverts	LF	400	$ 203.00	$ 109,200.00
		Rip Rap	TON	38	$ 150.00	$ 5,700.00
		Filter Fabric	SY	28	$ 3.50	$ 100.00
2.0	Dewatering					
		Cofferdams	SF	3000	$ 23.00	$ 69,000.00
		Dewatering, pump 8 hrs/day	per day	90	$ 1,025.00	$ 92,300.00
3.0	Roadway Cut					
		Demolition and paving	SY	2560	$ 18.70	$ 48,000.00
		MOT	per day	5	$ 500.00	$ 2,500.00
4.0	Mobilization					
		Mobilization	LS	1	15%	$ 66,900.00
					Subtotal	$ 513,100.00
5.0	General Items					
		Contractor's Bonds and Insurance	LS	1	5%	$ 25,660.00
		Taxes and Fees	LS	1	5%	$ 25,660.00
		Mobilization and General Conditions	LS	1	5%	$ 25,660.00
		Construction Quality Control Testing	LS	1	5%	$ 25,660.00
		Pollution Control	LS	1	5%	$ 25,660.00
					Subtotal	$ 641,400.00
				Contingency	10%	$ 64,100.00
				Total Project Cost		**$ 706,000.00**

Jekyll Island Construction Opinion of Probable Cost - Alternative 3						
		Description	**Unit**	**Quantity**	**Unit Cost**	**Amount (rounded)**
1.0	Earthwork and Materials					
		Earthwork	CY	5970	$ 20.00	$ 119,400.00
		39"-Equivalent, Elliptical Culvert	LF	28	$ 272.00	$ 15,200.00
		48" Circular Culverts	LF	400	$ 203.00	$ 109,200.00
		Rip Rap	TON	38	$ 150.00	$ 5,700.00
		Filter Fabric	SY	28	$ 3.50	$ 100.00
2.0	Dewatering					
		Cofferdams	SF	3000	$ 23.00	$ 69,000.00
		Dewatering, pump 8 hrs/day	per day	90	$ 1,025.00	$ 92,300.00
3.0	Roadway Cut					
		Demolition and paving	SY	2560	$ 18.70	$ 48,000.00
		MOT	per day	5	$ 500.00	$ 2,500.00
4.0	Mobilization					
		Mobilization	LS	1	15%	$ 66,900.00
					Subtotal	$ 528,300.00
5.0	General Items					
		Contractor's Bonds and Insurance	LS	1	5%	$ 26,420.00
		Taxes and Fees	LS	1	5%	$ 26,420.00
		Mobilization and General Conditions	LS	1	5%	$ 26,420.00
		Construction Quality Control Testing	LS	1	5%	$ 26,420.00
		Pollution Control	LS	1	5%	$ 26,420.00
					Subtotal	$ 660,400.00
				Contingency	10%	$ 66,000.00
				Total Project Cost		**$ 726,000.00**

Costs have some uncertainty due to the inherent error in the terrain data and the variability of construction methods. We based costs for earthwork on industry accepted unit costs from RS Means and the project's past estimates with Robert's Civil Engineering. The estimated materials and unit costs represent Taylor Engineering, Inc.'s best judgment as a professional design firm familiar with the type of construction proposed. Taylor Engineering has no control over the availability or cost of labor, equipment or materials, market conditions, or a contractor's methods of pricing. Accordingly, Taylor Engineering, Inc. makes no warranty, express or implied, that the actual bids or negotiated prices will not vary from these rough cost estimates.

5.0 DISCUSSION AND RECOMMENDATIONS

Taylor Engineering carefully evaluated each of the alternatives presented in this report by taking into consideration the effectiveness in flushing through the marsh, likely permitting requirements, and probable construction costs. Based on these evaluations we provide a summary of our findings and recommendations in the paragraphs below.

A1 results in improvement of flow, inflow and outflow to the North Marsh and Fortson Pond increases ± 1.5 cfs for more than 70% of the simulation period. This occurs because the aligned channel conveys more flow in both directions with tide fluctuations. Once the tide has peaked, the water flows out of the marsh area. The horizontal-ellipse culvert (A1) increases the conveyance area, allowing for an increased inflow rate and extends the outflow exceedance. A1 is the least costly of the alternatives evaluated. If feasible, we recommend with A1 as a supplemental construction project to enhance flushing.

A2 outperforms A1 with reduction of the inundation duration, but does not improve flushing as well as A3. The added culverts effectively drain and improve flood conditions within and adjacent to Fortson Pond. The Lower Culvert connecting the Small Marsh to the Big Marsh (Figure 2.18) also experiences increased flushing. The percent exceedance of both the outflow and the inflow increase by up to five percent or of the month-long simulation time. A2 is a good foundation for the construction project.

A3 is a combination of the other alternatives and with that is more expensive. However, A3 does provide additional flushing through the system since both the north and south side of the Fortson Pond are open for conveyance. A3 model results indicates that the ellipse combination most improves flushing with lower water surface levels and increased conveyance, especially during peak periods, in both culvert locations. The A3 Comparison also improves flushing, although flow through the upper culver increases to a lesser degree, which is attributed to the change in the upper culvert configuration. The A3 Comparison results are similar to A2, except the comparison has the added benefit of draining the lower Fortson Pond with a decreased water surface level. We recommend moving forward with A3 as a construction project to enhance flushing and by extension, the water quality.

In conclusion, our evaluation of all alternatives presented in this report indicate Alternative-3 as providing the most benefit in terms of remediation of the Fortson Pond ecosystem, overall cost, and maintenance.

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Van Rijn, L. C. 2007b. *Unified View of Sediment Transport by Currents and Waves. II: Suspended Transport*. Journal of Hydraulic Engineering, Vol. 133, No. 6, 668-689. June 1, 2007.

APPENDIX A

Floodplain Comparison Maps

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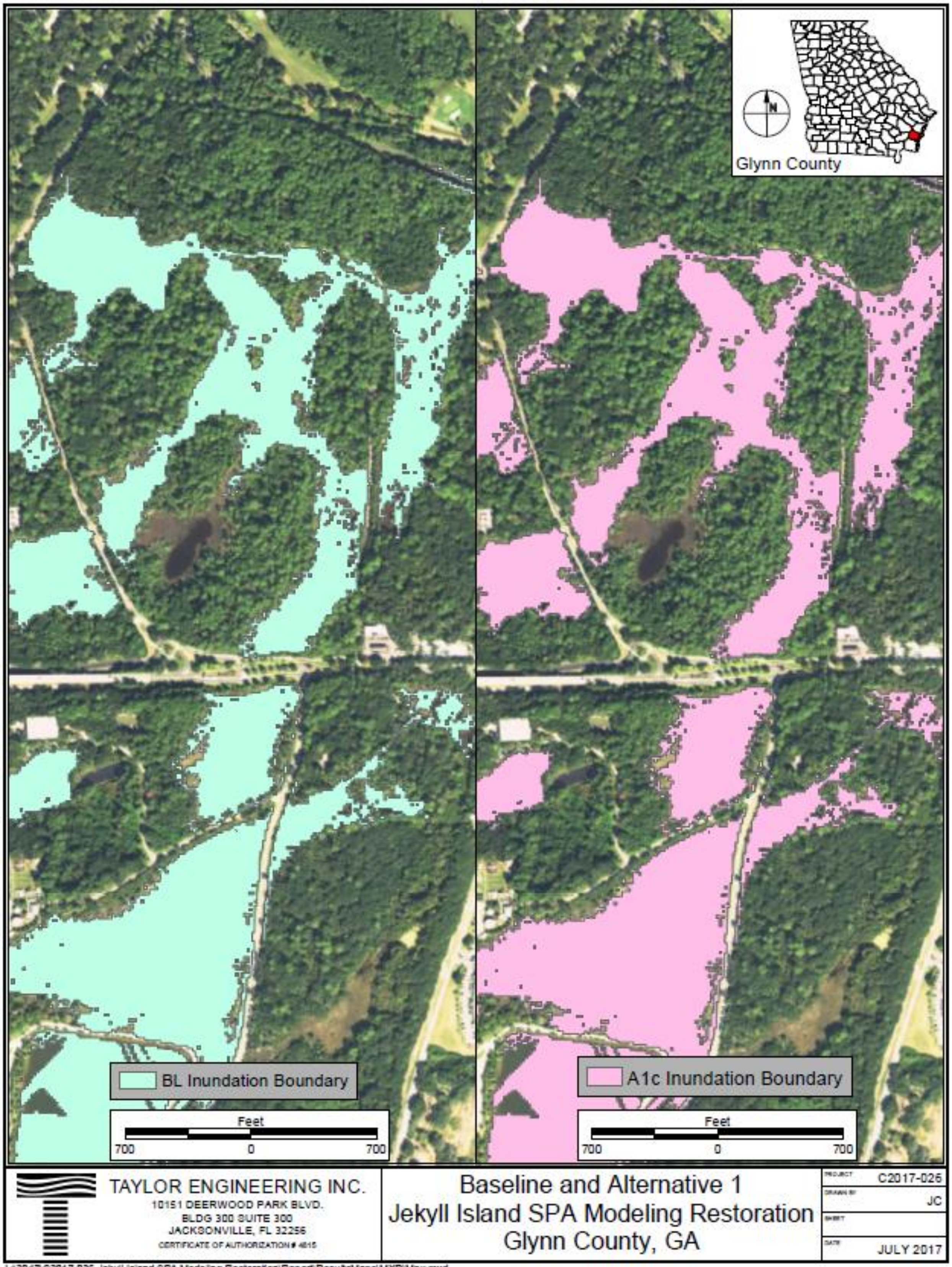
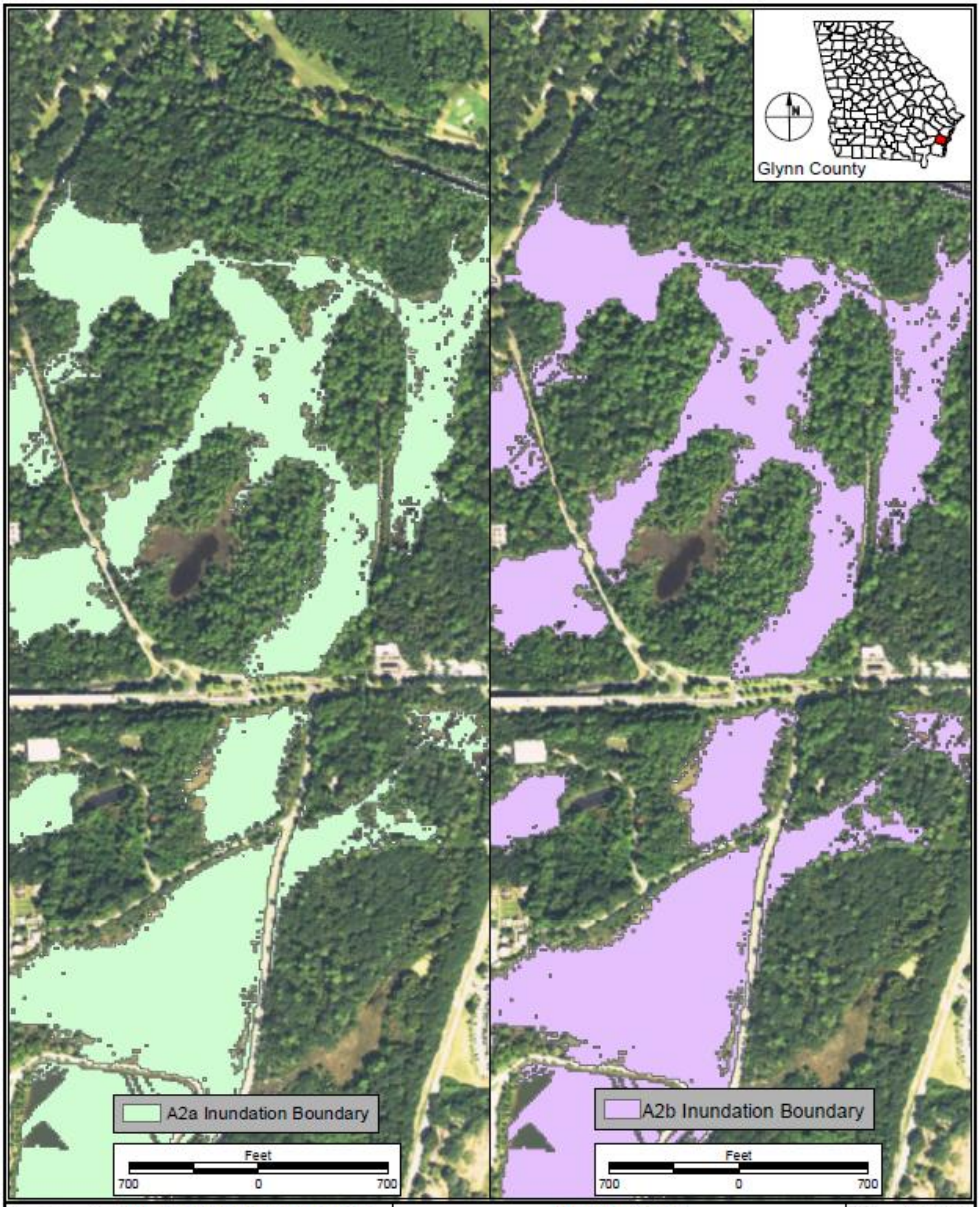

