

APPENDIX C

ICPR4 2D Model Setup

MEMORANDUM

TO: RAJU VASANSETTI, P.E. (WESTON & SAMPSON)
FROM: PETE SINGHOFEN, P.E. (STREAMLINE TECHNOLOGIES, INC.)
SUBJECT: CHURCH CREEK BASIN – ICPR4 2D MODEL SETUP
DATE: AUGUST 11, 2017
CC: ROBERT L. HORNER, P.E. (WESTON & SAMPSON)

1. Introduction – Weston & Sampson contracted Streamline Technologies, Inc. to port the most recent ICPR3 model of the Church Creek Basin in Charleston, South Carolina to ICPR4 and then to set it up for 2D overland flow. Initial tests were conducted on the preliminary ICPR4 model. The preliminary model accompanies this memorandum. The computational meshes have been constructed and numerous simulations have been executed. The output files are included in the project files for the preliminary model. Weston & Sampson will make final refinements to the model and make the production runs.

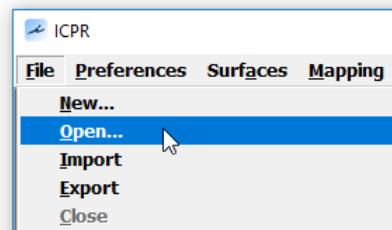
The purpose of this memorandum is to summarize the ICPR4 model setup for the Church Creek Basin. The general steps are outlined below.

- a. The latest Woolpert ICPR3 model data was imported into ICPR4. Note that the Woolpert model utilized the NGVD 1929 vertical datum and the ICPR4 model is based on the NAVD 1988 vertical datum. An adjustment of -0.97 ft was applied to all vertical data in the Woolpert dataset before importing to ICPR4.
- b. The nodes were spatially referenced by importing a shapefile of the node locations. The NAD 1983 NSRC2007 South Carolina State Plane coordinate reference system was used in the ICPR4 model.
- c. Spatial data was not available for links or cross sections. The ICPR4 “Place Link” tool was used to create simple 2-point polyline connections for each link.
- d. Each link polyline was spatially located by manually editing their respective polylines as best as possible using visual cues from aerial imagery and terrain data in the form of a DEM.
- e. The following base data were imported to ICPR4:
 - i. 2016 aerial imagery
 - ii. LiDAR-based DEM (10-foot grid)
 - iii. Soils map layer with soil hydrologic groups
 - iv. Land use map layer (drawn in ArcMap)

- v. Original ICPR3 basin map layer
- f. The following lookup tables were prepared:
 - i. Curve numbers
 - ii. Impervious percentages
 - iii. Roughness coefficients for 2D overland flow
 - iv. Boundary stage tables
- g. 2D graphic elements used for computational mesh construction were manually drawn and encompassed the following categories:
 - i. Elements to interface with 1D model components
 - ii. Elements for terrain characterization
 - iii. Elements for boundary conditions
- h. Preliminary meshes were constructed and reviewed. Refinements were made and the final computational meshes were constructed.
 - i. Simulation control data were prepared for the 2-, 10-, 25-, 50-, 100- and 500-year storm events and the August 2015 and October 2015 storms. These were executed and preliminary results were reviewed for reasonableness.

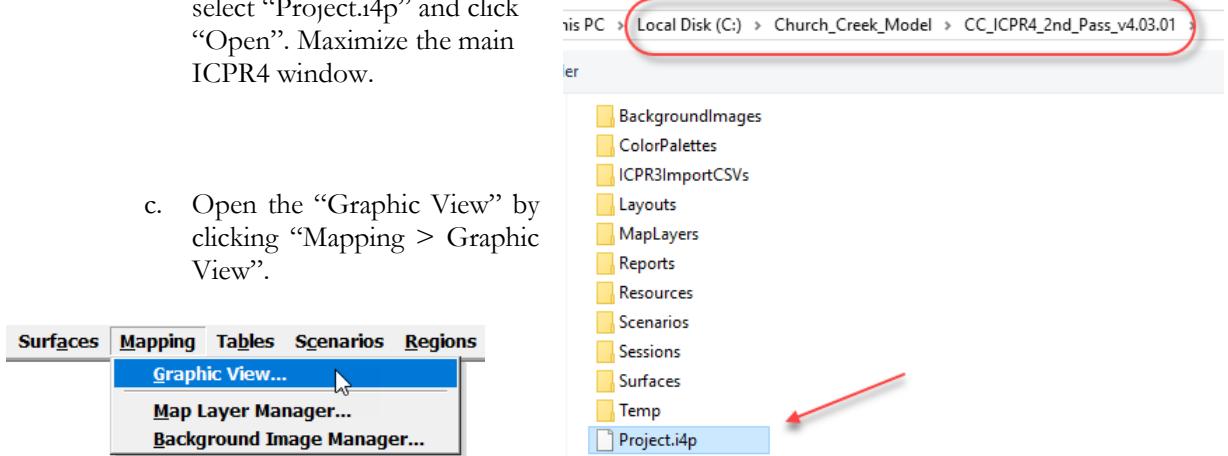
2. Opening the Project and Graphic View

- a. After opening ICPR4, click “File > Open”

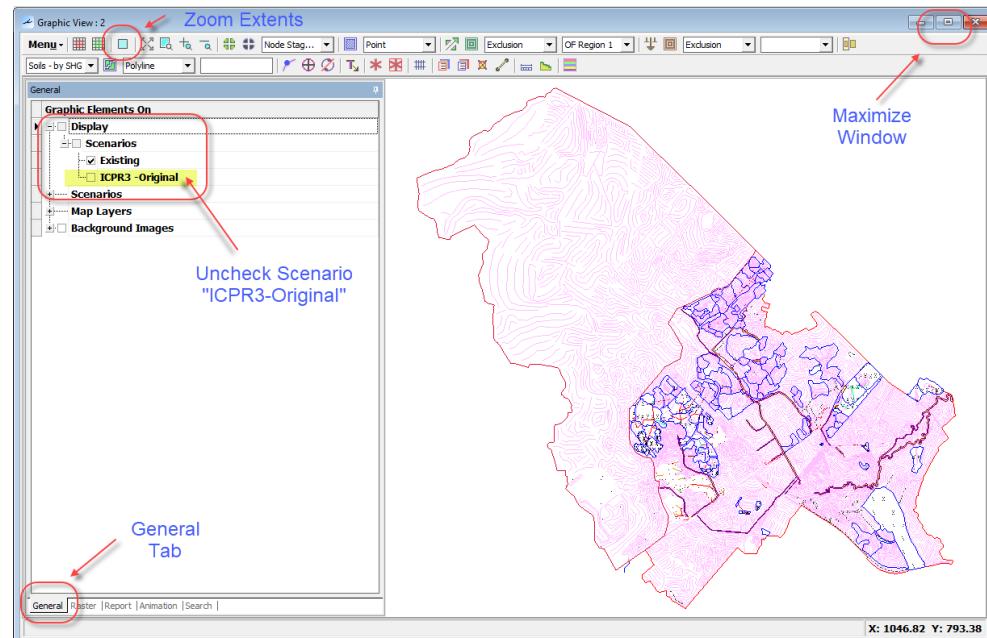


b. Navigate to the project folder, select “Project.i4p” and click “Open”. Maximize the main ICPR4 window.

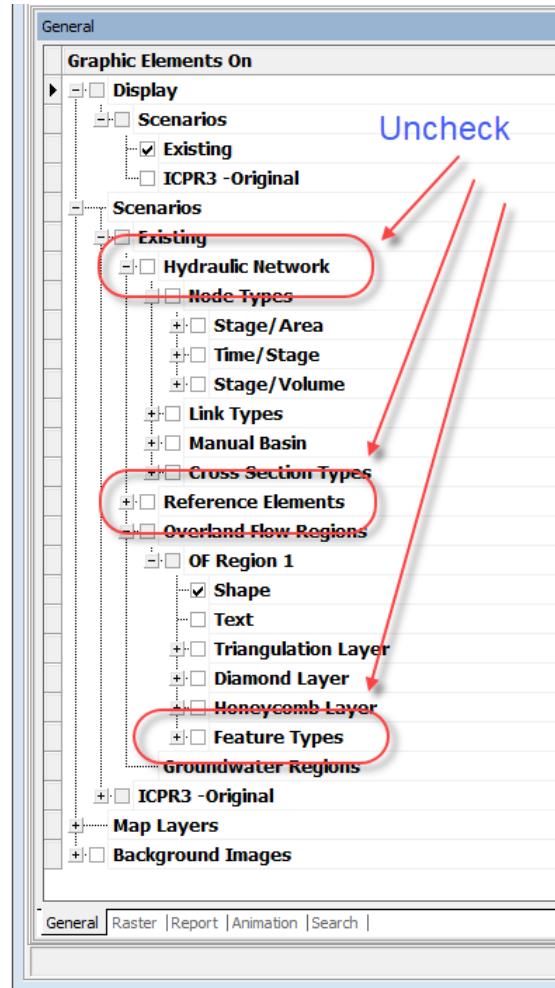
c. Open the “Graphic View” by clicking “Mapping > Graphic View”.



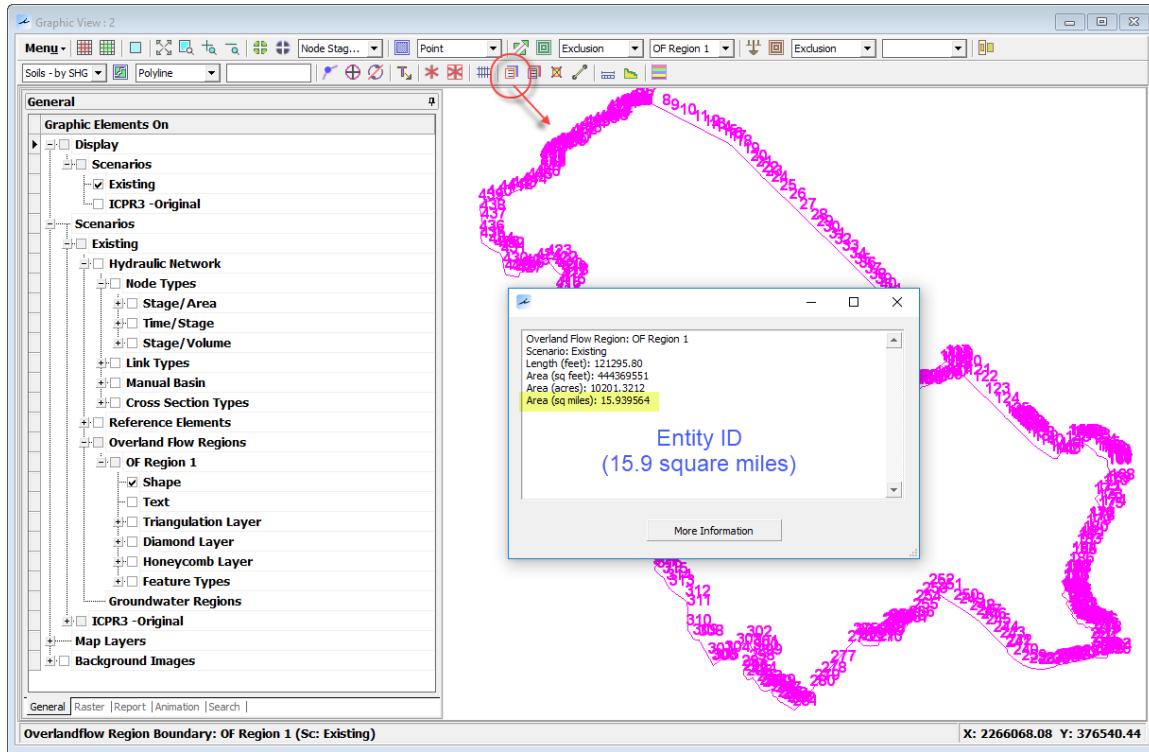
d. Maximize this window and click the “zoom extents” icon. Expand the “Display” options and uncheck scenario “ICPR3-Original”. Note that after importing the ICPR3 data, spatially referencing nodes and placing 2-point polyline link connections, a copy (clone) of the scenario was made to preserve the original data and is called “ICPR3-Original”. Scenario “Existing” contains all the changes and modifications needed for the 2D version of the model. The modified data can be compared with the original data by toggling on the “Display” for the scenario. It is generally better to leave the display turned off for this scenario to avoid confusion unless you want to compare data and the model setup.



e. Toggle off the hydraulic network, reference elements and overland flow features for now. These will be toggled on later as each item is discussed.

