2020 Turkey Creek Flood Risk Management Study

Prepared for the City of Hanahan

By the US Army Corps of Engineers
Charleston District

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Contents

1 Executive Summary

The City of Hanahan, South Carolina requested that the US Army Corps of Engineers (USACE) Charleston District partner with them to analyze potential measures to address flood-related impacts in the Turkey Creek watershed. The District proposed a phased approach to identifying measures and alternatives that would warrant modeling and conceptual design. The first phase would be an assessment of the causes of flooding in the watershed, with conceptual-level considerations of what could remedy the flooding problems. A potential second phase could include more in-depth analysis.

The USACE used models and existing resources to inventory the existing conditions, focused on hydrologic, hydraulic, and environmental conditions. Based on these existing conditions, the team was able to define three problem statements:

1. Stormwater Runoff Flooding: Properties near Turkey Creek are flooded due to stormwater runoff flowing toward Turkey Creek from throughout the watershed.
2. King tide flooding: king tides produce overbank flooding that affects properties near Turkey Creek.
3. Compound Flooding: Rainfall leading to stormwater runoff during king tides or storm surges produces compound flooding that affects properties near Turkey Creek.

Upon defining problem statements, the team provided an array of structural and non-structural measures that may be considered to address the problems identified. Examples include addressing specific stormwater system deficiencies, tidal gates, and property buyouts.

Finally, the team identified next steps for further study that the City of Hanahan may consider to further understand flooding challenges near Turkey Creek. Examples include economic analysis, detailed study of the stormwater and drainage system, and hydrologic and hydraulic analysis of conceptual measures proposed.

2 Study Background

2.1 Study Authority

Section 22 of the Water Resources Development Act, commonly known as Planning Assistance to States (PAS), is an authority granted to USACE to cooperate with states, political subdivisions of states, and Federally recognized Native American tribes to provide planning assistance in any matters related to water resources. No design or construction is authorized under this program. Some examples of services that can be performed under this authority include water supply studies, stormwater management studies, watershed studies, water resources and recreation planning, data collection, master drainage planning, surveying floodplain inventories, and pipe network analyses.

2.2 Location

The Turkey Creek watershed is located in the southern coastal region of South Carolina within the City of Hanahan and City of North Charleston. Hanahan is located within Berkeley County and North Charleston is in Charleston County. Figure 1 shows the location of the study area with the orange line encompassing the Turkey Creek watershed boundary. The CSXT Railroad track (colored blue in Figure 1) represents the dividing line between Berkeley County (City of Hanahan) and Charleston County (City of North Charleston). Turkey Creek discharges into the tidally influenced Goose Creek, then the Cooper River and Charleston Harbor.

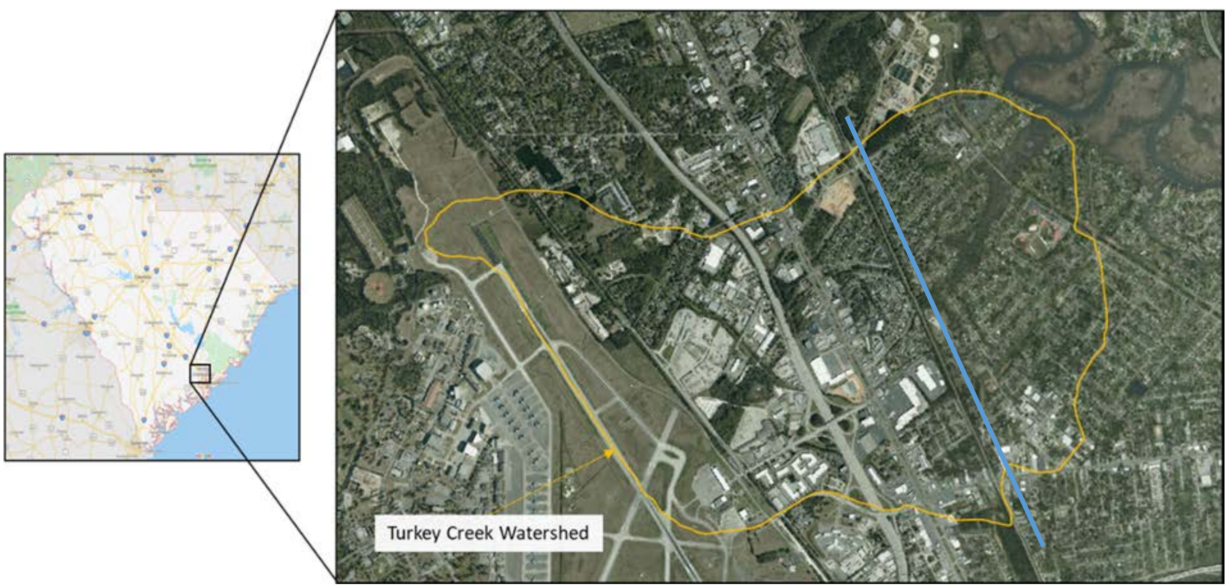


Figure 1: Location Map

2.3 Sponsor's Request for Study

On May 3, 2017, the City of Hanahan expressed interest in becoming a Non-Federal Sponsor (NFS) working with USACE under PAS or other applicable authority to address flooding problems in the residential area surrounding Turkey Creek (see Appendix 1). The City stated the problems have existed for decades and have significantly worsened over the past several years, resulting in significant damage and property loss. Their request was to find a solution to the ongoing problems.