Glynn County
BL Inundation Boundary
Feet
700
0
700
A1c Inundation Boundary
Feet
700
0
700
TAYLOR ENGINEERING INC.
10151 DEERWOOD PARK BLVD.
BLDG 300 SUITE 300
JACKSONVILLE, FL 32256
Baseline and Alternative 1
Jekyll Island SPA Modeling Restoration
Glynn County, GA
C2017-026
JC
JULY 2017



TAYLOR ENGINEERING INC. 10151 DEERWOOD PARK BLVD. BLDG 300 SUITE 300 JACKSONVILLE, FL 32256 CERTIFICATE OF AUTHORIZATION # 4815	Alternative 2 Jekyll Island SPA Modeling Restoration Glynn County, GA	PROJECT	C2017-026
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		DATE	JULY 2017

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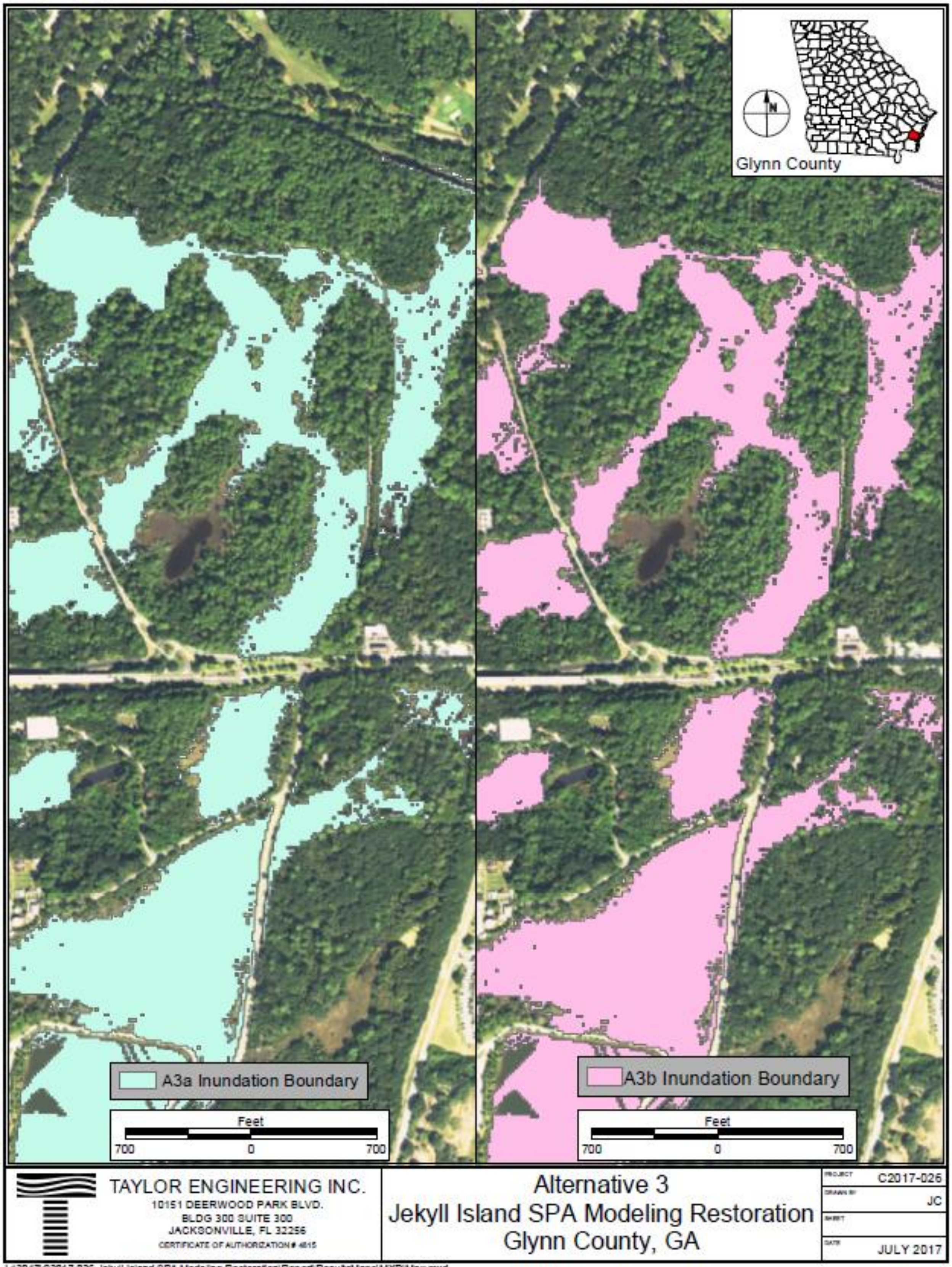

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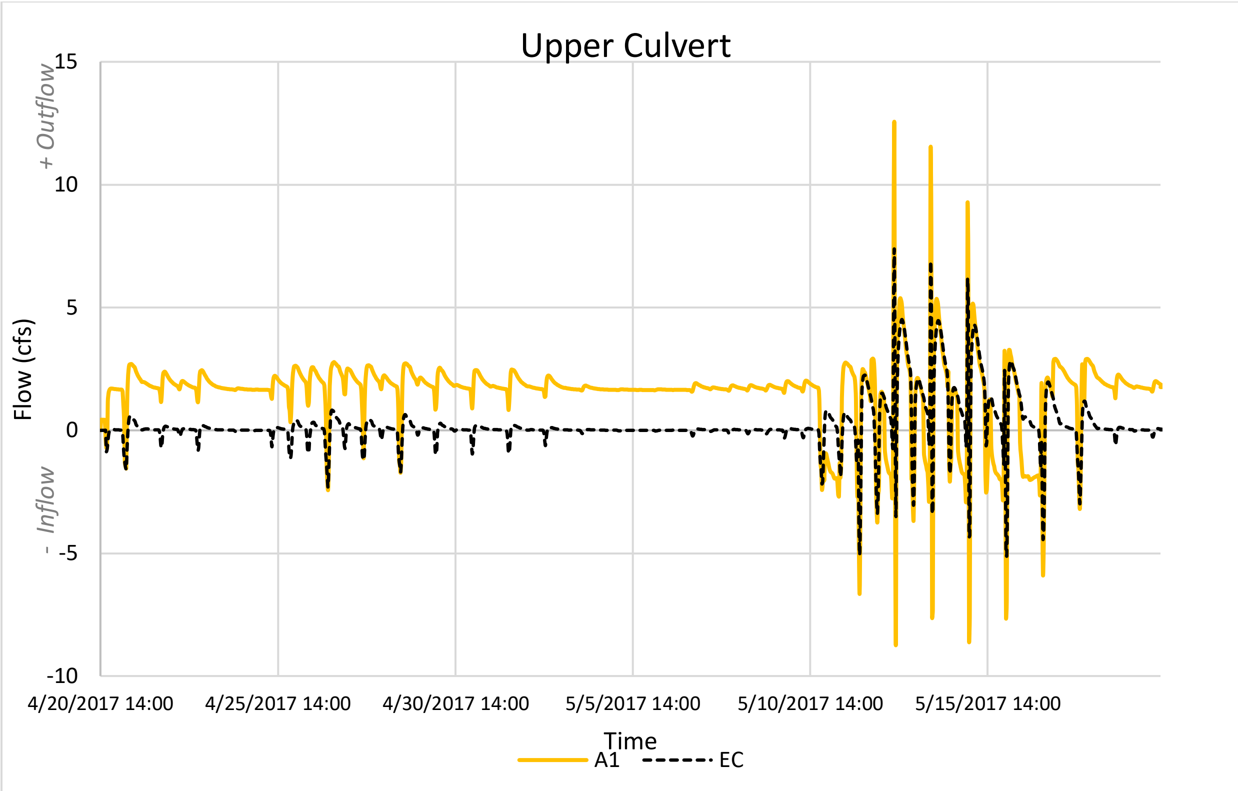
APPENDIX B