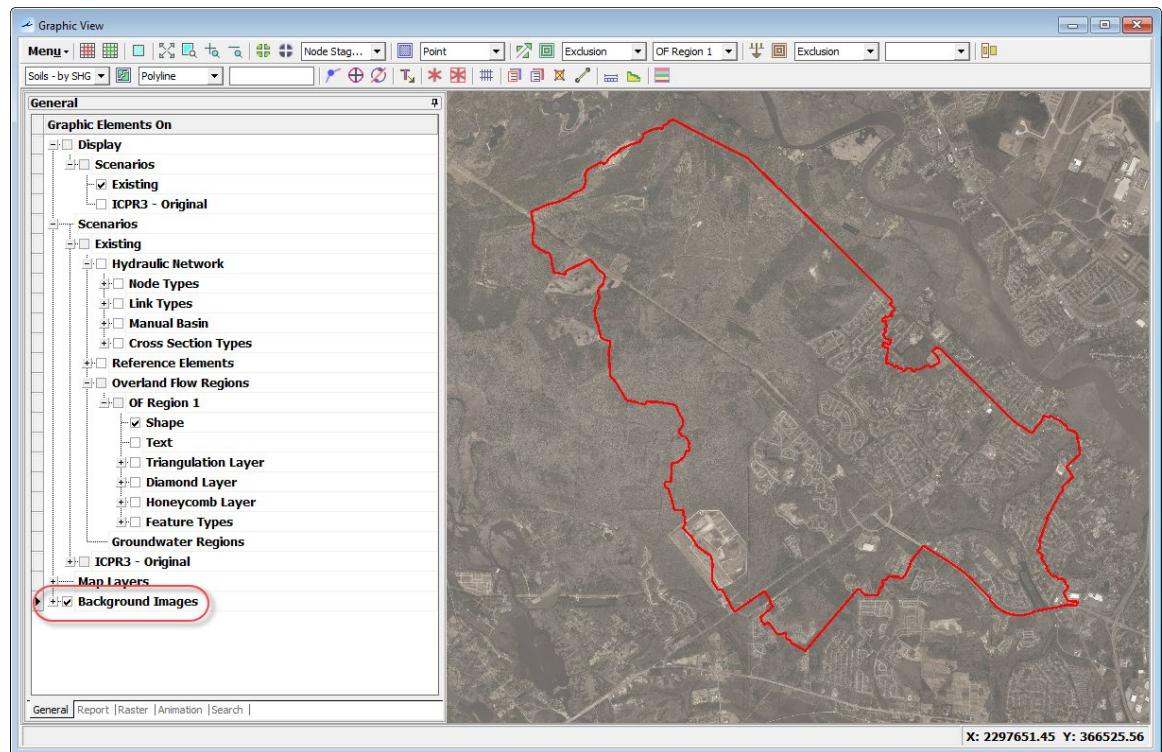


f. The only item on at this point is the overland flow region boundary which is the study area. Use the entity ID tool to see the area which is 15.9 square miles in size. This is almost double the size of the Woolpert ICPR3 study area of 8.5 square miles.

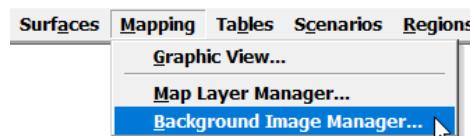


3. Base Data

a. Aerials – 2016 aerial imagery (1-foot pixels) was obtained online from Charleston County in the form of 25 jpg images. These were imported to ICP4 as background images. They can be toggled on and off from the data tree of the graphic view as shown below.



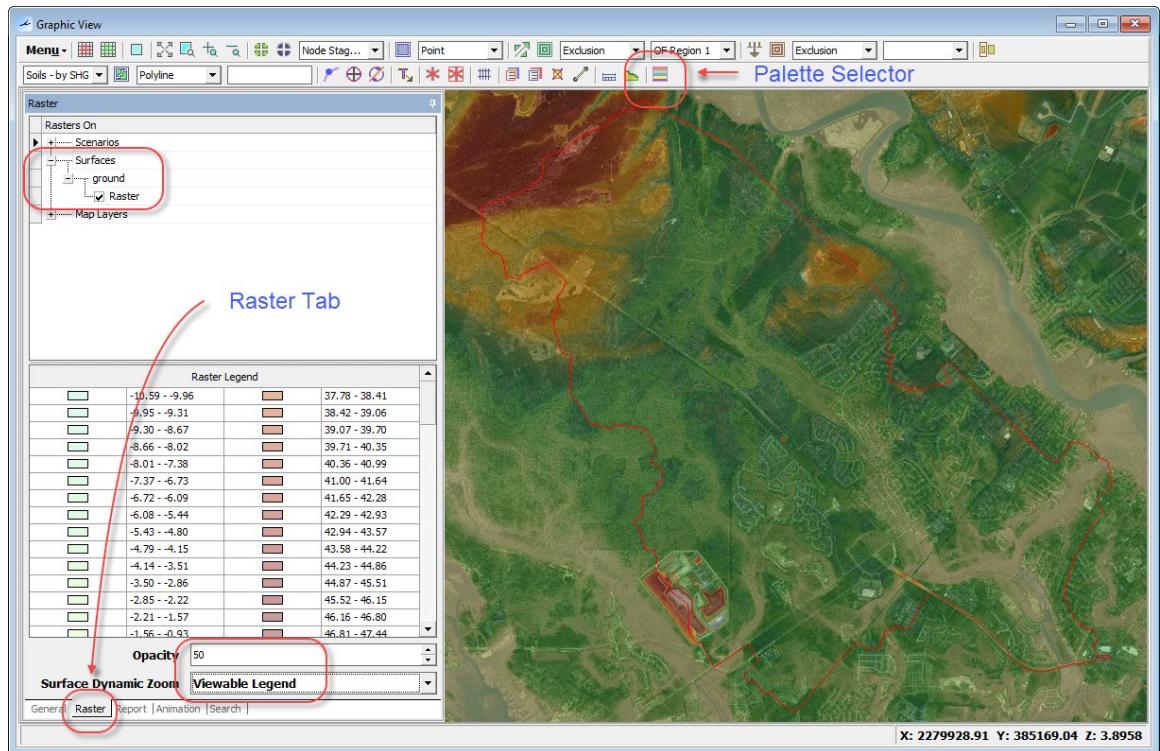
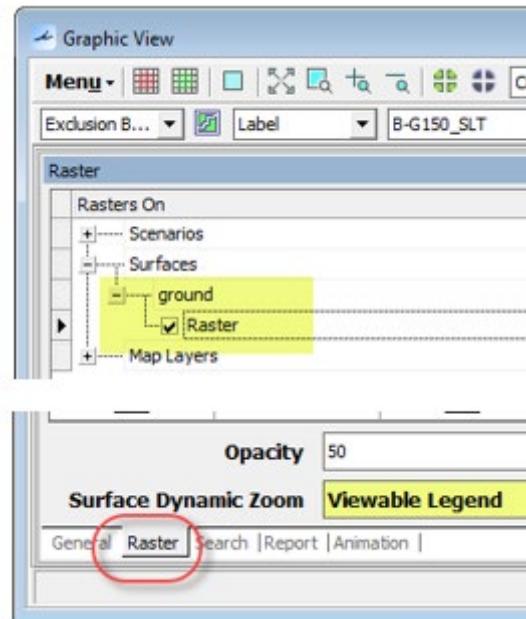
The opacity can be adjusted in the “Background Image Manager”.



Background Image Manager

Name	Origin X	Origin Y	Origin Z	Width	Height	Opacity	Comment
aerial_20160	2257242.514...	344041.6882...	-100	10000.02	10000.02	85	
aerial_20161	2267242.534...	344041.6882...	-100	10000.02	10000.02	85	
aerial_201610	2257242.514...	364041.7282...	-100	10000.02	10000.02	85	
aerial_201611	2267242.534...	364041.7282...	-100	10000.02	10000.02	85	
aerial_201612	2277242.554...	364041.7282...	100	10000.02	10000.02	85	

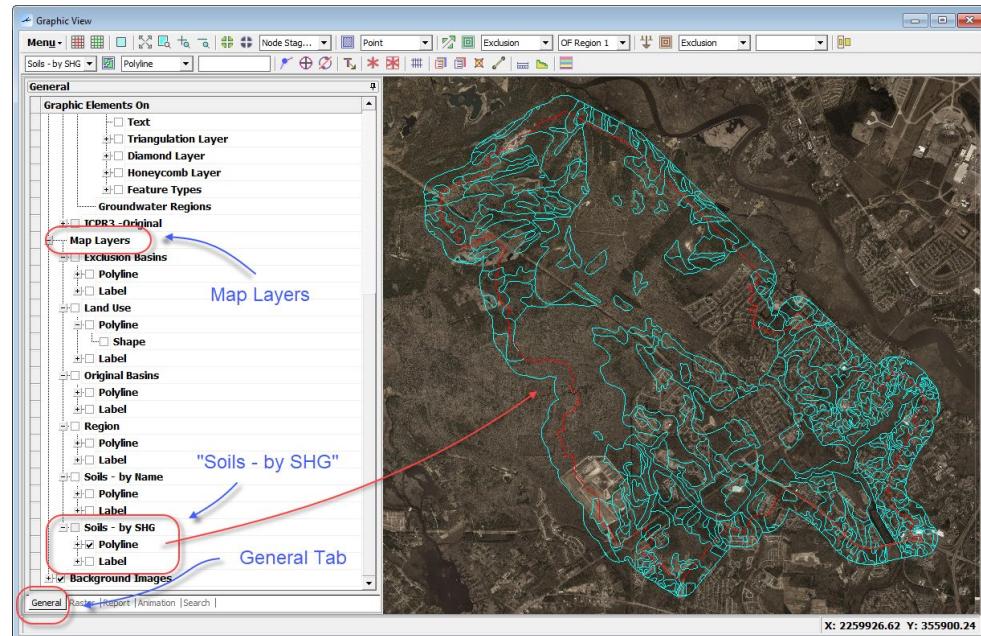
b. Ground Surface DEM – A LiDAR-based 10-foot DEM was obtained online from the South Carolina Department of Natural Resources (SCDNR) and imported to ICPR4 as the ground surface. The LiDAR was acquired between 2007 and 2009 and passed a final QC in 2014. The original DEM was not altered for this modeling effort. The raster view can be toggled on and off under the “Raster” tab of the graphic view as shown to the right. The opacity is set to 50% and the surface dynamic zoom is set to “Viewable Legend”. The viewable legend option sets the color ramp based on the maximum and minimum elevations in the current viewport. Color palettes can be changed by clicking the “Palette Sector” icon.



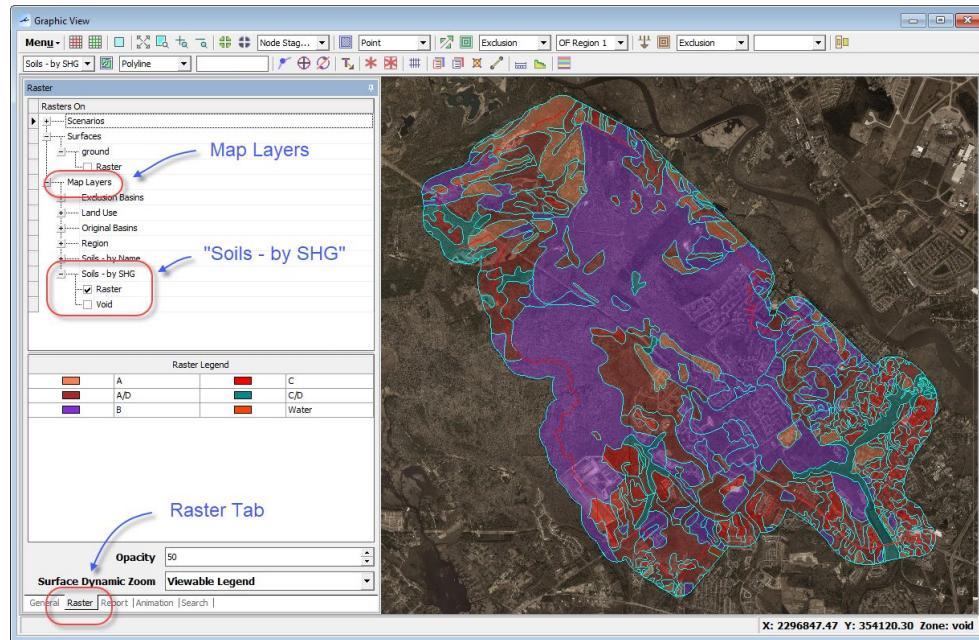
c. Map Layers – A total of 6 map layers have been imported for this project, although only 3 are used for parameterization purposes. The other 3 are for reference purposes. The “Map Layer Manager” is used to create, import and rasterize map layers. The 6 map layers were imported as vectors and then rasterized for display and parametrization purposes.