2.4 Site Visit

A site visit was conducted in April 2019 to better understand the study area conditions. The site visit examined the conditions of Turkey Creek and the culverts and drainages that lead into it. A report of this site visit is included as Appendix 2. A second site visit was conducted in June 2019, during which the culverts were examined and measured. The NFS identified areas where flooding problems were frequent.

2.5 Study Scope

The primary purpose of this study is to understand causes of flooding, and recommend potential measures for residents near Turkey Creek, Hanahan, SC.

In order to do so, the Project Delivery Team (PDT) focused on the following goals

1. Define the base conditions/existing conditions of flood extents to determine what the sources of flooding.
2. Suggest potential structural and nonstructural measures that can be more fully evaluated in a later phase.

3 Existing Conditions

Gathering information on existing conditions in the project area helps USACE define the problems in the study area and opportunities available to the non-federal sponsor. The breadth of information gathered to understanding existing conditions can include an inventory of physical, economic, social, environmental and cultural resources, and other conditions as needed. This study focused on gathering the physical and environmental information, with a special focus on hydrologic and hydraulic problem identification. Economic and social information was not addressed at this time due to funding and scope limitations, but are very important to increasing the understanding of the conditions and problems identified in this study. The important of understanding economic and social condition is important to understanding the benefits of mitigating flooding, and is further described in the next steps section.

All information gathered about the existing conditions can be used in subsequent studies to describe the effects of different alternative plans considered to address the problems and opportunities identified.

3.1 Physical Conditions

Datum

All elevations in this report are based on the North American Vertical Datum 1988, expressed as NAVD-88. A datum is a reference point used to ensure that all measurements are represented consistently.

Tidal effects

Tidal effects on Turkey Creek are pronounced and vary with the force, direction, and duration of winds and storm surges generated from the Atlantic Ocean and propagating from Charleston Harbor upstream along the Cooper River and its floodplain. The nearest USGS tide gauge to Turkey Creek is located in the Cooper River at Filbin Creek. The "king tide" is a higher than predicted high tide and is above the highest water level reached at high tide on an average day. In Charleston, tides fluctuate daily. The average high tide is about 5.5ft, whereas during a king tide event the high tide range may reach 7 feet or higher. These tides occur naturally and are typically caused when a spring tide (when the sun, moon, and earth align during a new and full moon, increasing tide ranges) takes place when the moon is closest to Earth during the 28-day elliptical orbit. Normal average tide at this gauge is 2.5ft NAVD-88 while the average "king tide" is 4.5ft NAVD-88 (Table 1).

3.1.1 Hydrologic and Hydraulic modeling

USACE uses models developed by the USACE Hydrologic Engineering Center (HEC). Two models were used for this study. HEC-HMS is the Hydrologic Modeling System, which computes the magnitude and timing of flows based on the size of the watershed, elevation, soil type and rainfall. HEC-RAS is the River Analysis System, which computes the stage (depth) and velocity of the water. Important features in this model include the Murray Drive bridge, the CSXT railroad culvert, and a roughness coefficient that simulates vegetation on the banks.

Best available data were used as inputs to the models. In LiDAR elevation data were collected in 2009, and land use/landcover data were from the 2011 USGS National Landcover database In addition, Changes to the landscape, landuse and landcover of the study area may have occurred since 2009, and products, modeling outputs, etc. should be viewed in that context.

Table 1: Boundary conditions for hydrologic and hydraulic modeling

Tide (obs. @ tidal station)	Rain	Goose Creek	Surge
•Normal (2.5ft. NAVD-88) •King (4.5ft. NAVD-88)	•2yr (4.16in) •5yr (5.37in) •10yr (6.36in) •25yr (7.75in) •50yr (8.88in) •100yr (10.10in)	•No flow •9" over weir	•Hurricane Matthew – (6.8ft., NAVD-88 on 8 Oct 2016)

Conditions included in modeling were tide, rain, flow over the Goose Creek Reservoir weir, and surge (Table 1). These conditions were combined into seventeen different scenarios developed to understand flooding in Turkey Creek (Table 2).

Figure 2 below shows modeled flooding in the Turkey Creek study area under conditions observed during Hurricane Matthew. All flooding in this scenario, and other scenarios modeled as part of this study, occurs within the AE flood zone established by the Federal Emergency Management

Administration (FEMA).