Modeled Flow Hydrographs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- Inflow
Flow (cfs)
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10
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-5
-10
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4/25/2017 14:00
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Time
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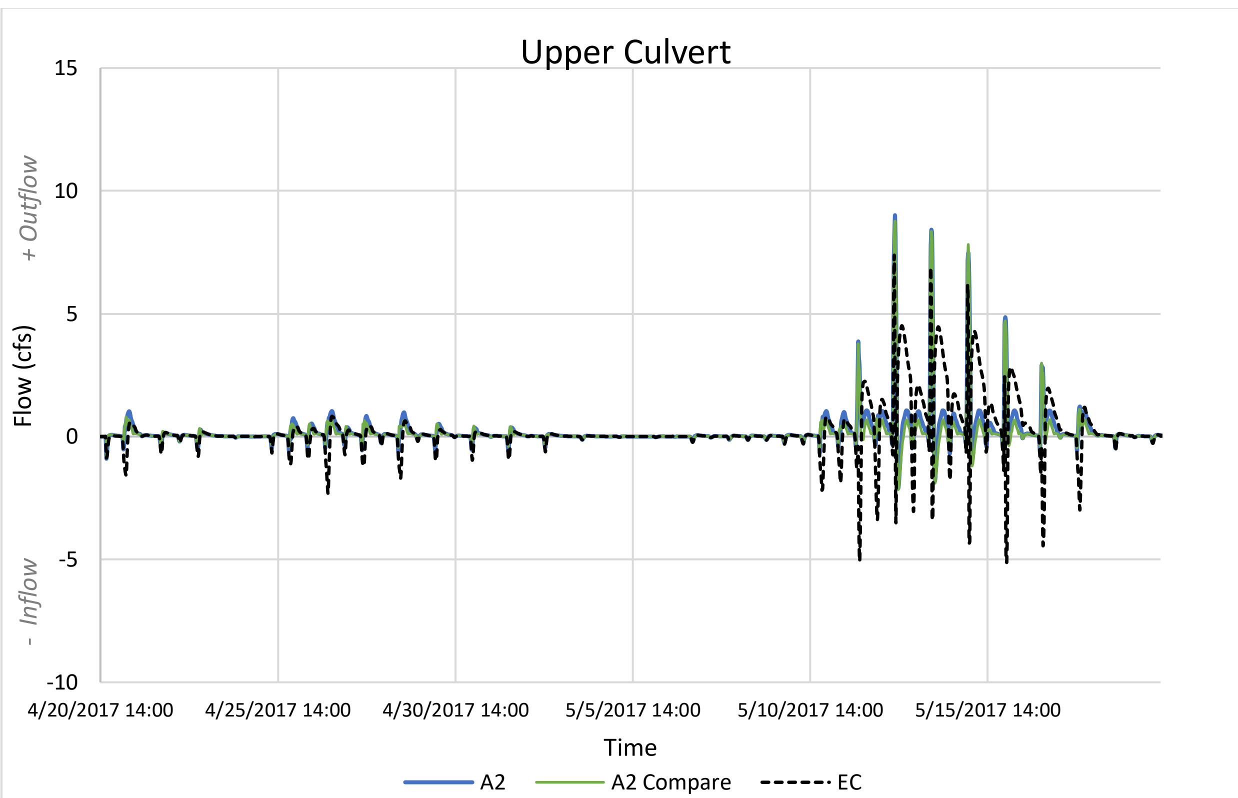
EC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Flow (cfs)