Name	Map Layer Type	Edit Lock	Cell Size	Point Color	Line Color	Line Width	Text Color	Text Font
Soils - by SHG	Polygon Zone	<input type="checkbox"/>	1	cyan	cyan	0	cyan	Arial
Soils - by Name	Polygon Zone	<input type="checkbox"/>	1	blue	blue	0	blue	Arial
Land Use	Polygon Zone	<input type="checkbox"/>	1	green	green	0	green	Arial
Region	Polygon Zone	<input type="checkbox"/>	1	red	red	0	red	Arial
Original Basins	Polygon Zone	<input type="checkbox"/>	1	red	red	0	red	Arial
Exclusion Basins	Polygon Zone	<input type="checkbox"/>	1	yellow	yellow	0	yellow	Arial

The vector form of the map layers can be toggled on and off from the general tab of the graphic view window.



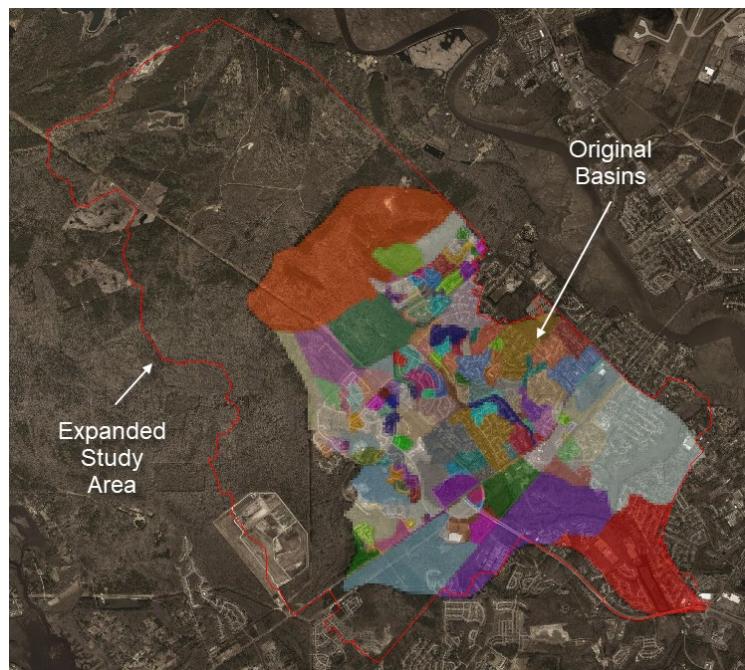
The raster form of the map layers can be toggled on and off from the raster tab of the graphic view window.



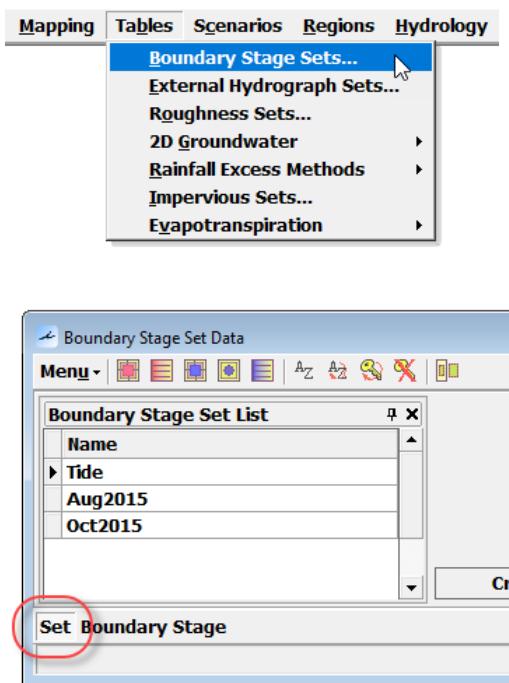
- i. Soils – A soils map was downloaded from the NRCS Web Survey. Attributes for soil name and soil hydrologic group were included in the map. There are 2 ICPR4 soil map layers: “Soils – by SHG” and “Soils – by Name”. “Soils – by Name” is for reference purposes only. “Soils – by SHG” are the soil hydrologic groups and are used for parameterization of curve numbers.
- ii. Land Use – A land use map was drawn in ArcMap as part of the model setup. It was based on 2016 and 2017 aerial imagery. The map was exported from ArcMap as a shapefile and then imported to ICPR4. It is used for parameterization of curve numbers, impervious percentages and roughness coefficients (Manning’s n) for 2D overland flow.
- iii. Exclusion Basins – There were 4 areas where newer development altered the terrain after the LiDAR had been acquired. Consequently, 2D overland flow could not be modeled in these areas. “Exclusion” polygons were established for these, which, as the name implies, excludes them from the 2D computations. Instead, these areas were incorporated into the model as manual basins and then interfaced with the 2D overland flow portion of the model. Parameterization of the manual basins was based on the “Exclusion Basins” map layer along with the “Land Use” and “Soils – by SHG” map layers.



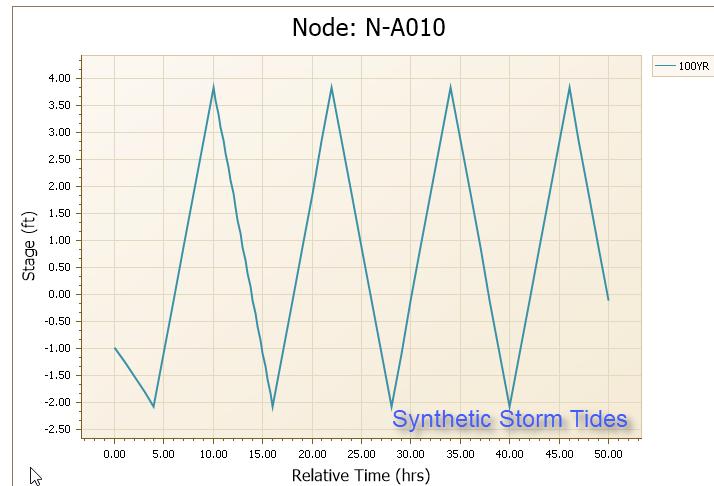
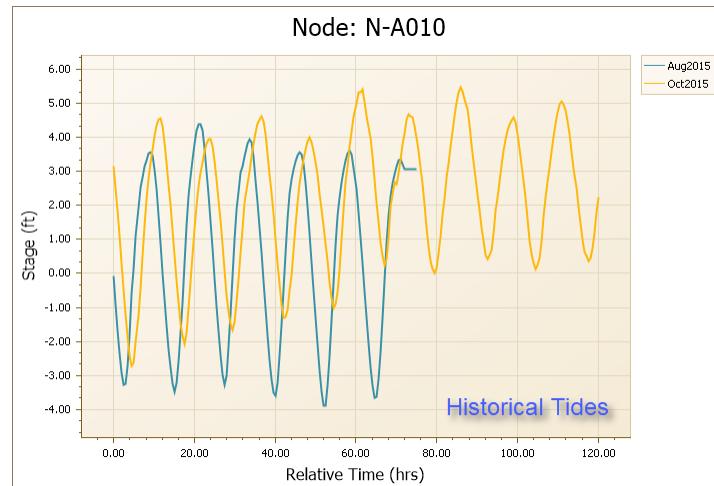
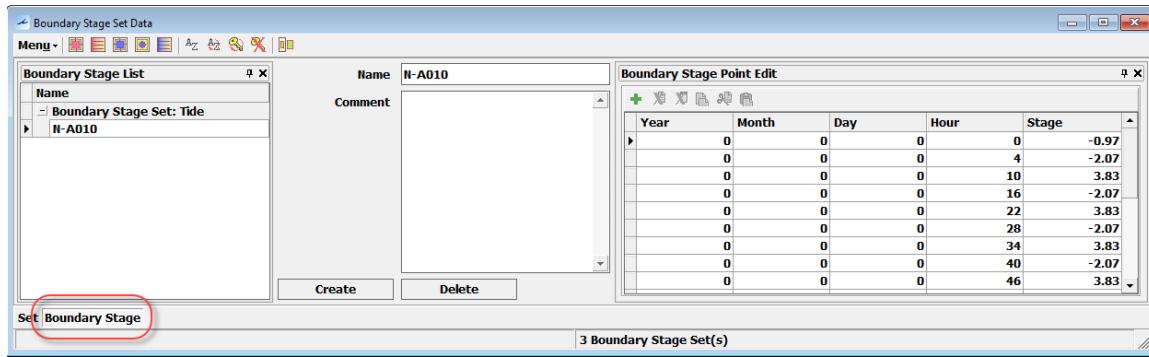
iv. Original Basins – The original Woolpert basins were imported as a map layer for reference purposes. The basins are shown below and cover an area of approximately 8.5 square miles. The study area was expanded to 15.9 square miles as shown by the red polygon below. Based on the LiDAR derived DEM, it appears that a larger offsite area may impact flooding conditions in the original study area.



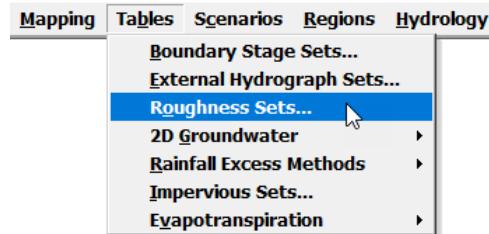
- v. Region – A map layer depicting the extents of the study area was imported for reference purposes. This was used as a starting point for the overland flow region boundary and was later adjusted slightly.
- d. Lookup Tables and Rainfall Data – Various lookup tables, including boundary stage data, must be prepared prior to executing simulations. The table names are referenced in the simulation control data forms and are used to parameterize various model components at run time. The various tables and rainfall text files are described below.
 - i. Boundary Stage Sets – There are 3 boundary stage sets used for this model: “Tide”, “Aug2015”, and “Oct2015”. These were imported with the ICPR3 dataset. Other than a vertical adjustment to convert the original data from NGVD 1929 to NAVD 1988 (-0.97 feet), no other adjustments were made.



There is a single table within each set that is called “N-A010”, which refers to the time-stage node at the project outfall near the Ashley River. The table data can be viewed by selecting a set and then clicking the “Boundary Stage” tab. Charts are shown on the following page.



- ii. Roughness Sets – Manning's n is needed for 2D overland flow and is defined in roughness set tables. There is a single roughness set used for this model called "1". This set includes a shallow and deep Manning's n for each unique land use (defined by the land use map layer). An exponential decay function is used in ICPR4 which decreases Manning's n exponentially with depth, down to the specified depth range.



Roughness Set Data

Menu |

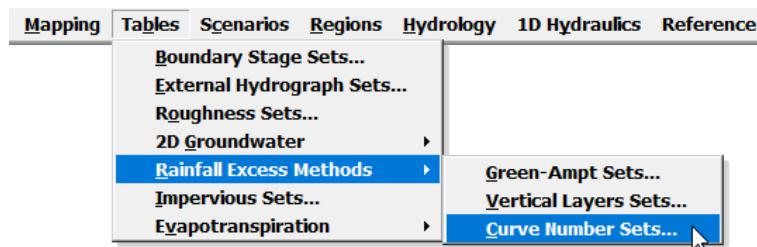
Set: Roughness (circled in red)

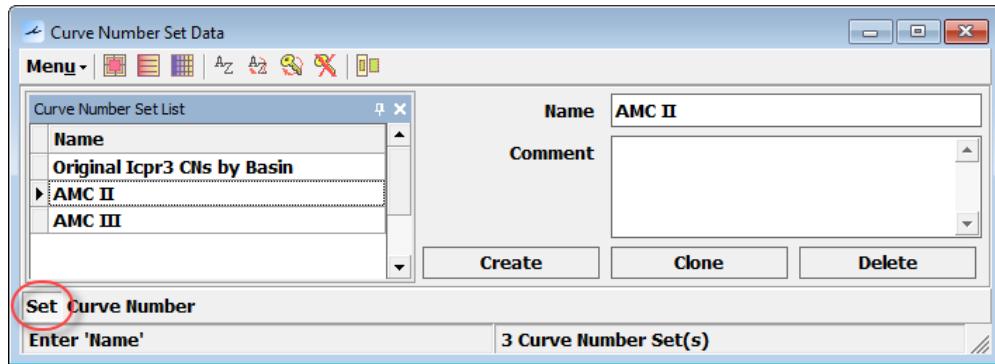
1 Roughness Set(s)

Roughness Zone	Shallow Manning's N	Deep Manning's N	Depth Range	Dampening Threshold	Area Reduction Factor
Bare Earth	0.08	0.04	1	0	1
Bottomland/floodp...	0.3	0.15	3	0	1
Brushland	0.3	0.15	3	0	1
Church	0.08	0.04	1	0	1
Commercial	0.08	0.04	1	0	1
Disturbed Land	0.08	0.04	1	0	1
Estate Lots (appro...	0.08	0.04	1	0	1
Estate Lots (appro...	0.08	0.04	1	0	1
Golf Course	0.08	0.04	1	0	1
Wet Prairie/Peat	0.08	0.04	1	0	1

Extract Import

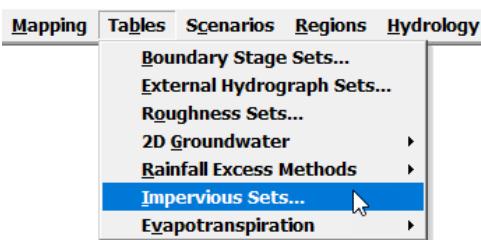
iii. Curve Number Sets – There are 3 curve number sets in this model: “Original Icpr3 CNs by Basin”, “AMC II”, and “AMC III”. The “Original Icpr3 CNs by Basin” includes the same CNs as those used in the ICPR3 model and were created at the time of import. These are not used in the 2D modeling effort, but have been kept for reference purposes. “AMC II” and “AMC III” are curve numbers for average and wet antecedent moisture conditions, respectively. CNs are provided for each unique land use – soil combination as defined by the “Land Use” and “Soils – by SHG” map layers. Impervious areas are incorporated into the curve numbers.