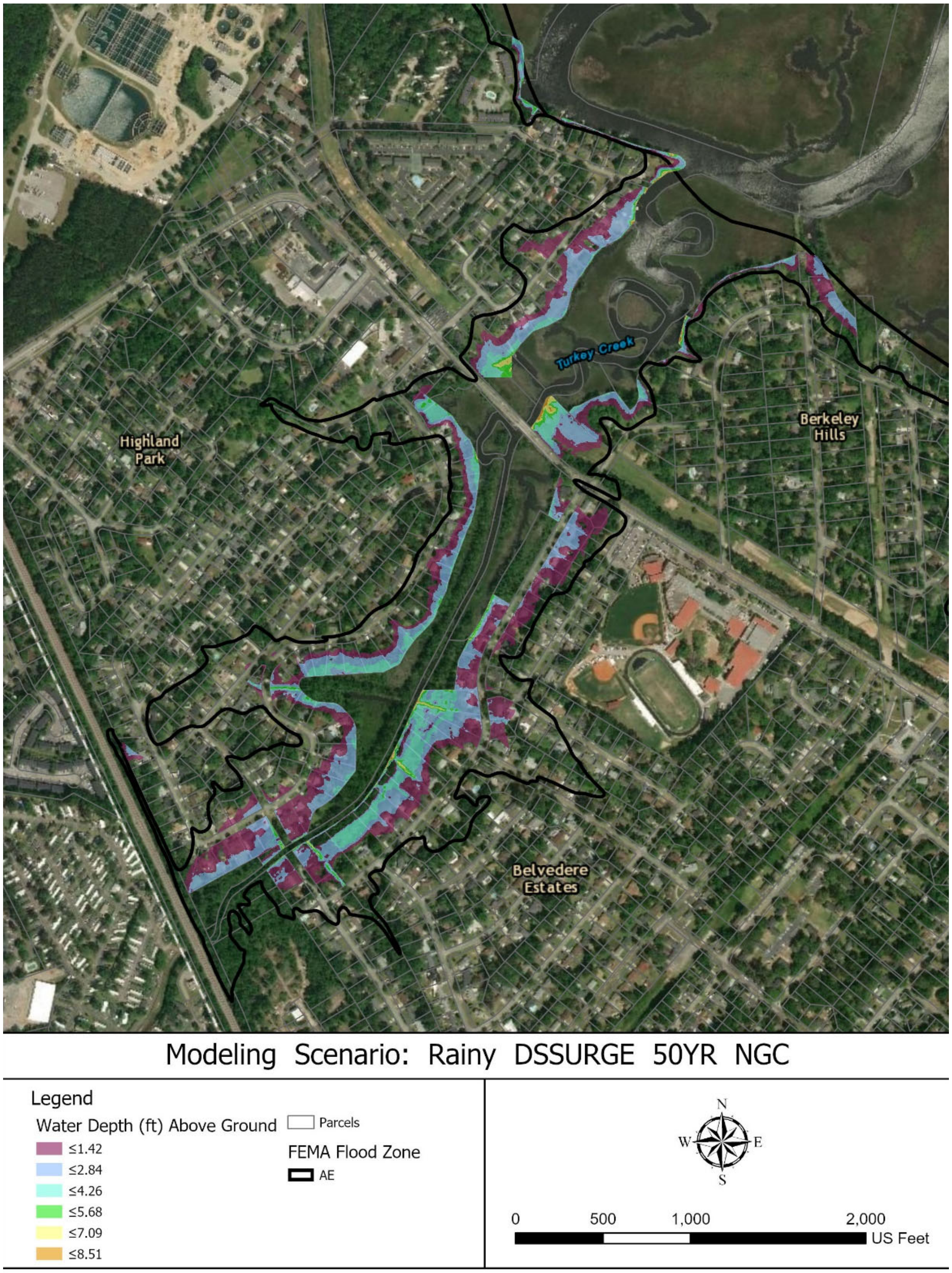


Figure 2: FEMA AE flood zone within the Turkey Creek study area

Table 2: Modeling Scenarios and simulated water surface elevations in feet NAVD-88

Scenario	*WSE at Point-A, ft NAVD*	*WSE at Point-B, ft NAVD*	*WSE at Point-C, ft NAVD*
SUNNY-NT	2.25	2.25	2.24
SUNNY-KT	4.47	4.47	4.47
RAINY-DSNT-2YRNGC	2.52	2.26	4.57
RAINY-DSNT-5YRNGC	3.50	2.54	5.20
RAINY-DSNT-10YRNGC	4.06	2.92	5.53
RAINY-DSNT-25YRNGC	4.75	3.33	5.96
RAINY-DSNT-50YRNGC	5.26	3.52	6.29
RAINY-DSNT-100YRNGC	5.77	3.72	6.61
RAINY-DSKT-2YRNGC	4.61	4.51	5.09
RAINY-DSKT-5YRNGC	4.81	4.57	5.51
RAINY-DSKT-10YRNGC	5.00	4.63	5.79
RAINY-DSKT-25YRNGC	5.32	4.68	6.15
RAINY-DSKT-50YRNGC	5.61	4.74	6.42
RAINY-DSKT-100YRNGC	5.95	4.83	6.70
RAINY-DSNT-25YR9"GC	4.75	3.33	5.96
RAINY-DSKT-25YR9"GC	5.33	4.70	6.15
RAINY-DSSURGE-50YRNGC	6.22	6.33	6.45

The water surface elevation (WSE) from hydraulic modeling analyses of different scenarios are compared at three different locations along Turkey Creek and are presented in Table 2, and depicted in Figure 3. Beginning with the most upstream, Point C is located near the CSXT Railroad crossing of Turkey Creek. This railroad also represents the municipal boundary between the City of North Charleston and the City of Hanahan. Point A is located on the upstream of Murray Drive Bridge, and Point B is located on the downstream side of the Murray Drive Bridge, closest to where Turkey Creek meets Goose Creek.