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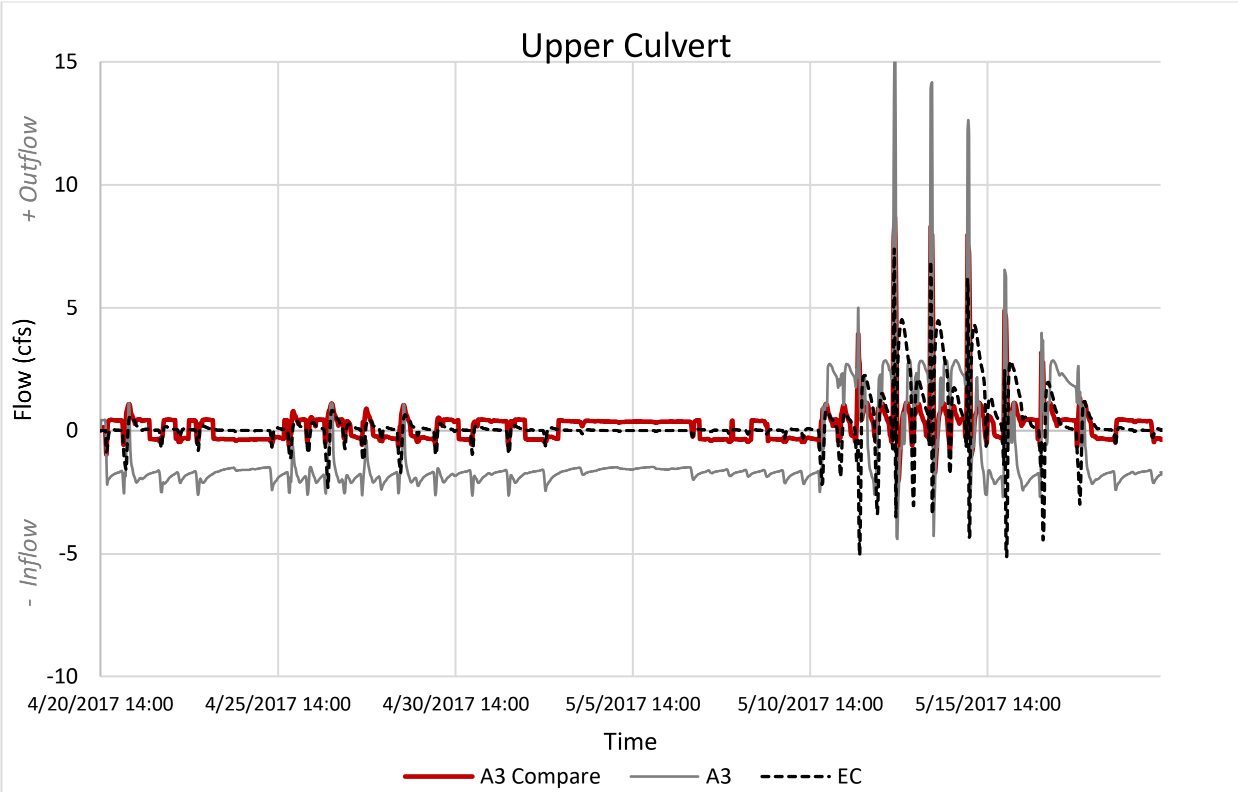
A2 Compare
EC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+ Outflow
- Inflow
Flow (cfs)
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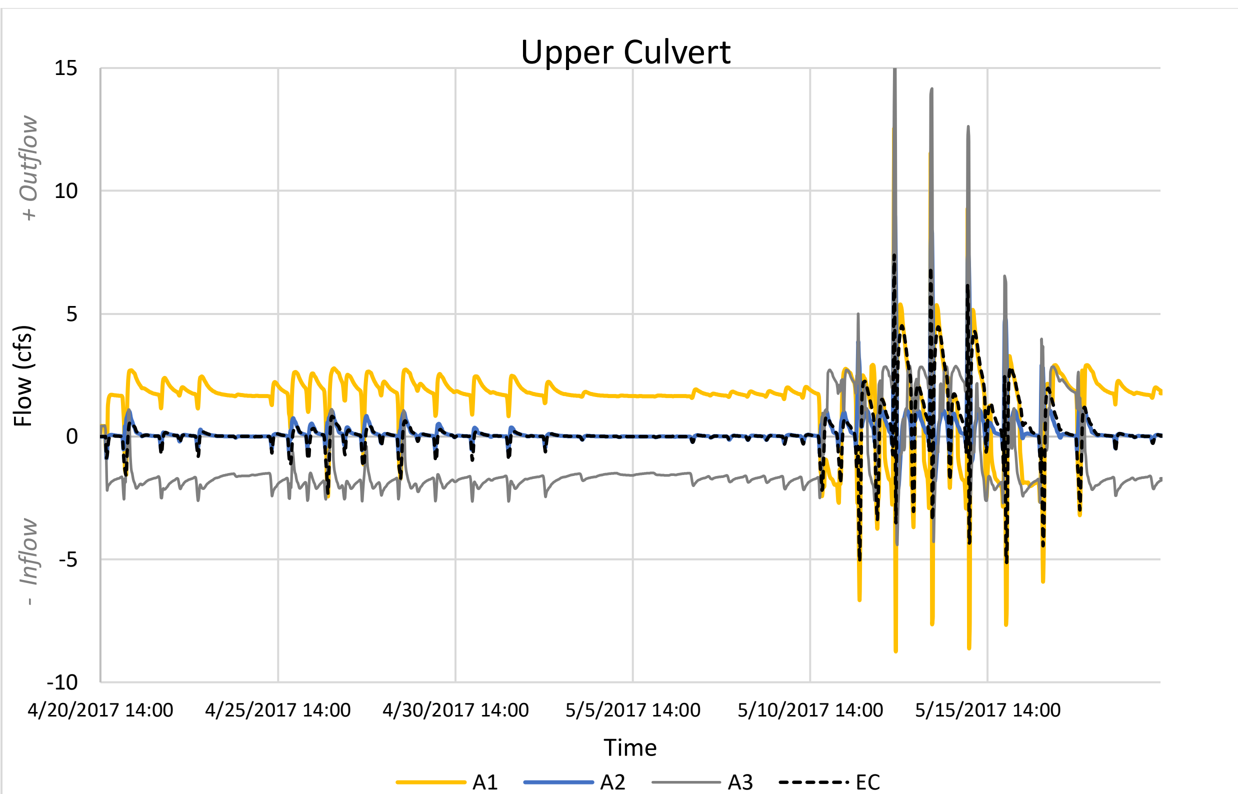
A3
EC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+ Outflow
- Inflow
Flow (cfs)
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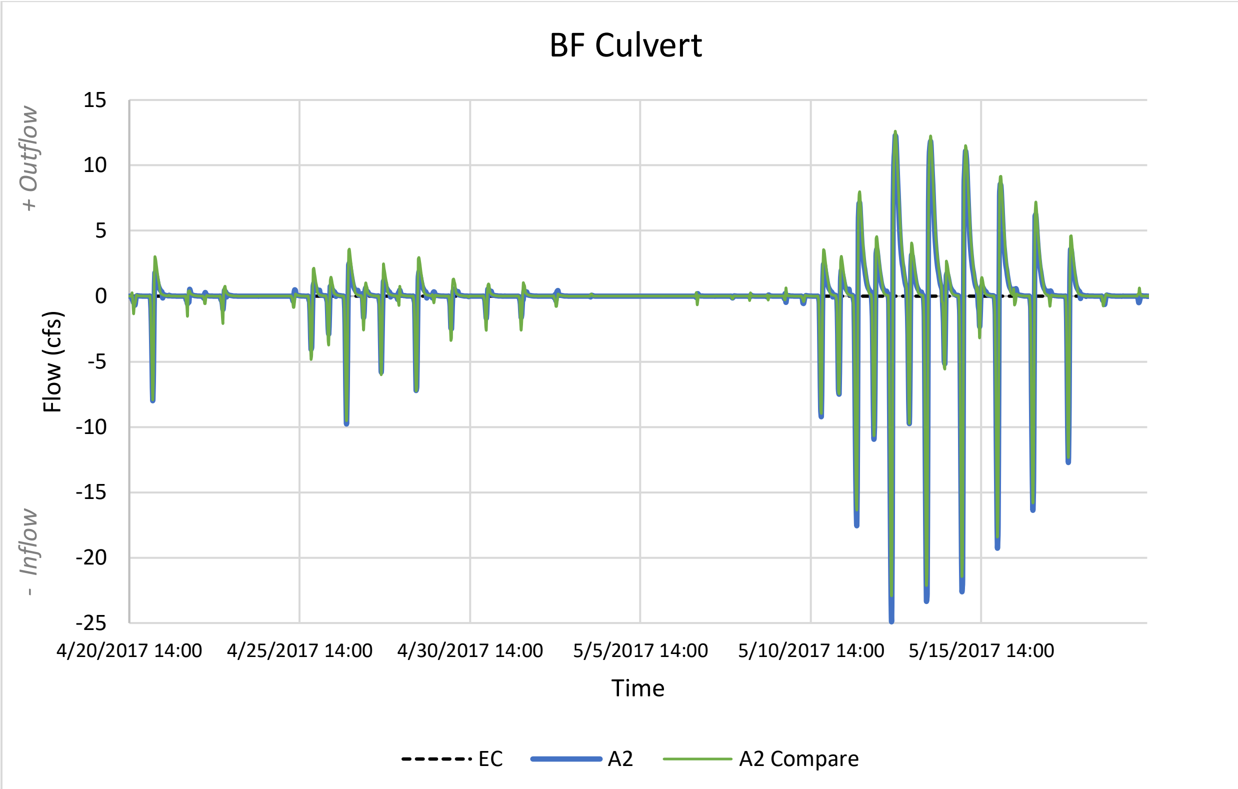
A1
A2
A3