Land Cover Zone	Soil Zone	Curve Number
Bare Earth	A	68
Bare Earth	A/D	89
Bare Earth	B	79
Bare Earth	C	86
Bare Earth	C/D	89
Bare Earth	Water	98
Bottomland/floodplain forest	A	90
Bottomland/floodplain forest	A/D	90
Bottomland/floodplain forest	B	90
Bottomland/floodplain forest	C	90

iv. Impervious Sets – There are 2 impervious sets: “Original ICPR3 %Imp by Basin” and “1”. The original set includes a table of impervious percentages for each basin in the original ICPR3 model and were imported with the ICPR3 dataset. These are not used for the 2D modeling effort and have been included for reference purposes only. Set “1” includes impervious percentages by land use category. Since impervious areas are included in the curve numbers, all impervious percentages for set “1” are zero.

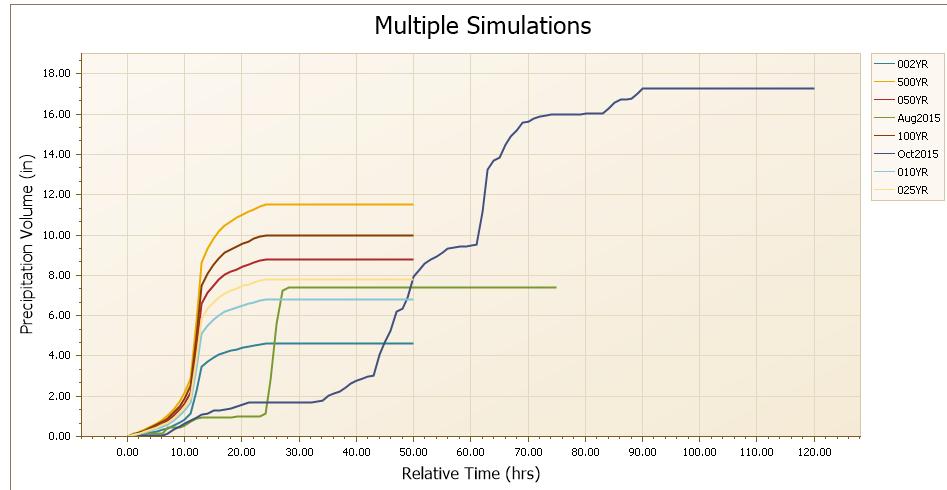


Land Cover Zone	% Impervious	% DCIA	% Direct	Ia Impervious	Ia Pervious
Bare Earth	0	0	0	0	0
Bottomland/flood...	0	0	0	0	0
Brushland	0	0	0	0	0
Church	0	0	0	0	0
Commercial	0	0	0	0	0
Disturbed Land	0	0	0	0	0
Estate Lots (appr...	0	0	0	0	0
Estate Lots (appr...	0	0	0	0	0
Golf Course	0	0	0	0	0
High Density Resi...	0	0	0	0	0

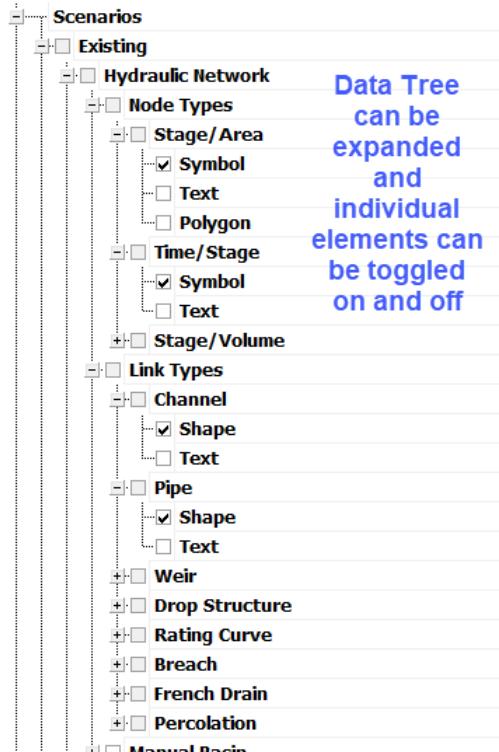
v. Rainfall Data – Text files for all the ICPR3 rainfall distributions are automatically created and placed in the an ICPR4 rainfall resources folder called “Icpr3” at the time of import. The “Aug2015.txt” and the “Oct2015.txt” files include historical data. The ICPR4 built-in SCS Type III rainfall distribution is used for all synthetic design storms.

Aug2015.txt	Fdot-72.txt	Scsi-48.txt
Delaney.txt	Fdot-168.txt	Scsia-24.txt
Fdot-1.txt	Fdot-240.txt	Scsii-24.txt
Fdot-2.txt	Flmod.txt	Scsii-48.txt
Fdot-4.txt	Oct2015.txt	Scsiii.txt
Fdot-8.txt	Orange.txt	Sfwmd72.txt
Fdot-24.txt	Scsi-24.txt	Sjrwm96.txt

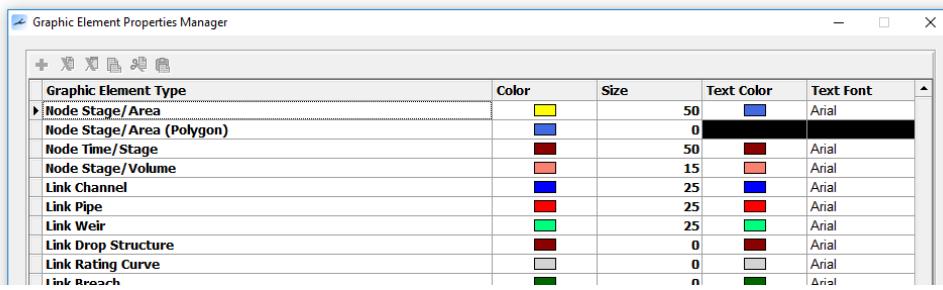
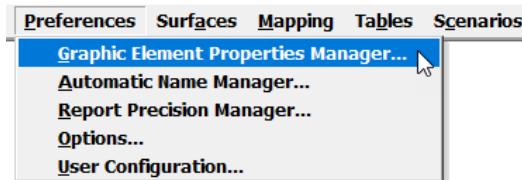
The rainfall amounts for each of the simulated storms is shown in the chart below.



4. 1D Model Setup – As previously mentioned, the ICPR3 dataset was imported to ICPR4 and then spatially referenced. This dataset has been preserved in a scenario called “ICPR3 – Original”. A duplicate or clone of this dataset was created and is called “Existing”. Changes were made only to scenario “Existing” to prepare it as a 2D overland flow model. To compare the original model setup with the 2D setup, you can toggle the scenario displays on and off. Also, individual model elements (e.g. nodes, channels, pipes, etc.) can be toggled on and off from the data tree as shown below.

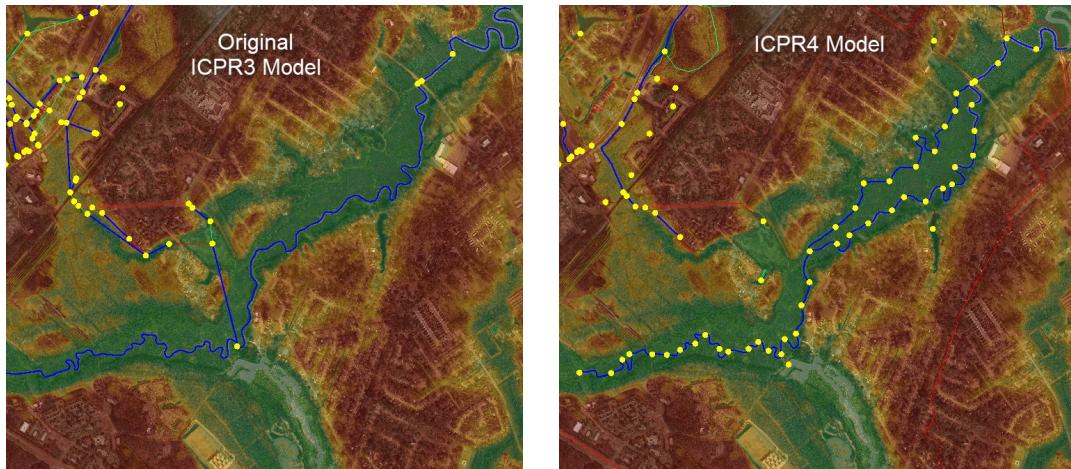


Colors and sizes can be adjusted in the “Graphic Element Properties Manager”.

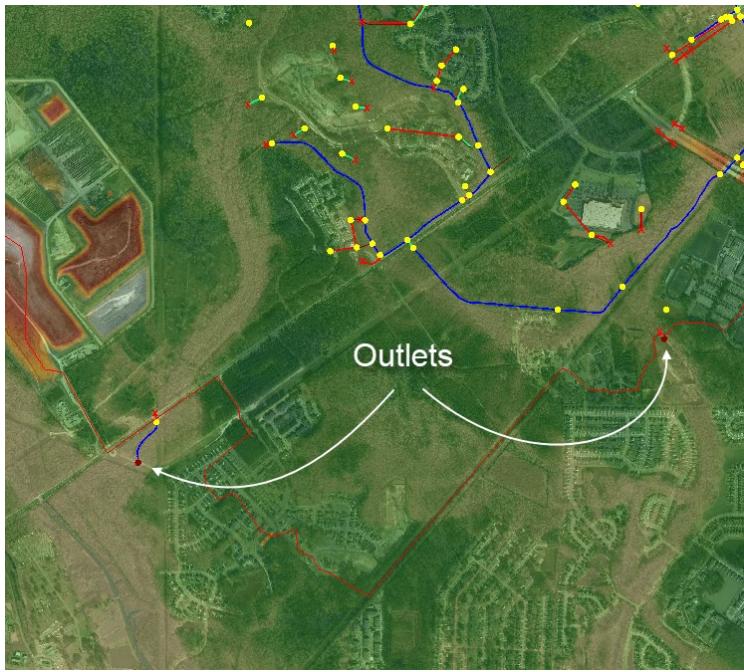


Graphic Element Type	Color	Size	Text Color	Text Font
Node Stage/Area	Yellow	50	Blue	Arial
Node Stage/Area (Polygon)	Blue	0	Black	Arial
Node Time/Stage	Dark Red	50	Dark Red	Arial
Node Stage/Volume	Red	15	Red	Arial
Link Channel	Blue	25	Blue	Arial
Link Pipe	Red	25	Red	Arial
Link Weir	Green	25	Green	Arial
Link Drop Structure	Dark Red	0	Dark Red	Arial
Link Rating Curve	Grey	0	Grey	Arial
Link Breach	Black	0	Black	Arial

- a. Nodes – Several modifications were made to the nodal network. Some nodes were deleted and replaced with 2D graphical elements. Other nodes were added. For example, numerous nodes were added along Church Creek in the tidal marsh area. This was to better reflect tidal fluctuations and transfer of water from the main channels into the marsh areas. Nodes were also added for several ponds that were not included in the original ICPR3 model.