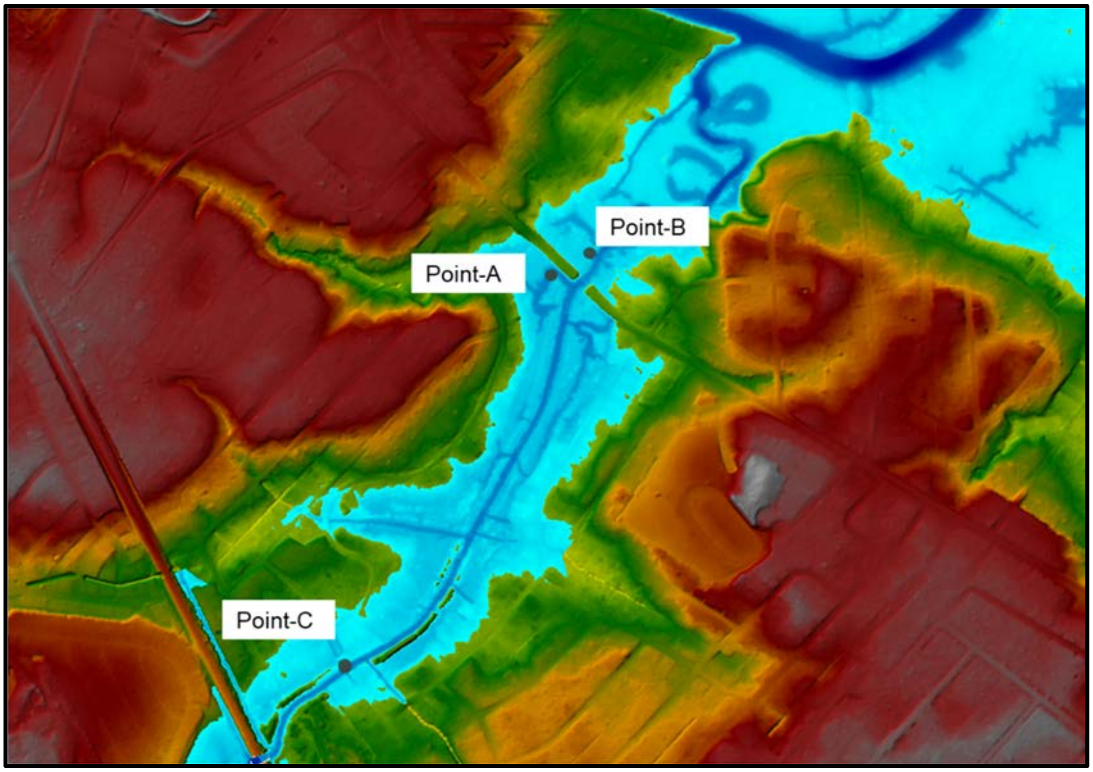


Figure 3: Locations of three observation points.

3.1.2 Summary of Findings of Hydrology and Hydraulic Analyses.

Each of these points can be examined under different modeled scenarios to better understand flooding along Turkey Creek. Beginning at the most upstream location, Point C, we see that this location is most affected by the magnitude of the rainfall event and to a much lesser degree by the magnitude of the tidal stage. Under king tide conditions, with no rainfall, the simulated water surface elevation (WSE) is 4.47ft NAVD-88. At the same point, the WSE with normal tide conditions and a 2yr rain event is 4.57ft NAVD-88. Another example that illustrates the effect of rainfall in the upstream portions of Turkey Creek is the comparison of 100 year rain event and the Hurricane Matthew observed conditions. At Point C, the effect of the king tide, relative to normal tide, only increases the peak 100yr flood stage from el. 6.61ft NAVD up to el. 6.70ft NAVD-88. Under a more severe tidal event such as Hurricane Matthew, the peak flood stage at Point C is predicted to be el. 6.45ft NAVD-88 lower than the above 100yr events because the rainfall associated with Matthew was a lesser amount, approximately 50yr.

Looking at map depictions of water depth on parcels surrounding Point C can also illustrate the effect of rainfall events (Figure 4). Complete map books for flooding scenarios overlayed with parcels near Turkey Creek can be found in Appendix 5. During a simulated 10yr rain event, parcels near Point C will experience water on their properties of 1.42ft or less, in some cases up to their permanent structures. At a more significant rain event, 25yr, water on these properties is more widespread and deep, up to 2.83ft, sometimes up to the permanent structure. This same 25yr rain at a king tide shows little change in water depth, and similar observations can be made at under the Hurricane Matthew conditions.