EC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Flow (cfs)
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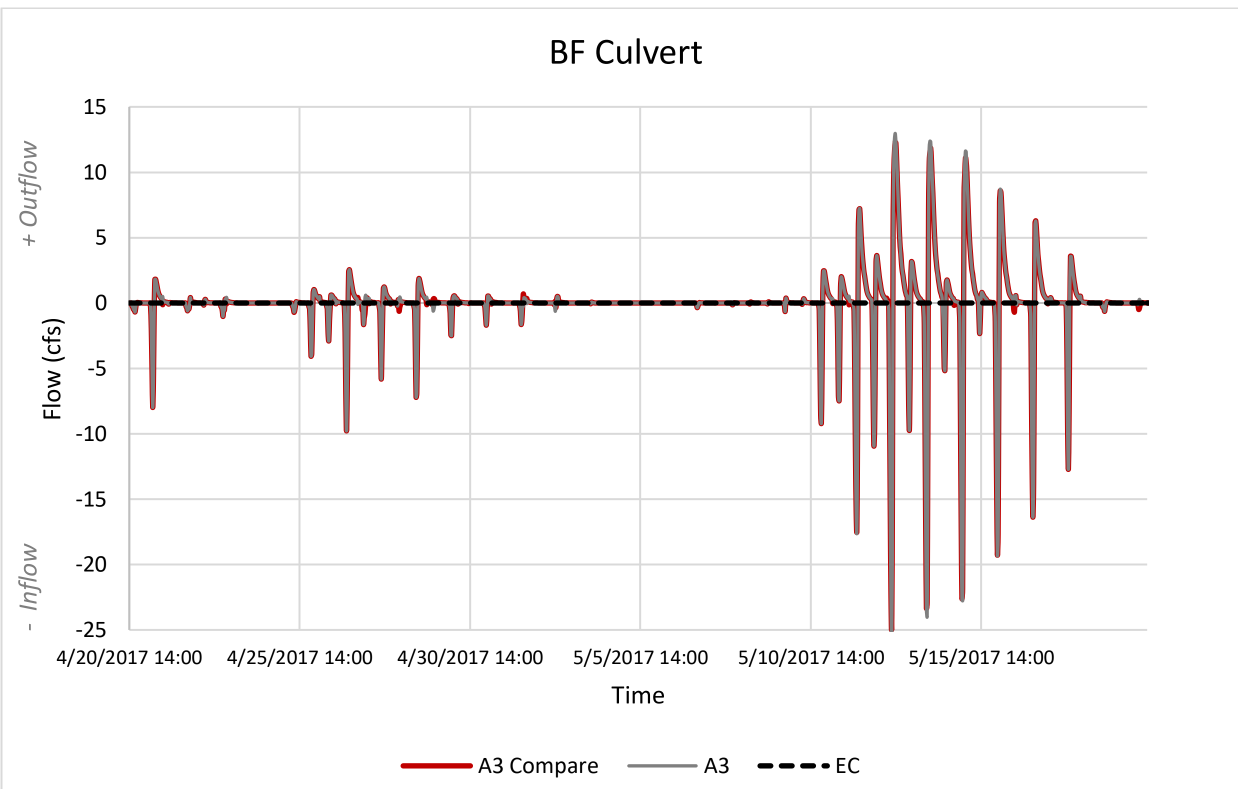
A2 Compare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Flow (cfs)
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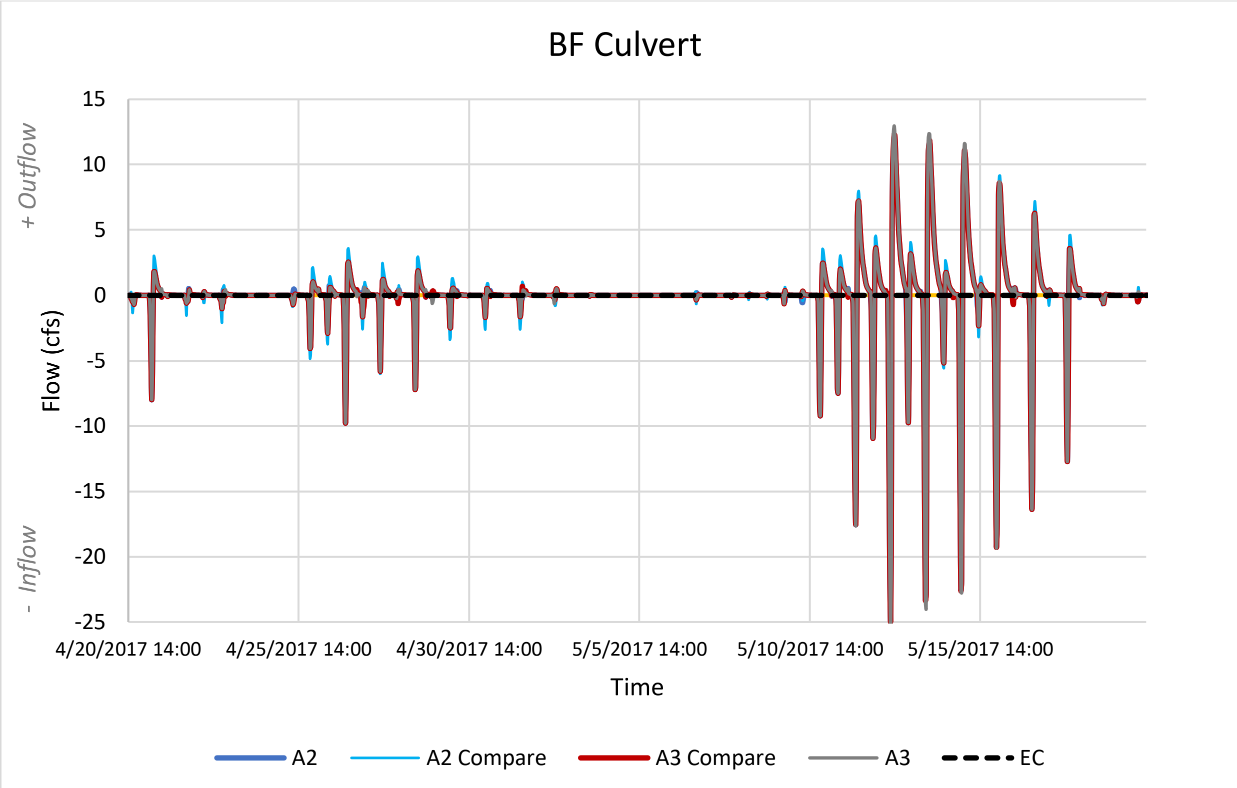
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A2 Compare
A3 Compare
A3
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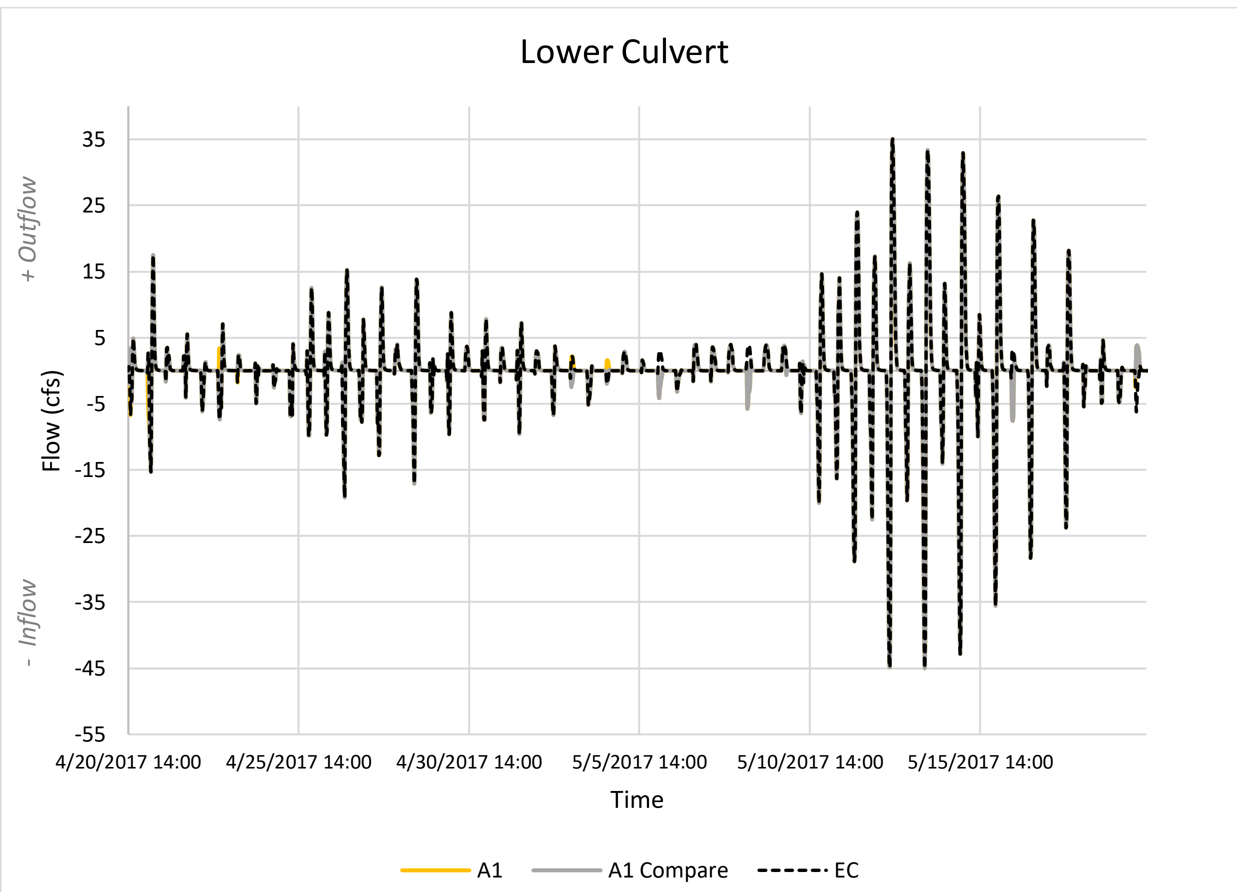