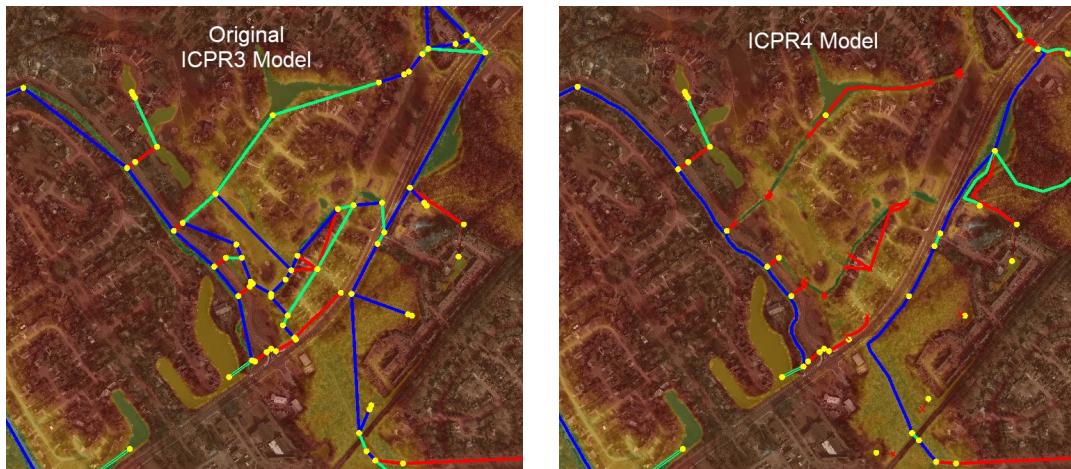


Two additional outlets were added near the southwest corner of the expanded study area as shown below.



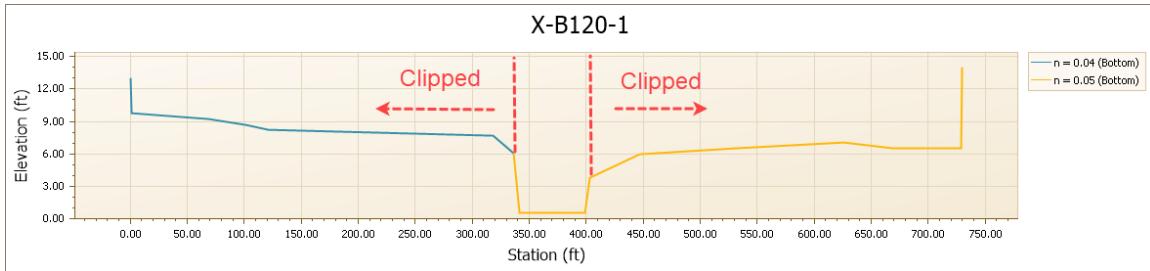
Stage-area tables were modified for many of the nodes used for ponds. The stage-area tables were extended into the adjacent streets and lots. Data was derived from the ground surface DEM in most cases.

- b. Links – Like nodes, many links were deleted and added to the model to better integrate it with 2D overland flow. An example is shown below. The original ICPR3 model is shown on the left and the ICPR4 model is shown on the right. Pop-off weirs and small channels were replaced with 2D overland flow graphical features. In other words, the computational mesh was used to move water instead of irregular shaped 1D weirs.



- c. Cross Sections – Most of the original channel cross sections were extended into the floodplain. These had to be shortened or clipped for the ICPR4 model

otherwise the floodplain storage would have been accounted for twice. For example, cross section “X-B120-1” is shown below. The original cross section extends into the overbank areas by more than 300 feet on either side. These were clipped to the top of bank.



- d. Basins – There were 184 basins in the original ICPR3 model. Most of these were deleted in the ICPR4 model. The exceptions are listed below. Basins ending with “_SLT” were added. The others in the list were taken from the original ICPR3 model. The terrain in these basins have been significantly modified since the LiDAR was acquired. Unless the DEM is modified, these areas cannot be modeled as 2D overland flow.

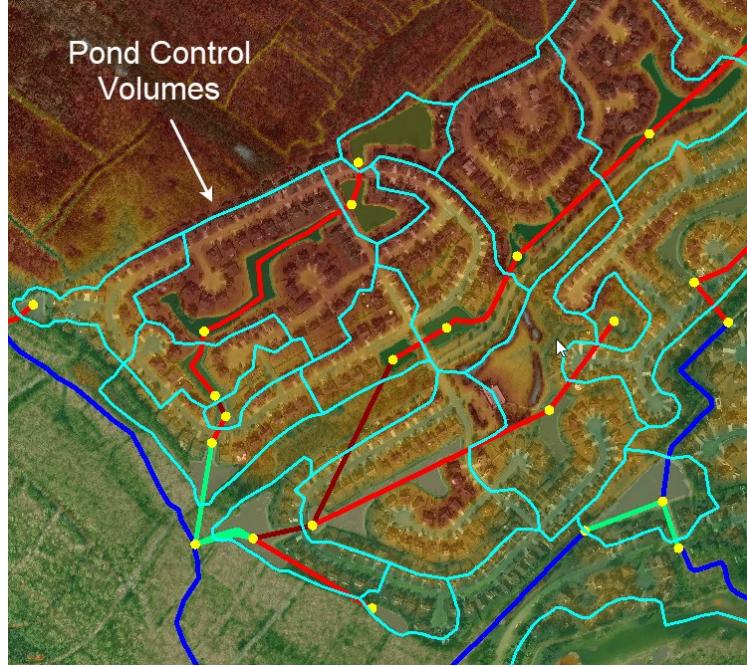
Name	Δ
- Scenario: Existing	
B-G025B	
B-G025C	
B-G028A_SLT	
B-G028B	
B-G028B_SLT	
B-G028C_SLT	
B-G028D_SLT	
B-G028E_SLT	
B-G028F_SLT	
B-G043A	
B-G044B	
B-G044C	
B-G045B	
B-G045C	
B-G150_SLT	
+ Scenario: ICPR3 - Original	

- 5. 2D Overland Flow Model Setup – The 2D model setup involves strategically placing graphical elements that are used to: (1) interface with 1D model components; (2) characterize the terrain; and, (3) address boundary conditions. Computational meshes are constructed from the graphical elements and parameterized from the ground surface DEM and various map layers. The various graphical elements and mesh construction are described below.

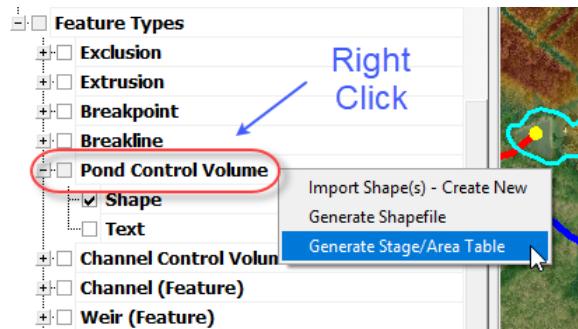
- a. 2D Overland Flow Graphical Elements

- i. Integrating 1D and 2D Surface Hydraulics

1. Pond Control Volumes (PCVs) – PCVs are closed polygons that are referenced to 1D stage/area nodes. They are used in overland flow regions for bodies of water where a level pool assumption is appropriate. In total, 125 PCVs were used. An example is shown below. The PCVs basically follow the contributing drainage area to the respective pond.



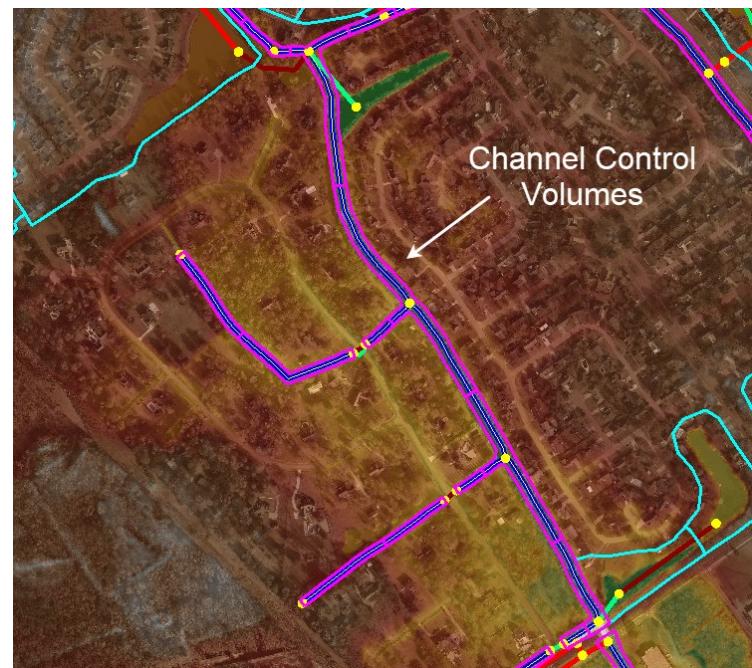
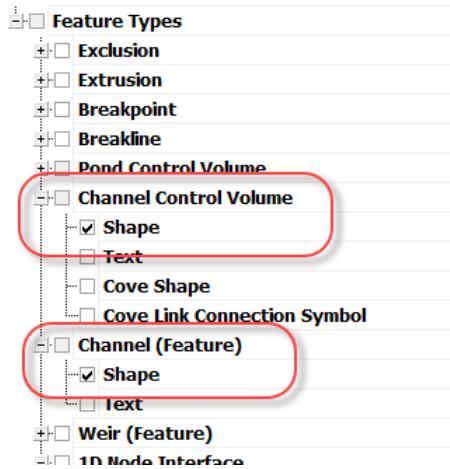
Stage-area tables can be automatically generated for PCVs by right clicking the “Pond Control Volume” feature type on the data tree and selecting “Generate Stage/Area Table” as shown below. The stage-area table is extended to the limits of the polygon that defines the PCV which includes storage in the pond plus the streets and lots.



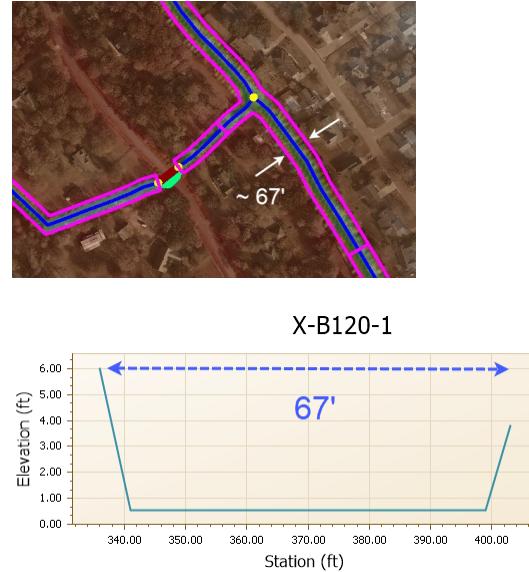
2. Channel Control Volumes (CCVs) – Like PCVs, CCVs are closed polygons referenced to 1D stage/area nodes. They can only be used where 1D channel links exist. Generally, they

extend approximately halfway upstream and downstream along any channel links attached to or from the node associated with the CCV. Unlike PCVs, CCVs have a sloping water surface. These work in conjunction with a channel (interpolation) feature. Examples of CCVs are shown below.

CCVs and Channel (Features) can be toggled on and off from the data tree. The channel (feature) typically follows the 1D channel link and is used to interpolate the water surface elevation along the 1D channel link. This affects how water moves from the channel into the 2D computational mesh.

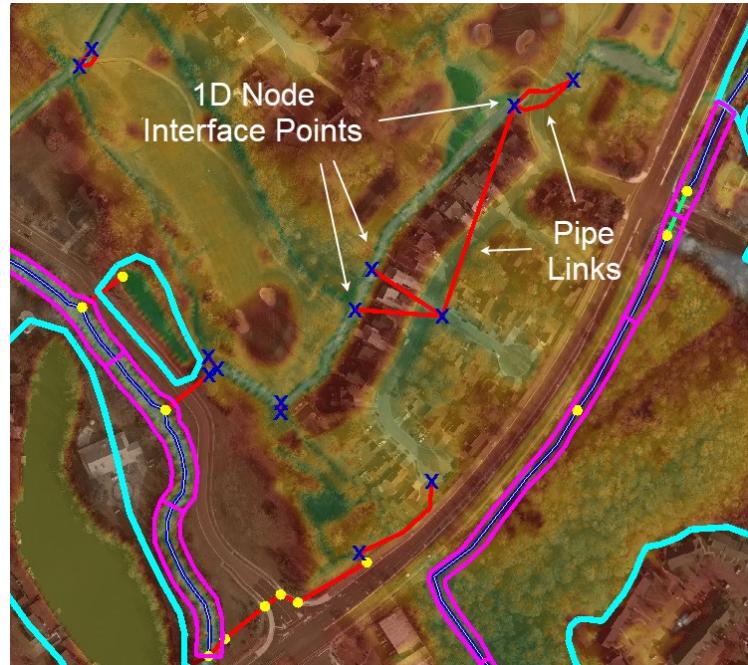
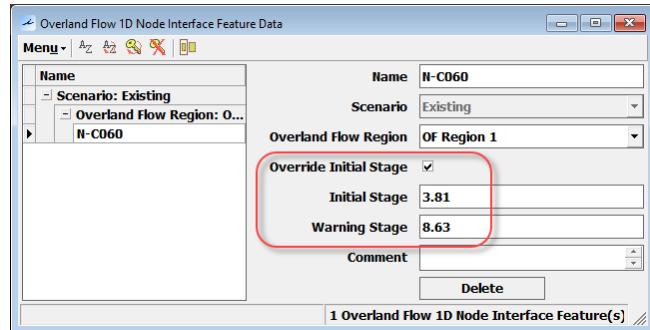


The width of the CCV should reflect the channel cross section. 1D flow occurs inside the CCV and 2D flow occurs outside of it. The channel cross sections imported from the ICPR3 model extended well out into the overbank areas. These were clipped near the top of bank and the channel control volume widths were based on the clipped cross sections. An example is shown below.