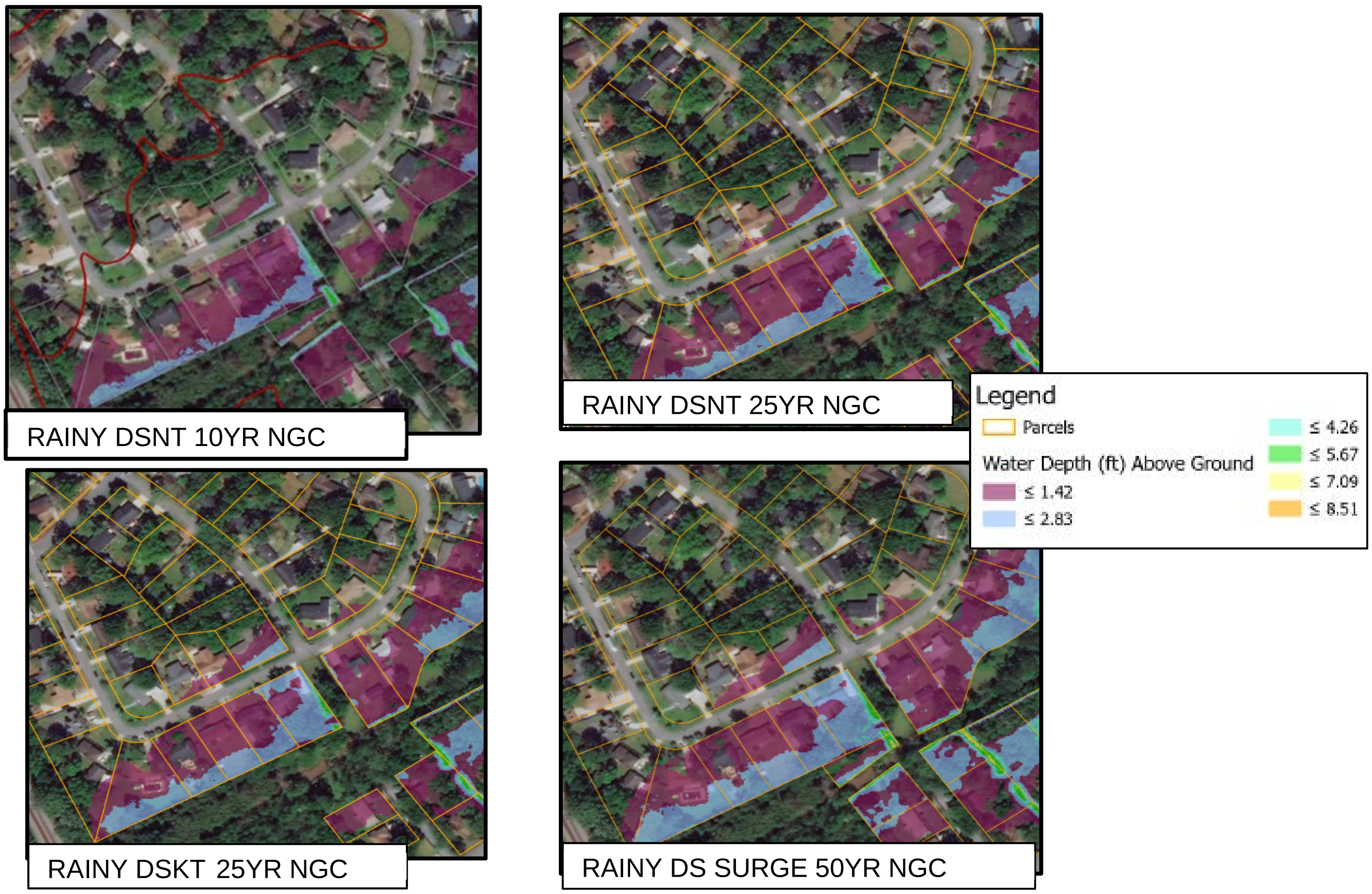


Figure 4. Simulated water depth over parcels near Point C

Moving downstream toward Murray Drive Bridge and the Goose Creek, the effect of tidal stage on flood conditions increases. The flood stages at the downstream side of the Murray Drive bridge are dominated by the tidal signal regardless of the size of the upstream watershed storm event.

Point A is located on the upstream side of the Murray Drive bridge (Figure 5). At this location, flooding is partially influenced by rainfall, but tide has a greater influence. The flooding effect of rainfall runoff on the upstream end of the Murray Bridge (Point-A) begins exceeding the effect of the king tide (4.47ft. NAVD-88) with no rainfall at the 2yr rainfall event under king tide conditions (4.61ft NAVD-88) and at the 25yr rainfall event under normal tide conditions (4.75ft NAVD-88).

During a 10yr rain event (6.36in rain), we see a water surface elevation at Point A of 4.06ft NAVD-88. Recall that upstream at Point C, the depth under these rain conditions was 5.53ft NAVD-88, signaling that rainfall has less effect here. The image shows us that residents near Point A may see water at or below 1.42ft deep on the edges of their properties, but not up to the permanent structures. As rainfall increases, such as in the 25yr (7.75in) or 50yr (8.88in) rain event, water depth anticipated on these parcels increases. When examining the difference between the 25yr rain event at normal tide versus king tide, one sees a greater increase in water depth, but still not up to permanent structures in most cases. Under the condition experienced during Hurricane Matthew, water depth at the edges of these parcels may reach depths of up to 7ft.