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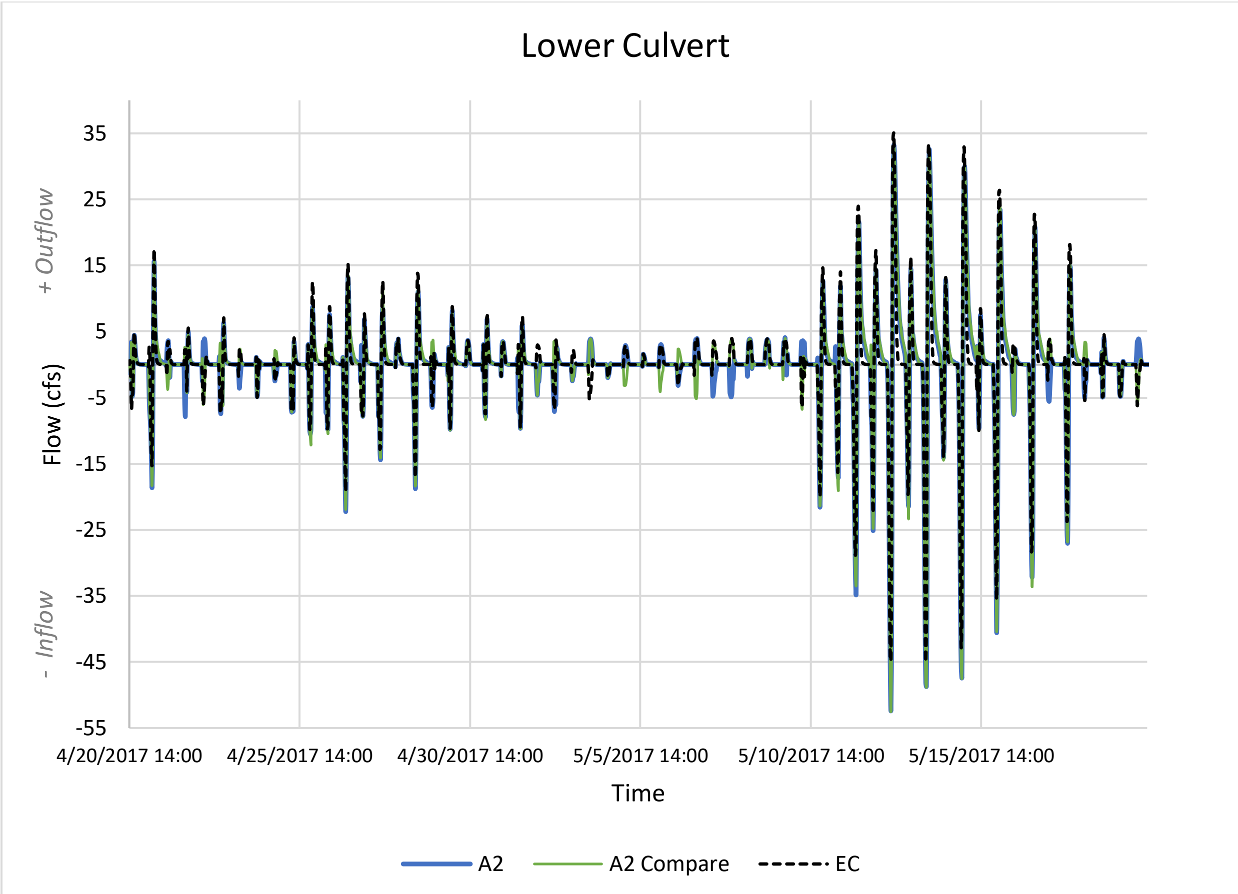
EC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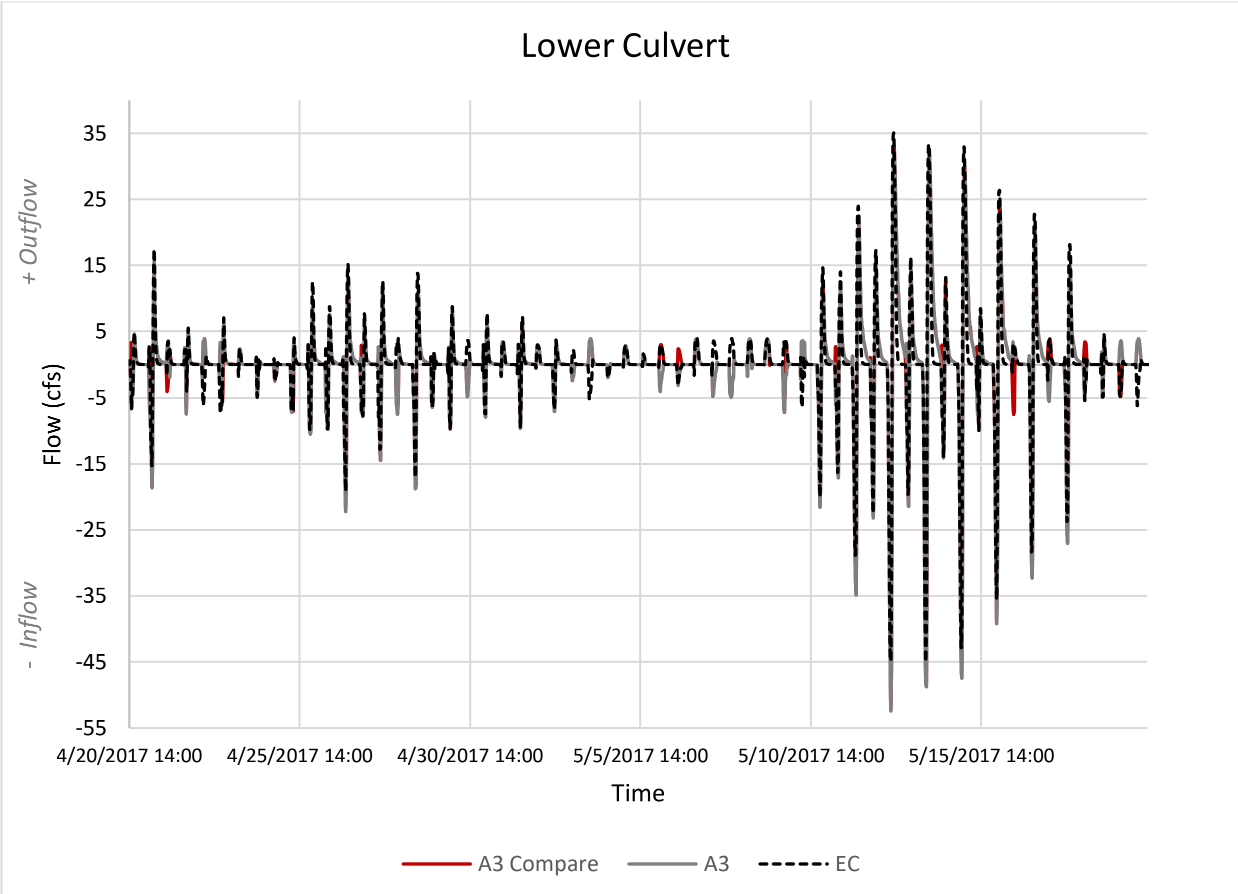
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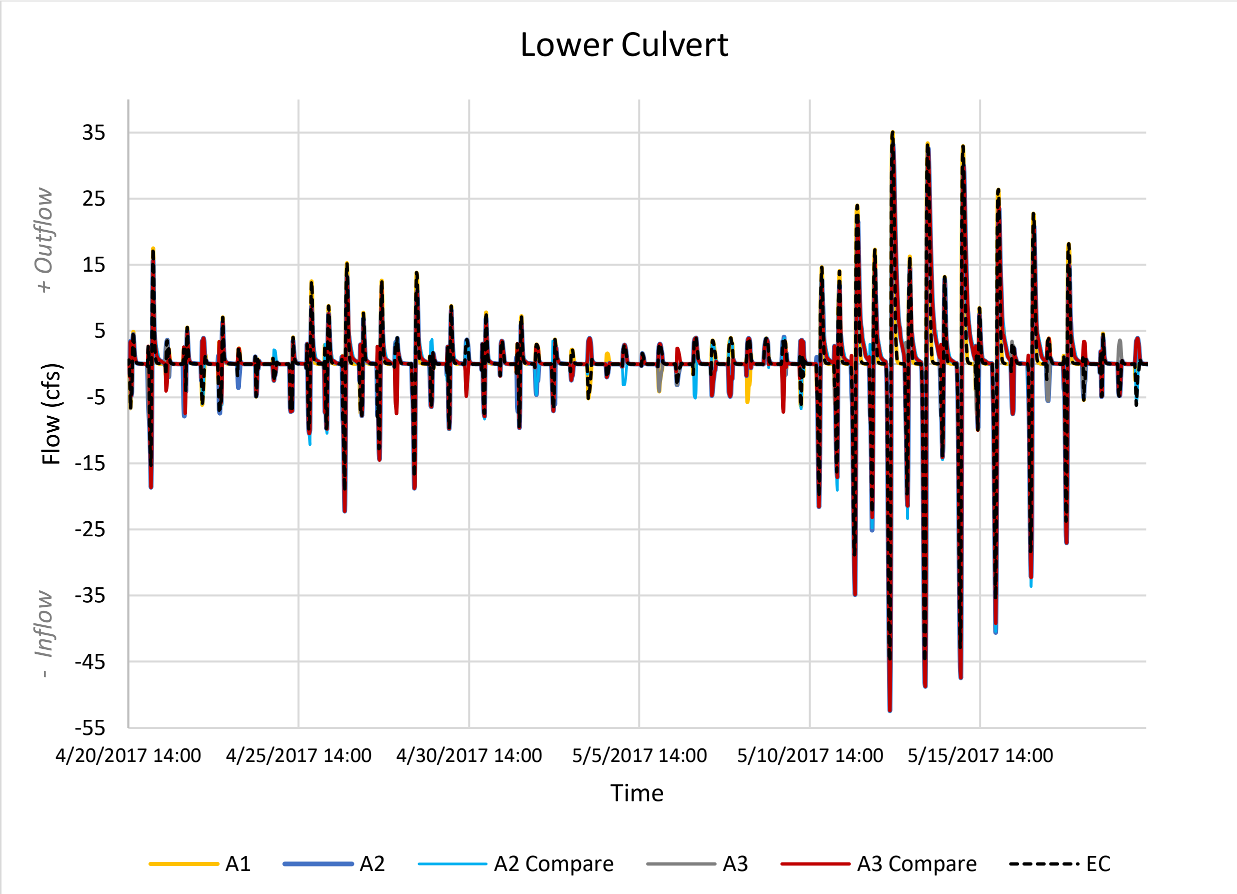
EC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Flow (cfs)
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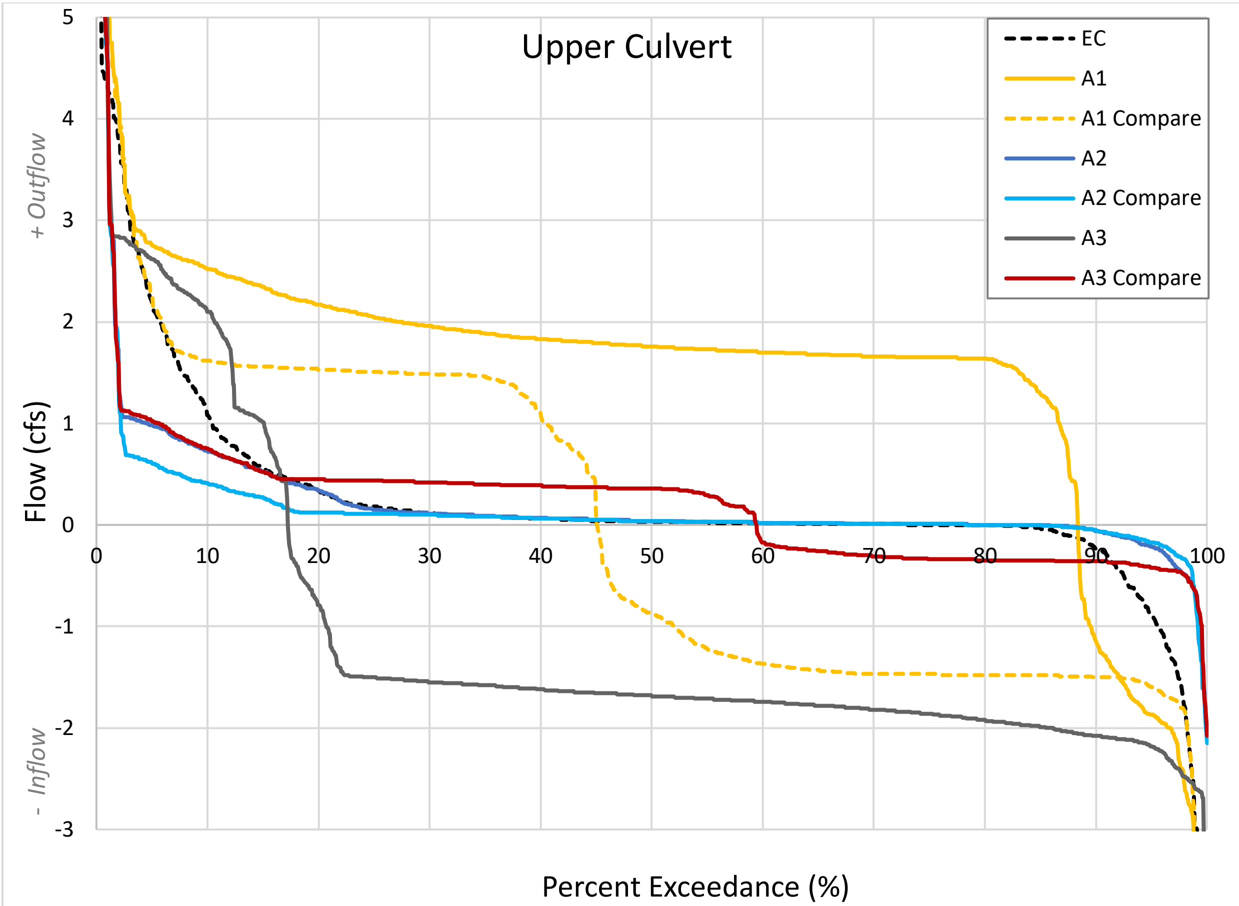
Time
A1
A2
A2 Compare
A3
A3 Compare
EC