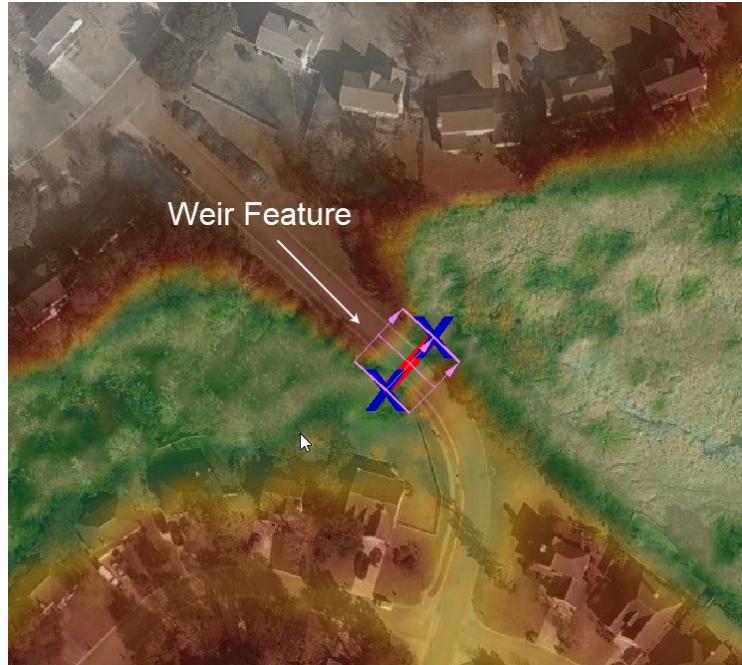
3. 1D Node Interfaces – These graphic elements allow hydraulic communication between the 2D mesh and 1D hydraulic components. For example, if you want to model sheet flow along a roadway and then have it drop into a storm inlet, you would place 1D node interface points at each inlet, then connect the 1D node interface points with pipe links. These can also be placed inside PCVs and CCVs. If one is placed inside a CCV, then its water surface elevation at any point in the simulation would be an interpolated value based on the associated 1D channel link.

An example use of the 1D node interface feature is shown below. Pipe links (red polylines) are connected from and to 1D node interface points (dark blue X's). A triangle vertex is forced at each 1D node interface. The initial stage is automatically set to the ground elevation based on the DEM, but it can be overridden by opening the 1D node interface data form and checking the “Override Initial Stage” box as shown below.



4. Weir Features – Weir features are graphic elements used to replace 2D overland flow with 1D weir flow. These are typically used at roadways, berms and levees. A total of 3 weir features were used in the Church Creek model to overcome hydro-correcting of the DEM at specific roadway crossings.

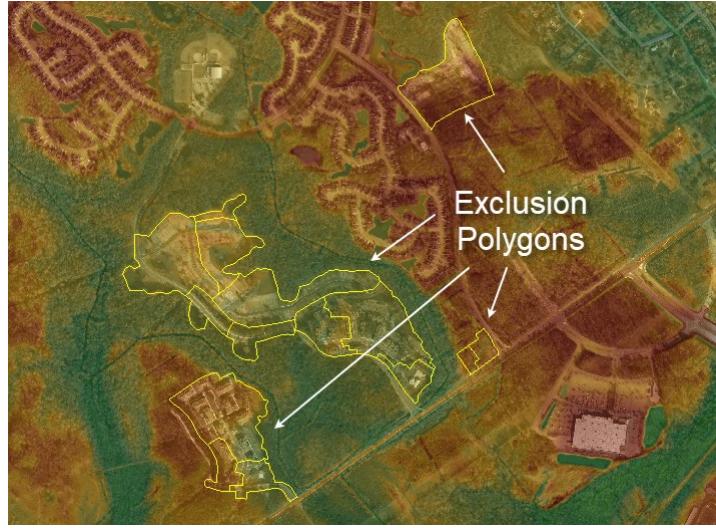
An example weir feature is shown below. There is a culvert under the roadway modeled as a pipe link. However, the DEM was burned in to the channel bottom. If the computational mesh is permitted to push through this area, the flow would be incorrect because of the roadway embankment. Ground elevations along the weir feature can be manually set in the weir feature data form to “fill” the hydro-corrected segment of the DEM.



Name	OFWF-0010	Points				
Scenario	Existing					
Overland Flow Region	OF Region 1					
Weir Type	Sharp Crested, Vertical					
Weir Discharge Coefficient	2.8					
Horizontal Offset	30					
Comment						
		Vertex	X	Y	Vertical Offset / Elev	Elevation Calculation Method
		0	2288458.746...	363759.8492...	8.5	User Specified Elevation
		1	2288485.426...	363735.6859...	7.8	User Specified Elevation
		2	2288506.066...	363715.5499...	7.2	User Specified Elevation

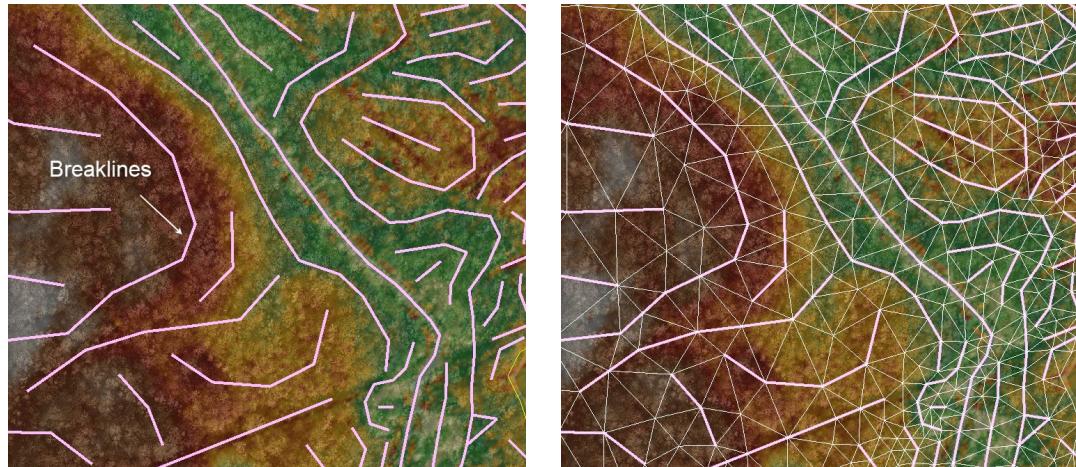
ii. Terrain Characterization

1. Exclusions – As previously mentioned, there are several areas where the terrain has been significantly altered due to land development since the LiDAR was acquired. Accurately modeling 2D overland flow in these areas is not possible without modifying the DEM. Consequently, exclusion polygons were used to remove these areas from the 2D overland flow area. They were replaced with manual basins (i.e. traditional hydrology).



2. Breaklines – Water flows along triangle edges in ICPR and triangle edges are guaranteed along breaklines. Consequently, breaklines are useful for defining local valleys and ridges. Breaklines are also placed inside PCVs and CCVs, but they do not cross the CCV or PPC boundaries. Very tiny triangles can result if the breaklines cross CCVs or PCVs.

An example of breakline placement is shown below on the left. The resulting computational mesh is shown on the right.



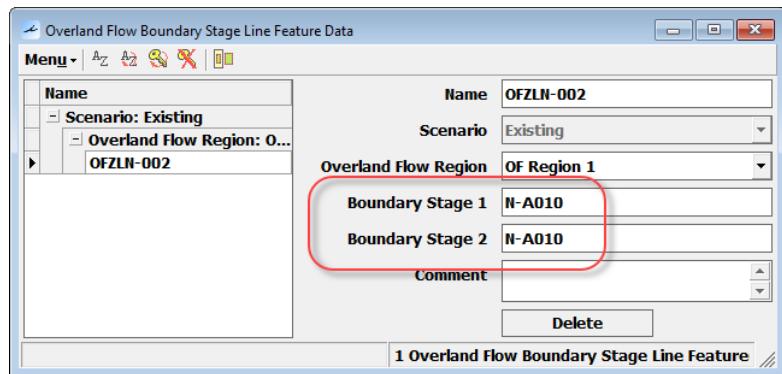
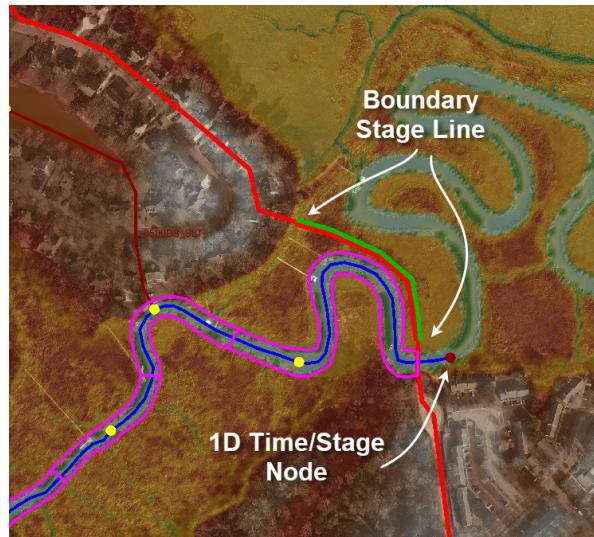
An example of a PCV with breaklines is shown below. The purpose of the breaklines inside a PCV is to refine the mesh so that flooding of streets and residential lots will appear in the animations after the simulations are executed.



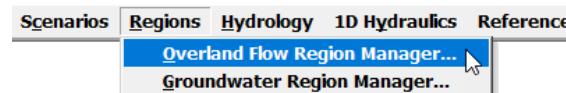
3. Breakpoints – Breakpoints are placed last for refinement purposes. A triangle vertex is placed at each breakpoint and a polygon (honeycomb) is formed around the vertex. Water surface elevations are calculated at each vertex. An example of breaklines and breakpoints inside a PCV is shown below.



- iii. Boundary Conditions – Vertical walls are assumed along the overland flow region boundary unless a boundary condition is explicitly identified. A single boundary stage line feature was used at the outfall near the Ashley River as shown below. A 1D channel link is connected to a time/stage node but this does not account for out of bank tidal flooding in the salt marsh next to the main channel. The boundary stage line opens the “vertical wall” along the region boundary and allows tidal fluctuations into the 2D mesh. A boundary stage table must be specified at both ends of the boundary stage line feature.



b. Overland Flow Region Manager and Mesh Preprocessing – The overland flow region manager is used to identify surfaces (DEMs) and map layers needed for parameterization of the computational mesh. You can right click on these data fields to select from a list of available surfaces and map layers.