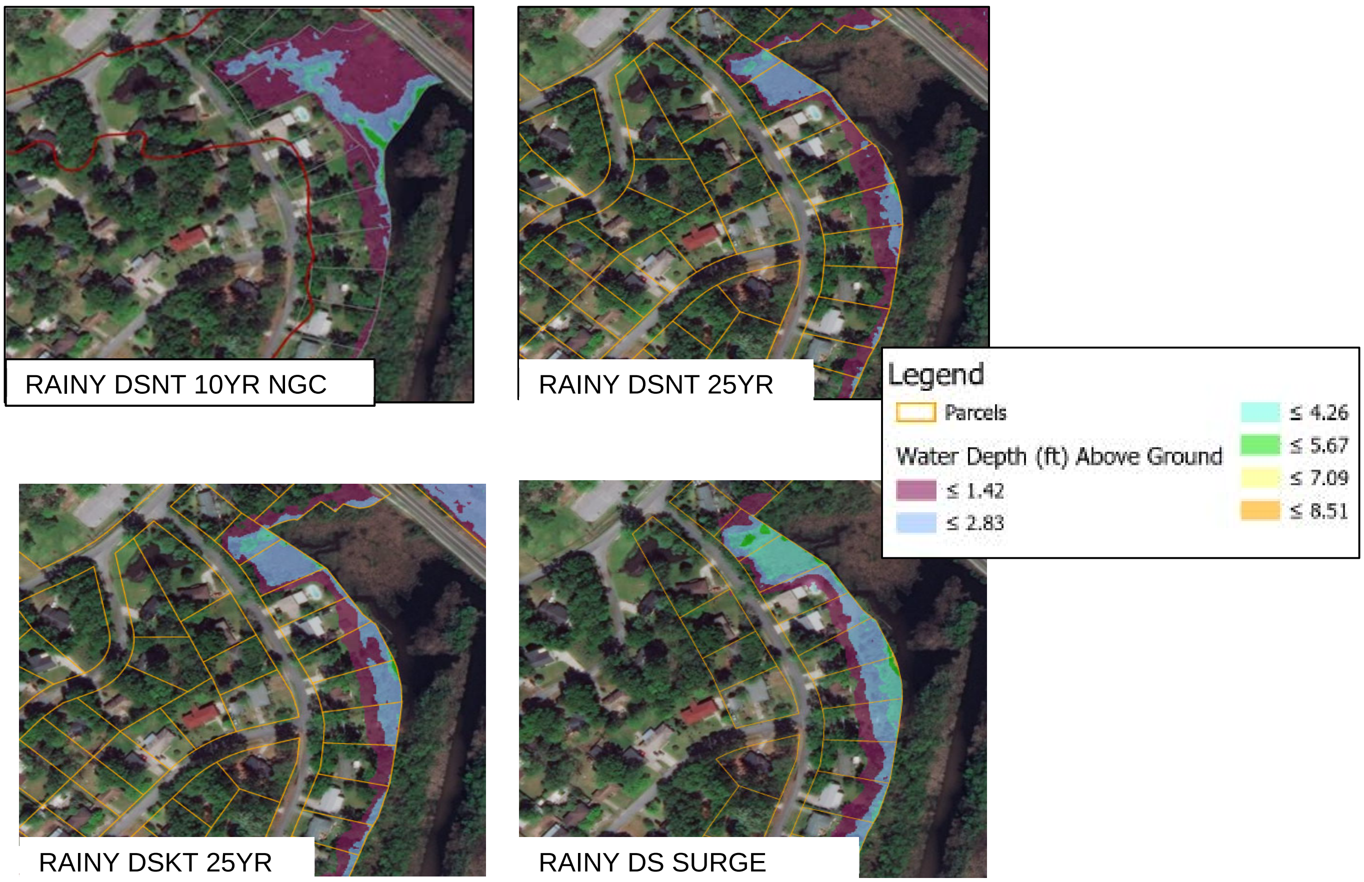


Figure 5: Simulated water depth over parcels near Point A

Point B is located on the downstream side of the Murray Drive bridge (Figure 6). At this location, flooding is primarily influenced by tide. These images show the range of expected water depth in parcels near Point B under four conditions. During a 10 year rain event (6.36in), there is a water surface elevation at Point B of 2.92ft. Recall that upstream at Point A, just on the upstream side of the bridge, the depth under these rain conditions was 4.06ft NAVD-88. The image shows us that parcels near Point B may see no water on their properties at 10yr or 25yr rain events, under normal tidal conditions. During a 25 year rain event (7.75in) in king tide conditions, property owners in this area may see water at or below 1.42ft, in most cases not affecting permanent structures. Under the conditions experienced during Hurricane Matthew, water depths can be expected to be 2.83ft or less, in some cases up to permanent structures.