APPENDIX C

Simulation Flow Duration Curves


Upper Culvert
EC
A1
A1 Compare
A2
A2 Compare
A3
A3 Compare
Flow (cfs)
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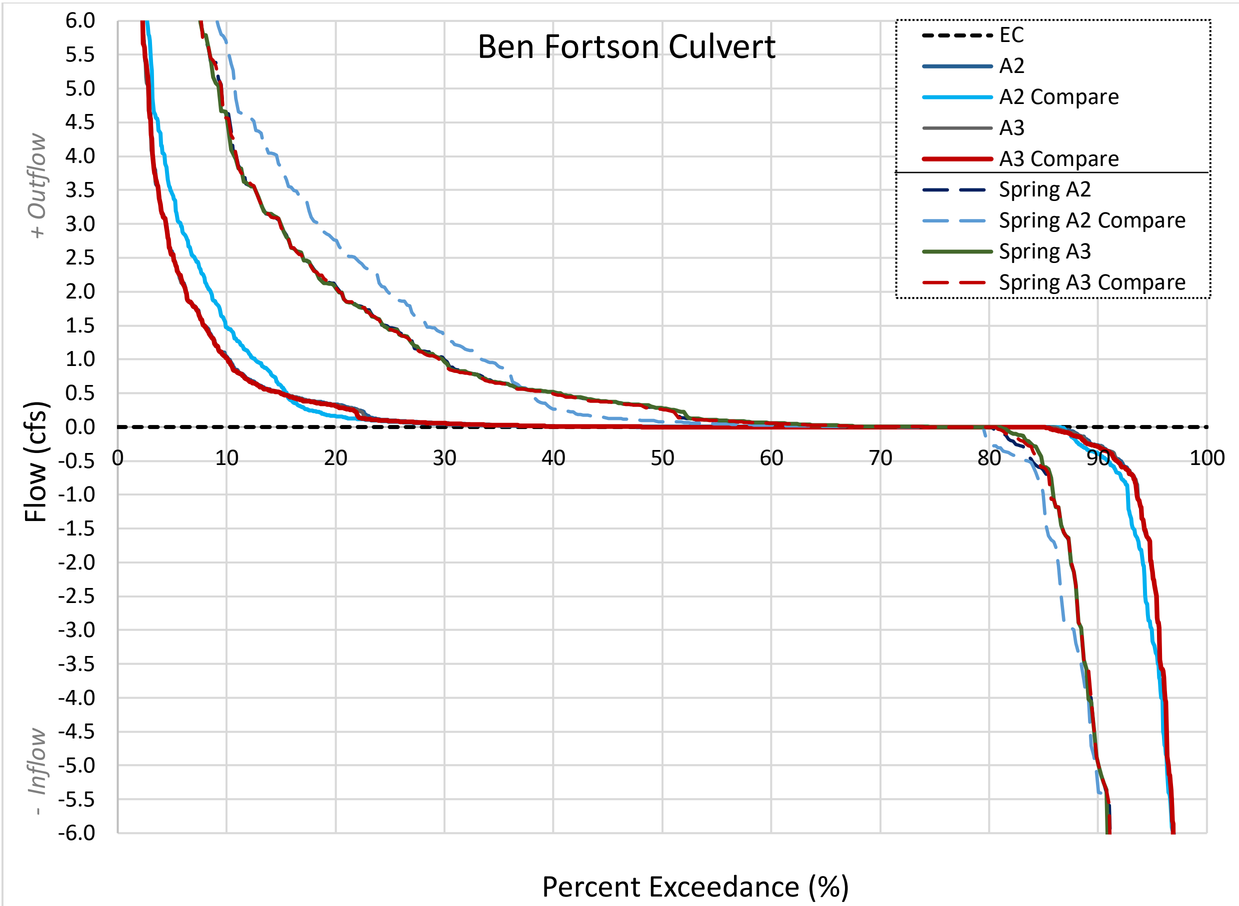
- Inflow
5
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedance (%)