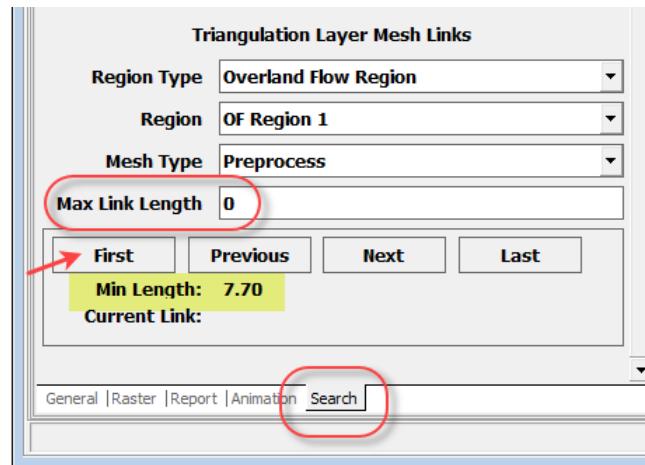


Name	OF Region 1
Scenario	Existing
Minimum Triangulation Angle	45
Minimum Triangulation Area	150
Diamond Layer Cell Size	1
Honeycomb Layer Cell Size	1
Ground Surface	DEM
Use Single Elevation (Ground)	<input type="checkbox"/> ground
Initial Stage Surface	<input type="checkbox"/> ground
Use Single Elevation (Initial Stage)	<input type="checkbox"/>
Roughness Zone Map Layer	<input type="checkbox"/> Land Use
Use Single Roughness Zone	<input type="checkbox"/>
Soil Zone Map Layer	Map Layers
Use Single Soil Zone	<input type="checkbox"/> Soils - by SHG
Land Cover Zone Map Layer	<input type="checkbox"/> Land Use
Use Single Land Cover Zone	<input type="checkbox"/>
Use Single Rainfall Zone	<input checked="" type="checkbox"/> Rain
Use Region as Mapped Basin Feature	<input type="checkbox"/>
Mapped Basin Map Layer	<input type="checkbox"/>
Use Single Mapped Basin	<input type="checkbox"/>
Use Single Infiltration Method	<input checked="" type="checkbox"/> Curve Number
Include Evapotranspiration	<input type="checkbox"/>

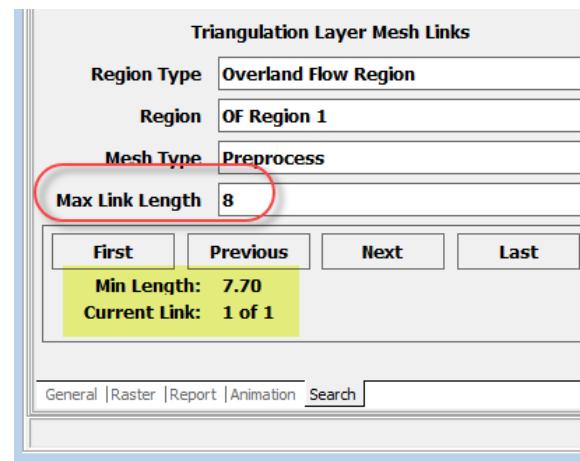
The “Preprocess” button is at the lower left corner of the region manager and can be used to generate a triangular mesh from the graphical elements. It does not do a full parameterization of the mesh. The purpose of preprocessing the mesh is to locate small and tiny triangles prior to full parameterization. It is always better to locate small triangles and rectify their cause prior to parameterization.

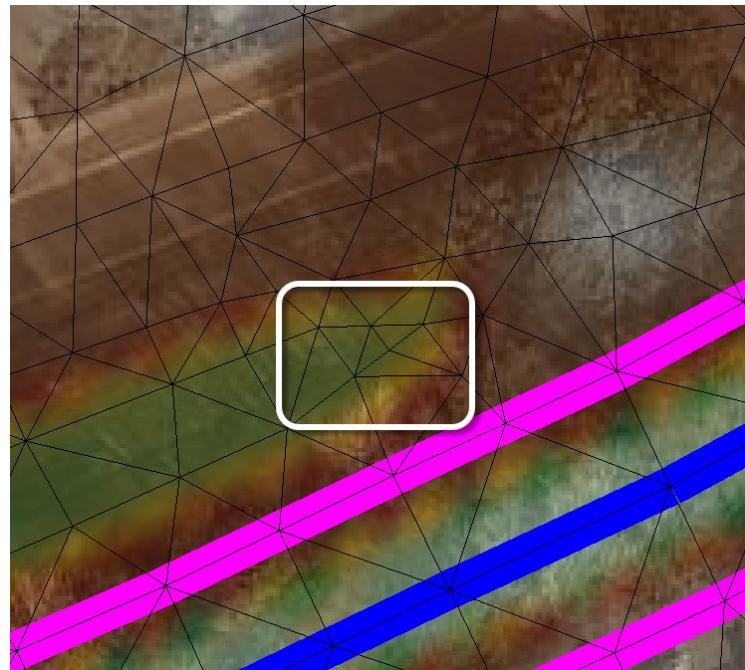
Preprocess	Status	Comment	Log	Delete
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After the preprocess is completed, you can search for short triangle edges on the “Search” tab of the graphic view. As a first pass, set the “Max Link Length” to zero and click the “First” button. The shortest triangle length (7.70) appears as shown below.



To find the offending triangle edge, zoom in tight anywhere. Then set the “Max Link Length” to say 8’ and click “First”. In this case, there is only one triangle edge that is less than or equal to 8 feet. The offending triangle edge will appear in the middle of the graphic view. You can then decide whether to adjust or refine the model. For this case, 7.7’ is not too small and no changes are required.



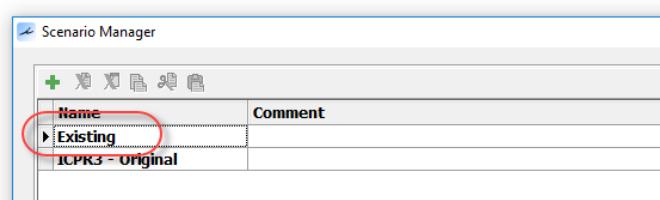


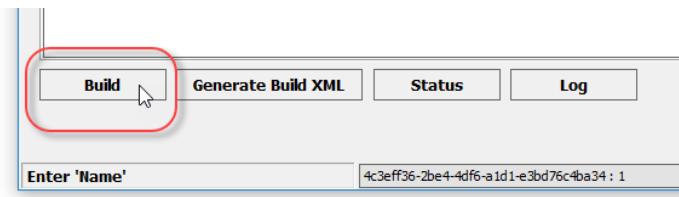
c. Final Mesh Construction with the Scenario Build – The final fully parameterized computational meshes are constructed in the Scenario Manager.



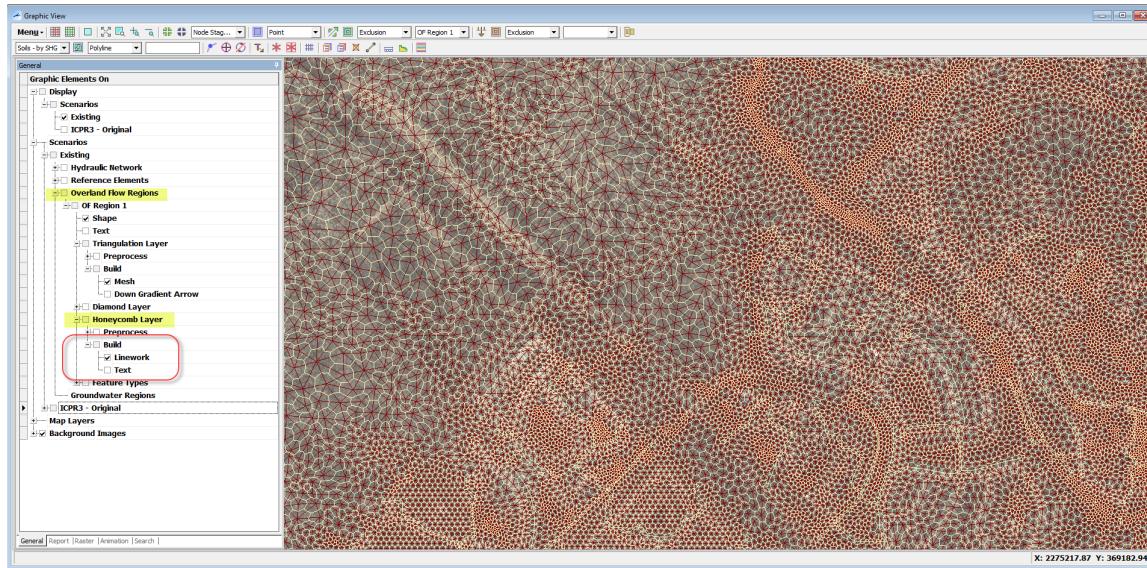
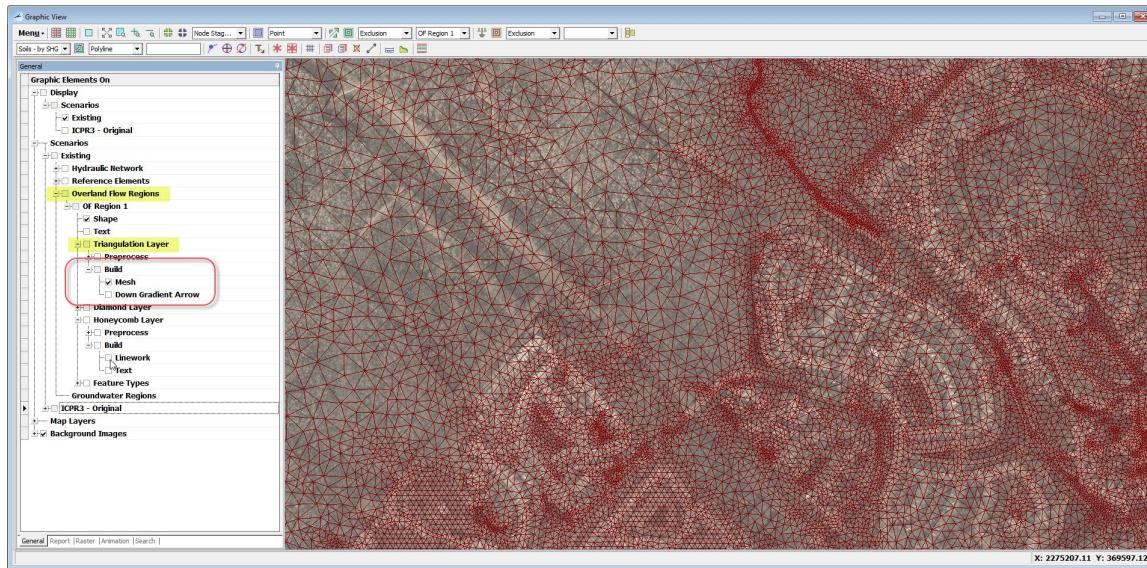
Note: The final computational meshes have already been constructed and parameterized in the ICPR4 model that accompanies this memorandum. There is no need to rebuild them unless spatial changes are made to the model. Also, be aware that all simulation results are deleted with the “Scenario Build”.

To begin the build process, click the “Build” button and follow the instructions. This is a complicated project, so the build will take an hour or more to complete. But once it is completed, it will not have to be built again unless there are changes to the spatial graphical elements.

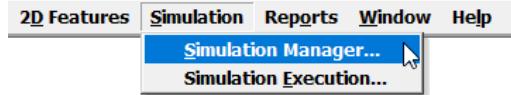




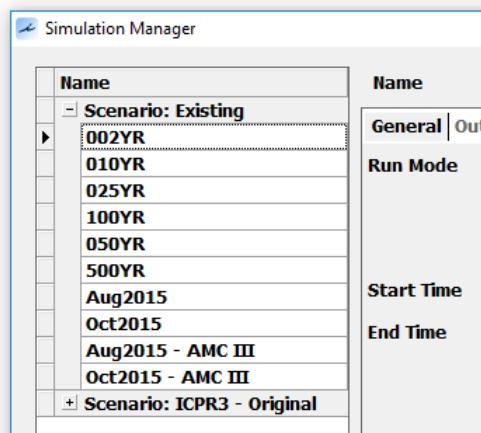
Partial final triangular and honeycomb meshes are shown below.



6. Simulation Control and Execution



There are 6 synthetic storms (2-, 10-, 25-, 50-, 100- and 500-year events) and 2 historical storms (August and October 2015). These were run assuming an average antecedent moisture condition (AMC II). The 2 historical storms were also run with a wet antecedent moisture condition (AMC III).



- General Tab – Start and end times and calculation time steps are set on the general tab of the simulation manager. Notice that the minimum and maximum calculation times for surface hydraulics are set to 0.01 and 2.561 seconds, respectively. The “Fireball” time marching algorithm is recommended for large complex models like the Church Creek Basin and it utilizes time step levels. The time step doubles with each successive level. Therefore, a minimum time step of 0.01 seconds and a maximum of 2.561 seconds results in the following time step levels: (1) 0.01; (2) 0.02; (3) 0.04; (4) 0.08; (5) 0.16; (6) 0.32; (7) 0.64; (8) 1.28; and, (9) 2.56. Each node in the model is assigned a time step level. Neighboring nodes can only increase or decrease by one level. This approach allows very small time steps where necessary without penalizing the entire computational mesh.
- Output Time Increments Tab – Output time increments can be staggered during the simulation, increasing frequency during peak conditions. Keep in mind that 2D models produce a lot of output data that must be stored. So you should try to minimize the output intervals as much as possible without compromising the end product.
- Resources & Lookup Tables – There are 4 sets of tables that must be specified for each of the simulations: (1) Boundary Stage Set; (2) Curve Number Set; (3)

Impervious Set; and, (4) Roughness Set. A rainfall folder is also required for the historical storms.

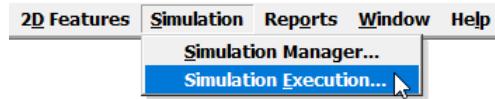
Name	Oct2015	Scenario	Existing
General Output Time Increments		Resources & Lookup Tables Tolerances & Options	
Resources		Lookup Tables	
Rainfall Folder	ICPR3	Boundary Stage Set	Oct2015
Reference ET Folder		External Hydrograph Set	
Unit Hydrograph Folder		Curve Number Set	AMC II
		Green-Ampt Set	
		Vertical Layers Set	
		Impervious Set	1
		Roughness Set	1
		Crop Coefficient Set	
		Fillable Porosity Set	
		Conductivity Set	
		Leakage Set	

d. Tolerances & Options Tab – Rainfall and various computational tolerances are set on this tab. Notice that the “Diffusive Wave” option is used as the default for 1D and 2D hydraulic computations. This tends to work better in very flat areas like Charleston.