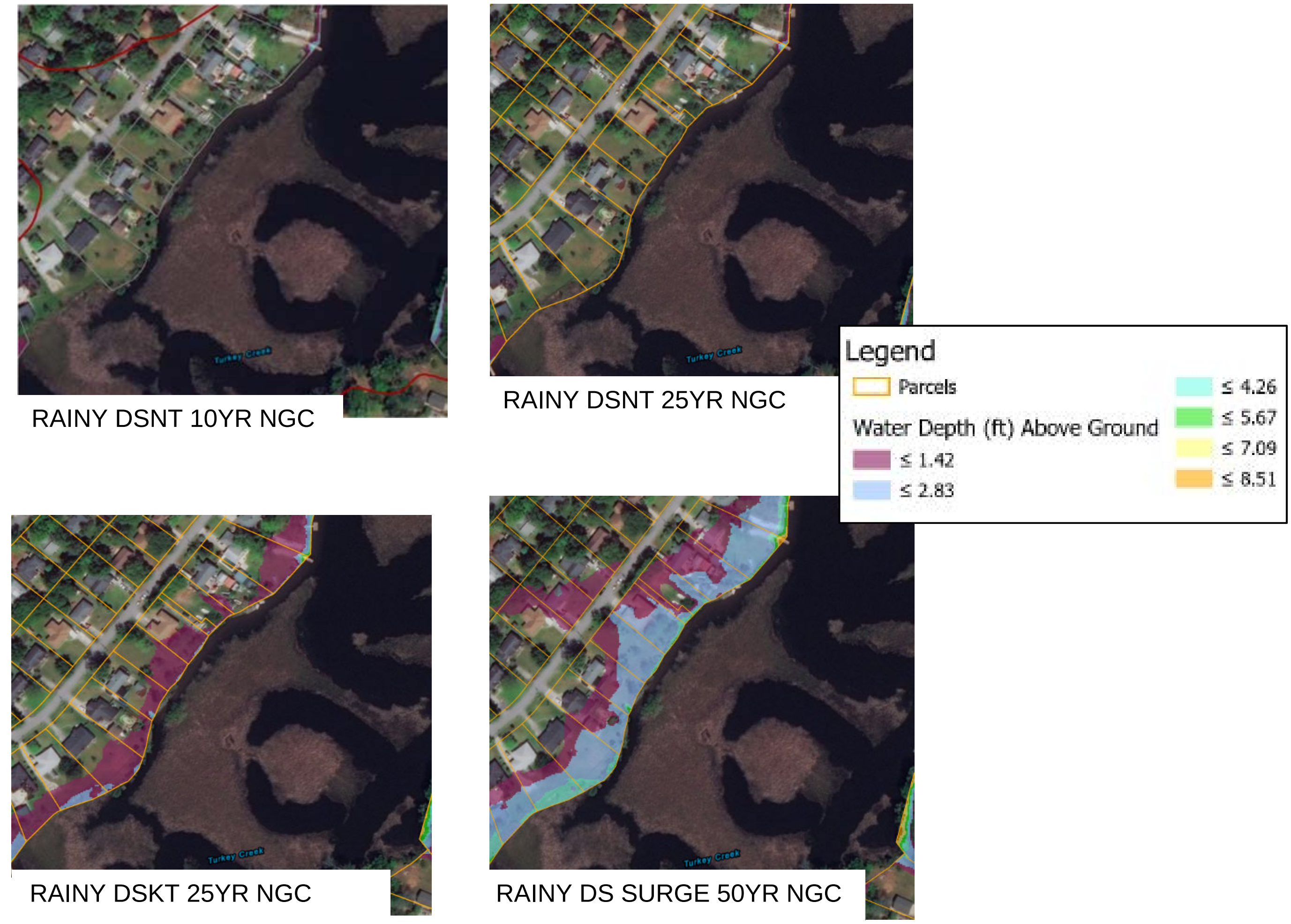


Figure 6: Simulated water depth over parcels near Point B

3.1.3 Flooding not caused by stormwater or tide

Simulated model results have revealed the reasons for several reported flooding issues. For example, there are several reported locations of flooding along Hillside Drive indicated as deep blue dots (numbered 1-4) in Figure 7. The simulated WSE from an extreme event i.e., Hurricane Mathew with 50yr-24hr rainfall, is found to be 6.22ft NAVD-88 in the vicinity whereas the ground elevation in between points 2 and 3 is 7.5ft NAVD-88. It is unlikely for this location to be flooded due to direct effects of the water stage in Turkey Creek. This area might have been flooded from local drainage restrictions as the size of pipe culvert on Hillside Drive may be inadequate and the lined canal that carries flow through the pipe is narrow. Additionally, due to the elevated tail-water during a rainfall-event further reduces the efficiency of the culvert. At this point, the pipe culvert has not been modeled incorporating it with HEC-RAS 2D mesh. The lined canal geometry could not be integrated into the mesh due to data unavailability.

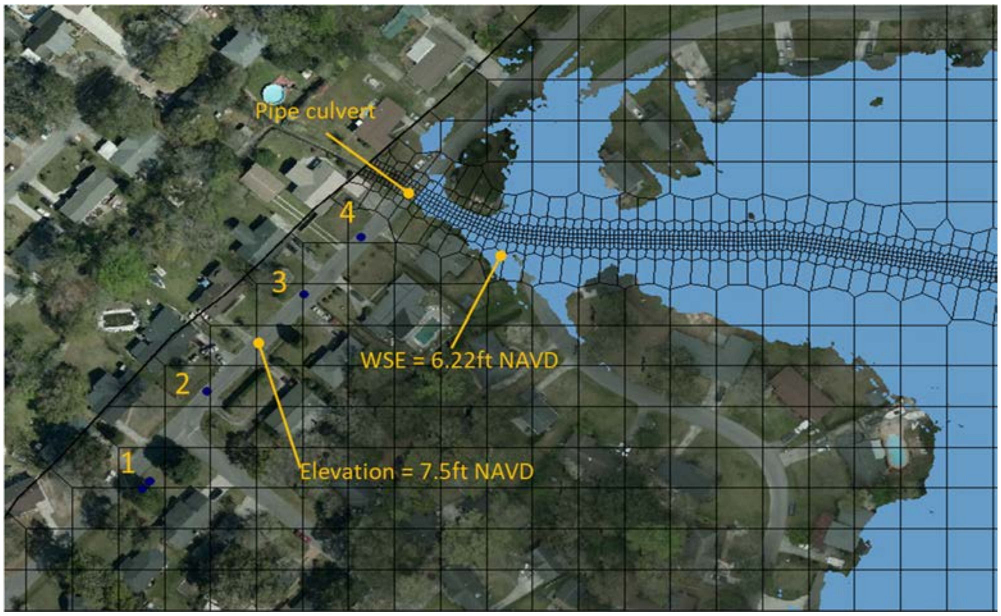


Figure 7: Reported flooding locations on Hillside Dr.

Possible restrictions in flow at this Hillside drive location were also noted during the April 2019 site visit. At Redeemer Drive (pink circle in Figure 8), culverts have been installed to convey a tributary beneath the roadway. At the upstream side, there are three culverts. At the downstream side, there are only two culverts. If the downstream culverts have a smaller diameter and length, this will cause water to back up on the upstream side, in the vicinity of Hillside Drive. The same tributary, between Hillside Drive and Springhill Road (blue circle in Figure 8), is narrow and constricted, which will also cause water to back up.