Ben Fortson Culvert
EC
A2
A2 Compare
A3
A3 Compare
Spring A2
Spring A2 Compare
Spring A3
Spring A3 Compare
+ Outflow
- Inflow
Flow (cfs)
Percent Exceedance (%)
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5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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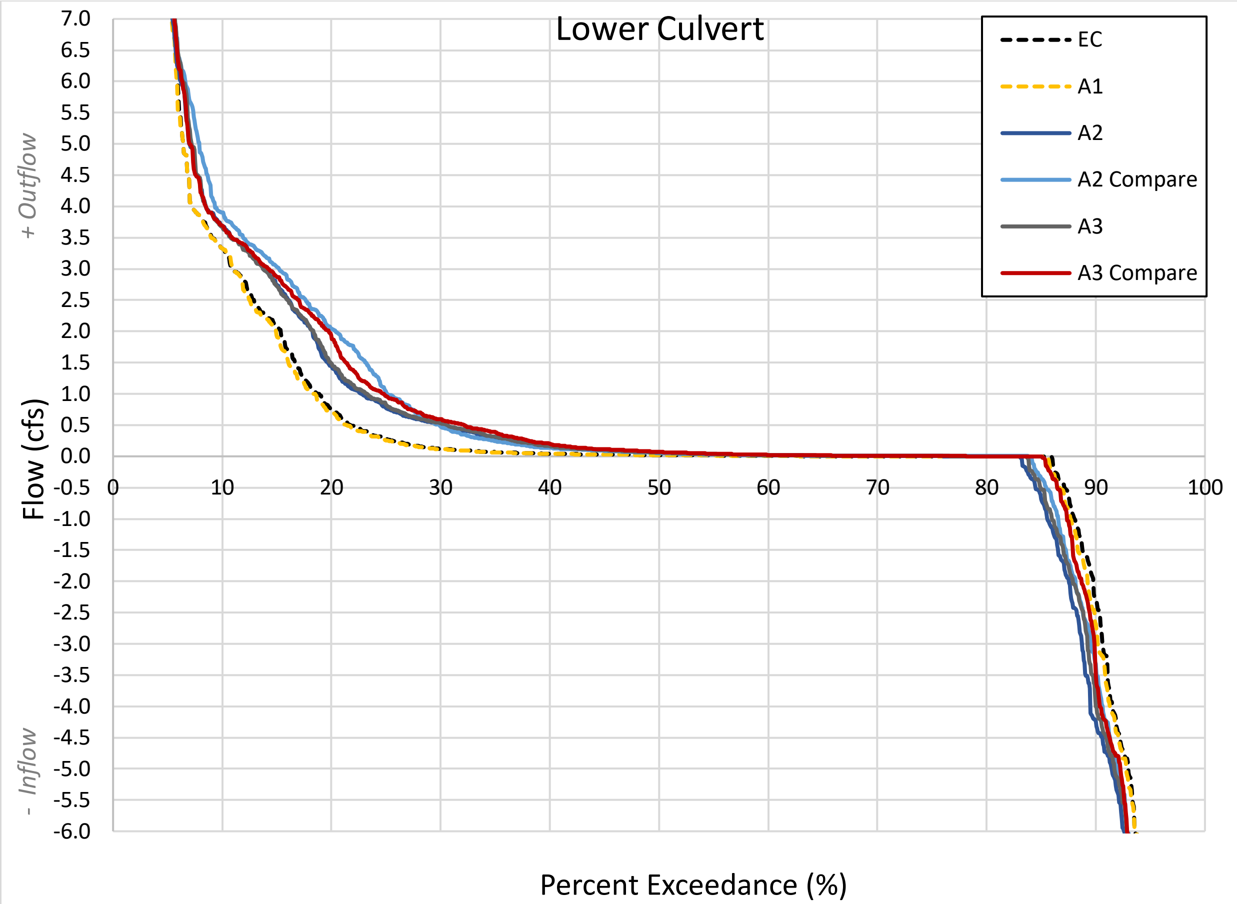
Lower Culvert
EC
A1
A2
A2 Compare
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A3 Compare
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Flow (cfs)
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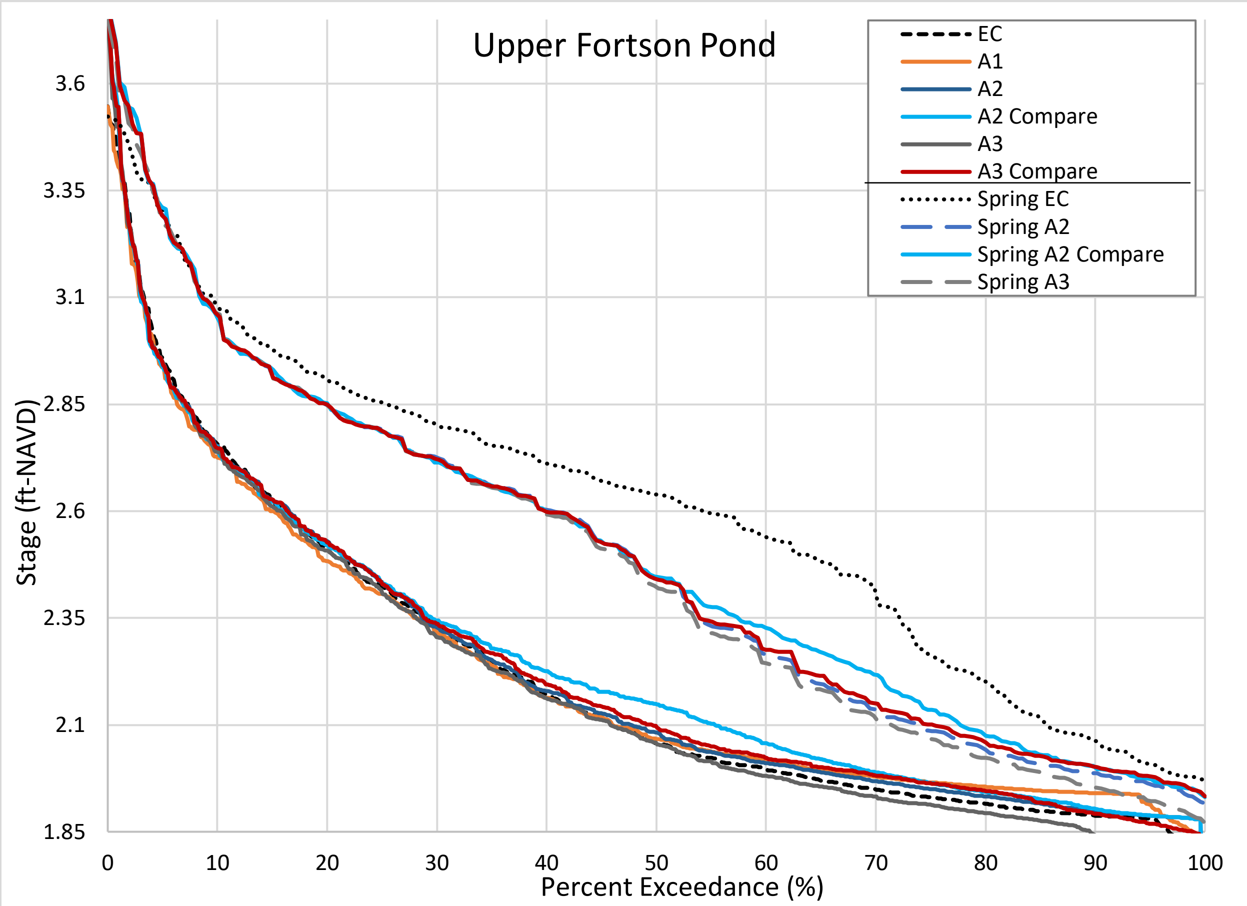
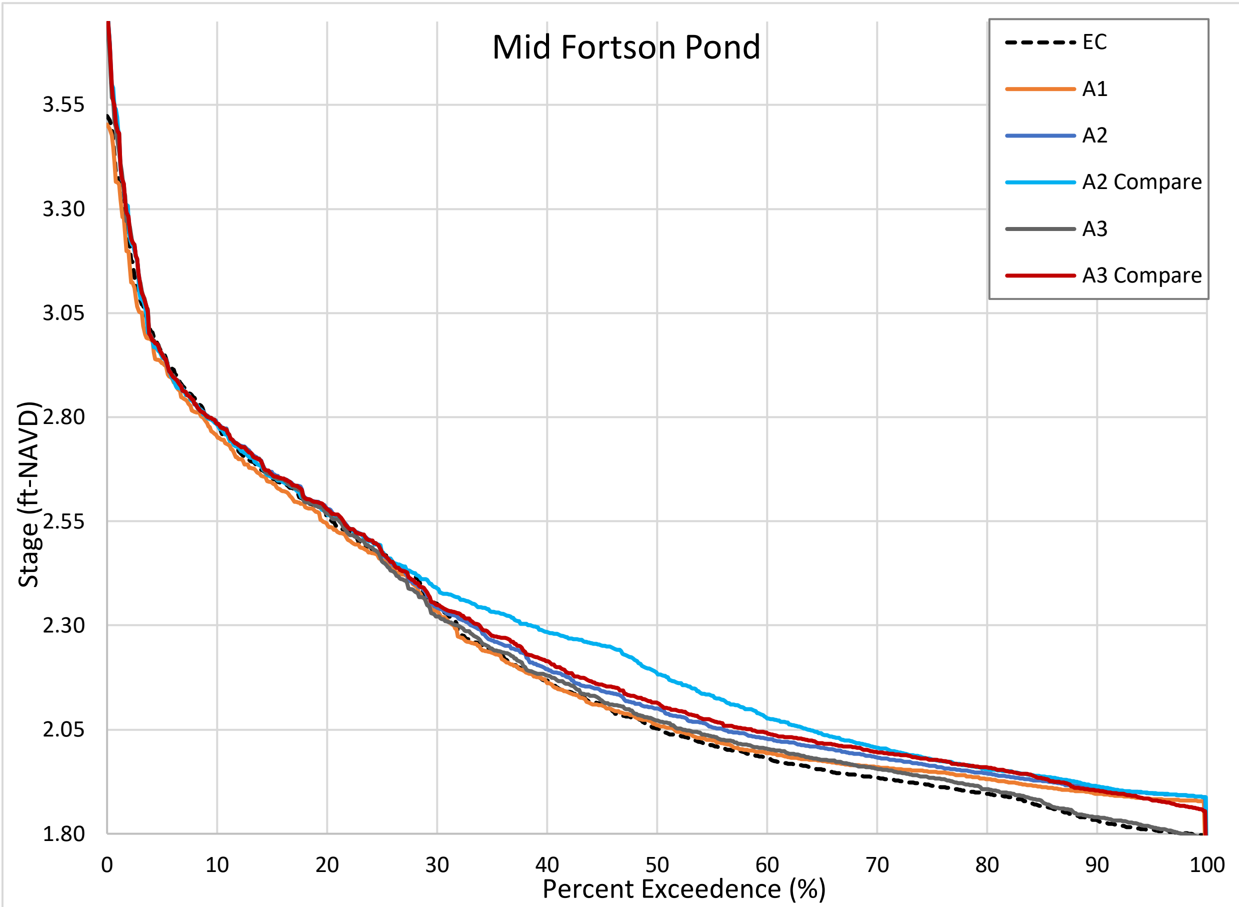
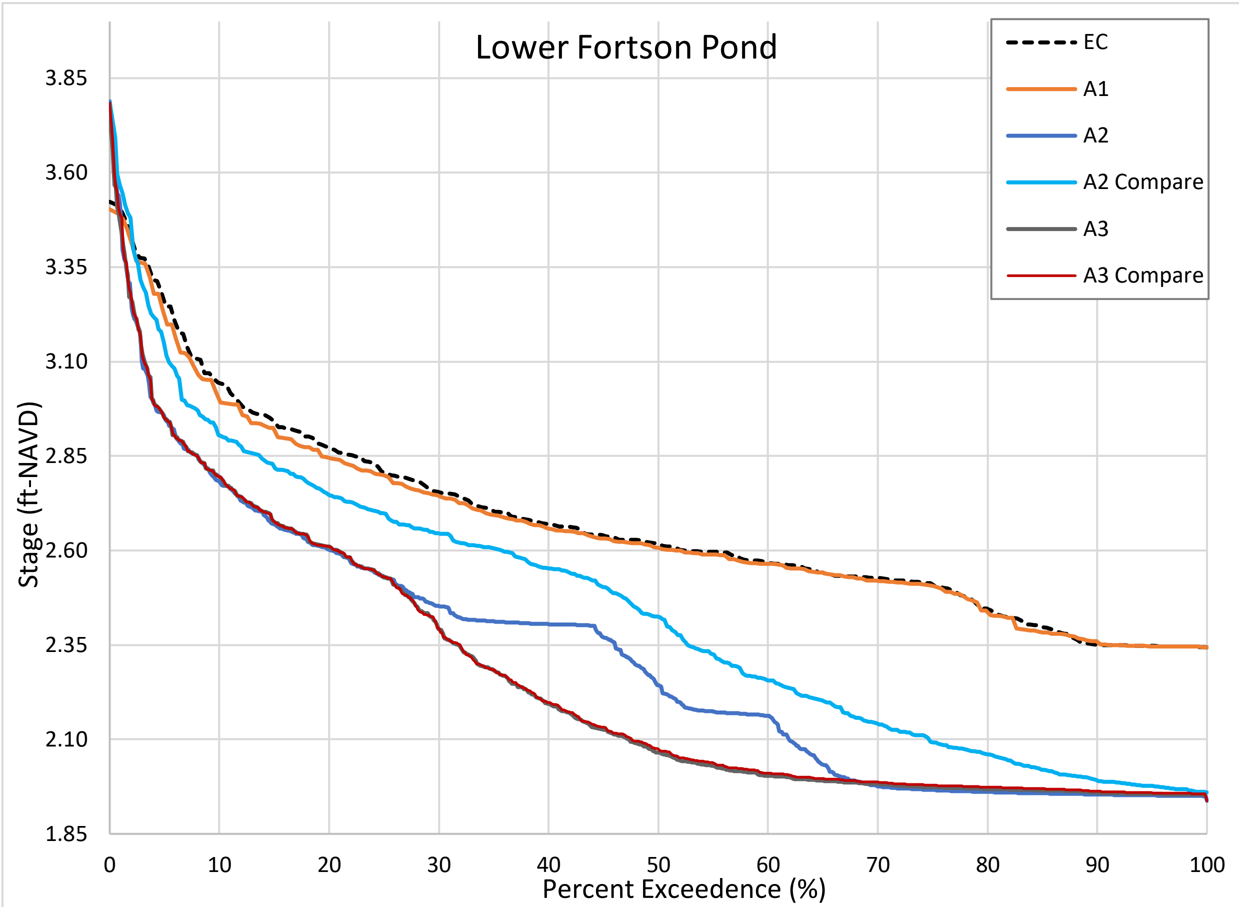
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedance (%)

APPENDIX D

Simulation Stage Duration Curves


Upper Fortson Pond
EC
A1
A2
A2 Compare
A3
A3 Compare
Spring EC
Spring A2
Spring A2 Compare
Spring A3
Stage (ft-NAVD)
3.6
3.35
3.1
2.85
2.6
2.35
2.1
1.85
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedance (%)


Mid Fortson Pond
EC
A1
A2
A2 Compare
A3
A3 Compare
Stage (ft-NAVD)
3.55
3.30
3.05
2.80
2.55
2.30
2.05
1.80
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedence (%)


Lower Fortson Pond
Stage (ft-NAVD)
3.85
3.60
3.35
3.10
2.85
2.60
2.35
2.10
1.85
0
10
20
30
40
50
60
70
80
90
100
Percent Exceedence (%)
EC
A1
A2
A2 Compare
A3
A3 Compare