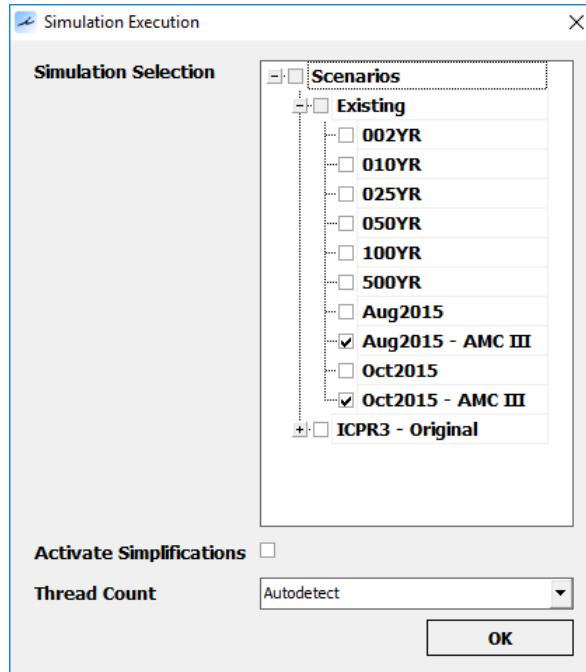
Name	Oct2015	Scenario	Existing
General Output Time Increments Resources & Lookup Tables		Tolerances & Options	
Time Marching	FIREBALL	Initial Abstraction Recovery Time	24
		Include ET for Manual Basins	<input type="checkbox"/>
dZ Tolerance	0.001	Manual Basin Rainfall Option	Global
Maximum dZ	1	Of Region Rainfall Option	Global
Link Optimizer Tolerance	0.0001	Rainfall Name	Oct2015
Edge Length Option	Automatic	Rainfall Amount	17.28
Default Dampening Threshold (2D)	0.05	Storm Duration	97
Minimum Node Surface Area (2D)	225		
Energy Switch (2D)	Diffusive Wave	Default Dampening Threshold (1D)	0.05
		Minimum Node Surface Area (1D)	100
		Energy Switch (1D)	Diffusive Wave

e. Simulation Execution

Note: The various simulations described in this section have already been executed and are included in the ICPR4 model that accompanies this memorandum. There is no need to re-execute them unless changes are made to the model.

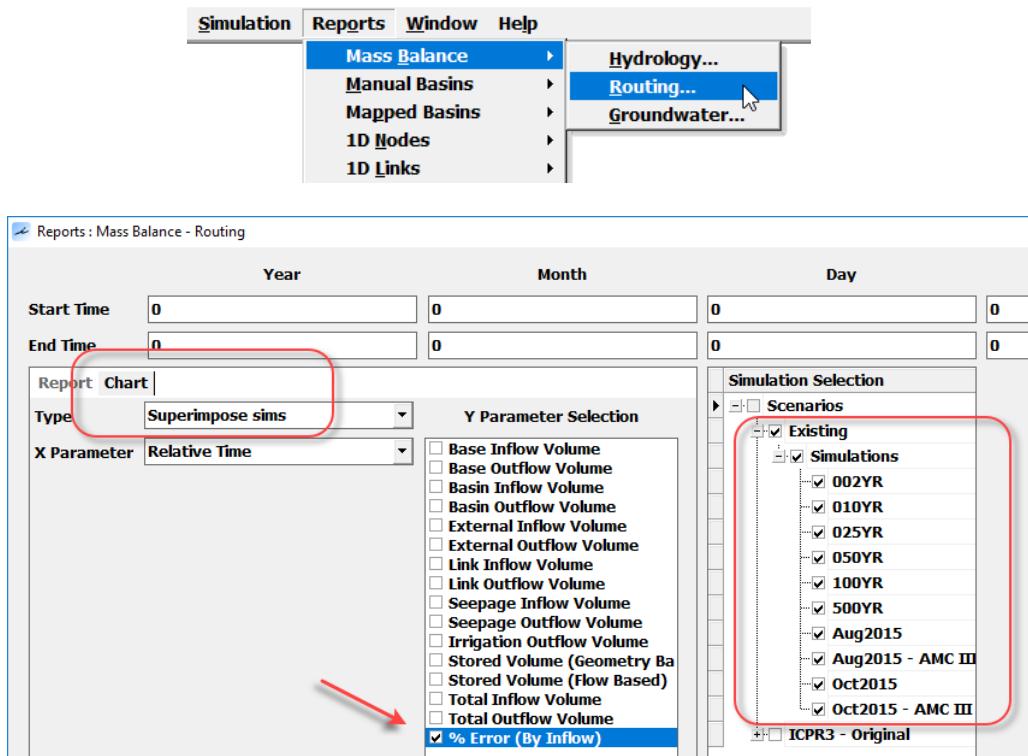


Select the simulations you want to run and then click the OK button. Remember that this is a very complex model and run times will be lengthy. The synthetic storms took about 2.5 - 5 hours each to run on an Intel I7 @ 2.5GHz. The Aug2015 storm took about 5 hours and the Oct2015 storm took about 14 hours. Faster computers with more threads will improve run times.

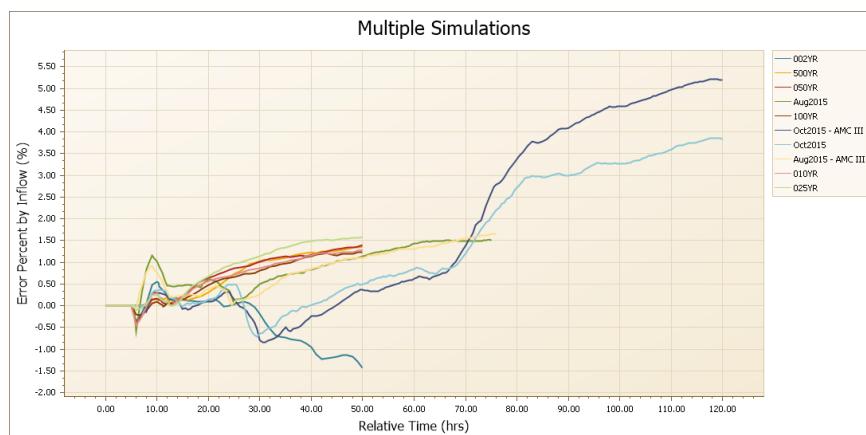


7. Reviewing Results – There are a wide variety of reports and animations but we will focus on 3 here.

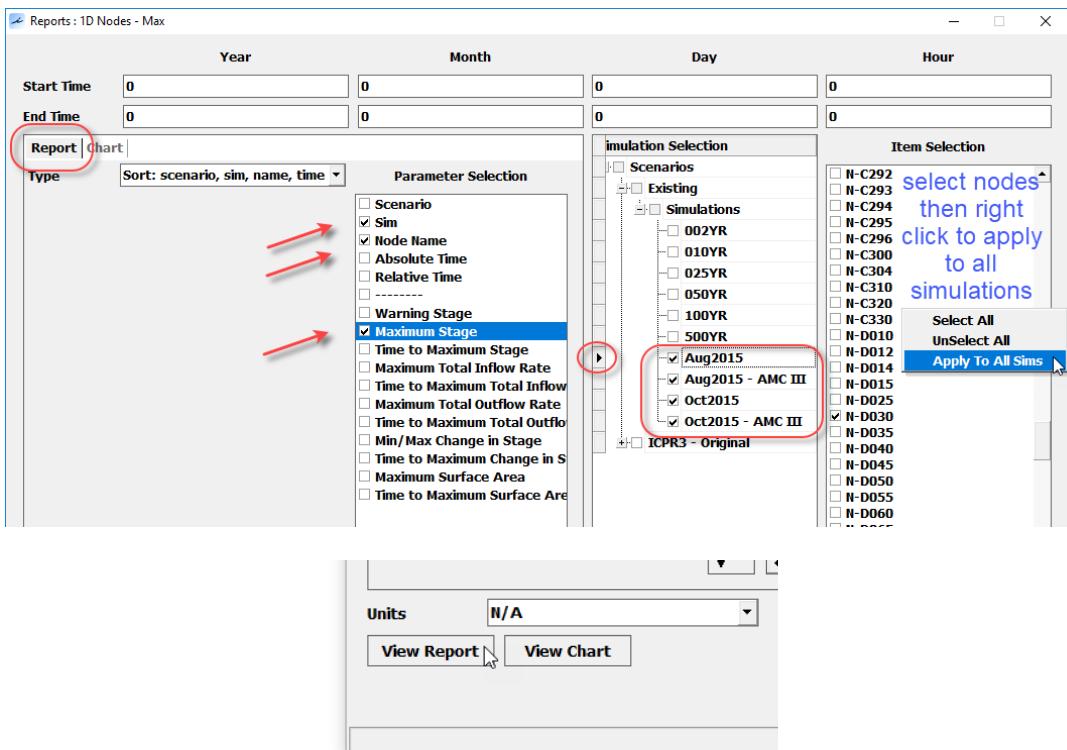
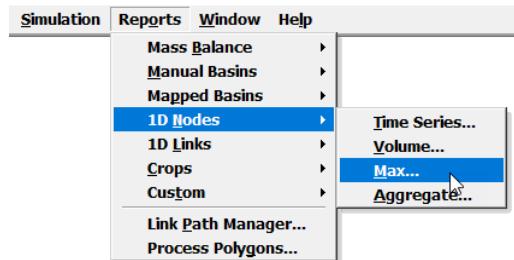
a. Mass Balance – The mass balance error should be checked first.



Generally, the mass balance error (absolute value) should be less than 2-3%. All storms meet this criteria except the Oct2015 simulations which climb to about 4-5%. This could probably be reduced by reducing the minimum and maximum hydraulic calculation times from 0.01 and 2.561 seconds to say 0.005 and 1.281, respectively. However, this would likely increase run times. As will be seen, excellent correlation with the few recorded high water marks for this storm was achieved.



- Max Node Stage – Woolpert surveyed a couple of high water marks for the Aug2015 and Oct2015 storms. The nearest nodes are “N-D030” and “N-I100”. A node maximum conditions report for these nodes can be generated as follows.



Report Viewer : 1D Nodes - Max

Menu ▾

	Sim	Node Name	Maximum Stage [ft]
	Aug2015	N-D030	7.40
	Aug2015	N-I100	8.87
	Aug2015 - AMC III	N-D030	8.06
	Aug2015 - AMC III	N-I100	9.22
	Oct2015	N-D030	10.71
	Oct2015	N-I100	10.93
	Oct2015 - AMC III	N-D030	10.82
	Oct2015 - AMC III	N-I100	11.11

8 Row(s)

The following tables were prepared by Woolpert and are in NGVD 1929. The model comparisons are with ICPR3.

Table 4: August 2015 High Water Marks

August 2015 High Water Marks				
Survey Location	High Water Elevation (ft)	Nearest Model Node	Model Max WSE (ft)	Difference (ft)
Bridge Point Unit 608	9.30	N-D030	9.2	-0.1
Bridge Point Unit 508	9.40	N-D030	9.2	-0.2

Table 5: October 2015 High Water Marks

October Storm High Water Marks				
Survey Location	High Water Elevation (ft)	Nearest Model Node	Model Max WSE (ft)	Difference (ft)
Bridge Point Unit 512	11.77	N-D030	10.9	-0.9
Golf Course Restroom	11.86	N-I100	11.2	-0.6

The ICPR4 simulation results are summarized below at the HWM locations. The Aug2015 AMC II simulation does not match well and is about 1-foot lower than recorded. The AMC III simulations for Aug2015 and Oct2015 are all within -0.32 and +0.22 feet, which is within 4 inches of recorded elevations. Although further verification is warranted, an argument could be made for using the AMC III condition for the synthetic storms based on this limited analysis.

Simulation	Nearest Node	HWM ft – NAVD88	ICPR4 Max ft – NAVD88	Difference ft
Aug2015 – AMC II	N-D030	8.38	7.40	-0.98
Aug2015 – AMC III	N-D030	8.38	8.06	-0.32
Oct2015 – AMC II	N-D030	10.80	10.71	-0.09
Oct2015 – AMC II	N-I100	10.89	10.93	0.04
Oct2015 – AMC III	N-D030	10.80	10.82	0.02
Oct2015 – AMC III	N-I100	10.89	11.11	0.22

c. Flood Extents Using the Max Depth Animation