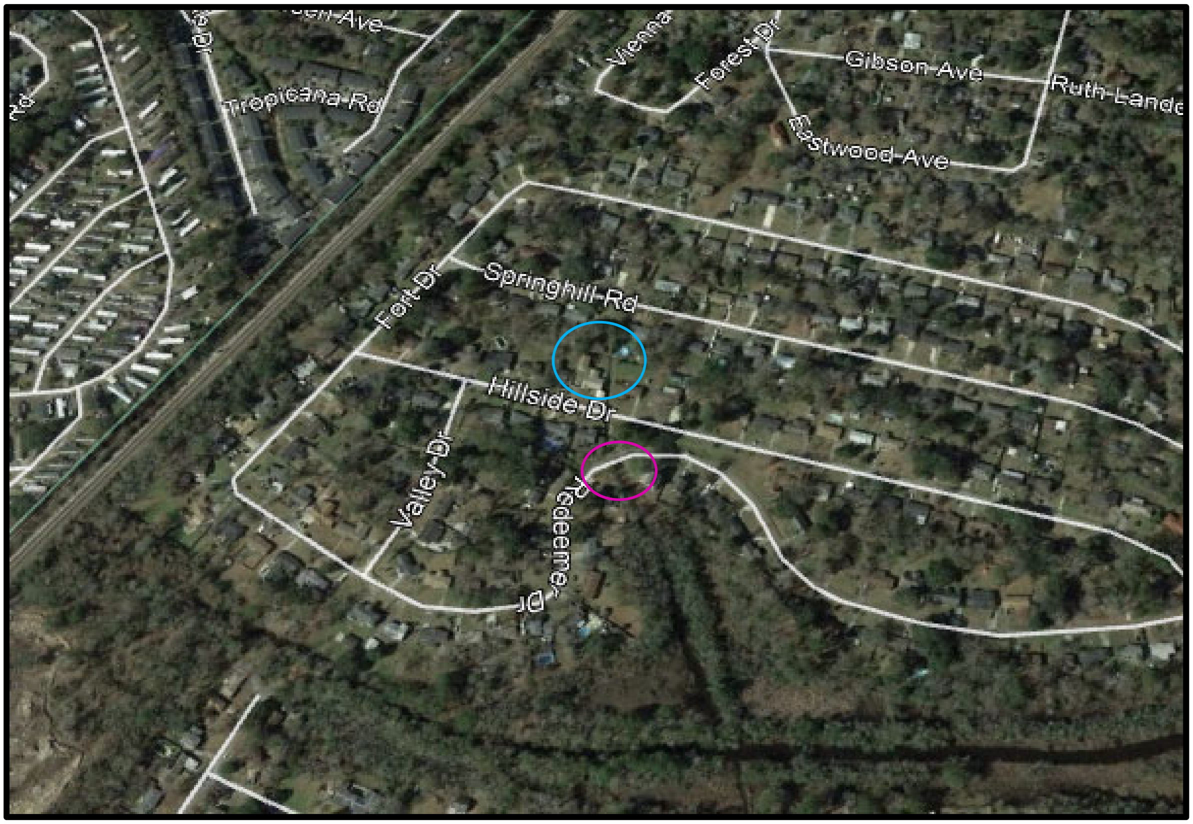


Figure 8. Field observations of potential stormwater system challenges

Similar reported flooding has been reported by the NFS on Wedgewood Dr. (Deep blue dot on Figure 9) where average ground elevation is 9ft NAVD-88 and the nearest simulated WSE from same event is found to be 6.6ft NAVD-88. The adequacy of the culvert has not been checked or incorporated into the model mesh because of data unavailability, but the reported area was likely not flooded due to the backwater effect of the Turkey Creek stages.

Figure 9: Reported flooding locations on Wedgewood Dr.

Other locations examined during the April 2019 site visit were at Forth Drive and Brookside Drive.

On Fort Drive, a small channel (red line in Figure 10), drains to a tributary that runs parallel to the railroad and drains into Turkey Creek. This channel has a partial bulkhead installed. Maintenance of this channel would improve water movement.

On Brookside Drive, there is a tributary that drains into Turkey Creek. Where the tributary crosses Brookside (green circle in Figure 10), there is an open channel on the upstream side, and three culverts that pass beneath the roadway. On the downstream side of Brookside Drive, there is a visual gap in the channel. It is unknown if there are pipes connecting the channel beneath the ground. Depending on this connection, water could back up in this area and upstream.

Silt and debris removal via dredging upstream of the Murray Bridge (orange line in Figure 10) may help move water entering the stream from surface water runoff during rain events. This will not alleviate any flooding caused by tide. Regular dredging maintenance would be required, and costs may outweigh benefits.

Between Murray Drive and the railroad, ditches and tributaries drain into Turkey Creek. Property owners should keep ditches and culverts beneath driveway clear to allow water to flow. Clearing ditches may help move water entering the stream from surface water runoff during rain events. This will not alleviate any flooding caused by tide.

Figure 10. Field observations of potential stormwater system challenges

3.1.4 Effect of the Goose Creek Weir

The simulated results with and without Goose Creek dam release indicate that the contribution of release to Turkey Creek flooding is not significant. We have considered both typical and significant dam releases for the Goose Creek reservoir based on conversations with the reservoir operators. The main portion of Goose Creek weir has a crest elevation 6in below the crest elevation of the higher (wider) part of the weir. A typical release would be 6in of flow over the lower weir and no discharge over the top weir. A significant release would be 9in of flow over the lower weir and 3in of flow over the top weir.

3.2 Environmental Conditions

To fully understand the existing conditions, USACE inventories a wide array of information in accordance with federal regulations. This information will be pertinent if the NFS independently pursues any potential measures for which a permit is needed. This section will summarize the findings. The full report is provided in Appendix 4.

The Turkey Creek area contains approximately 50 acres of wetlands, according to the National Wetland Inventory (Figure 11). Wetlands provide important functions such as flood water storage, nutrient transformation, and clean water. These systems are protected under state and federal regulations.

Figure 11. National Wetlands Inventory in the Turkey Creek area

According to the South Carolina Heritage Trust (SCHT) database, there are no Federal Endangered Species Act (ESA) listed species or Federally-designated critical habitat located within the study area. However, the SCHT database indicates the presence of bald eagle species within the study area boundary. While this species is no longer listed under the ESA, it is designated as a state listed species and is federally protected by the Bald & Golden Eagle Protection Act of 1940, as amended (BEGPA).

According to the National Marine Fisheries Service (NMFS) Essential Fish Habitat Mapper, Snapper Grouper species have been found in the Turkey Creek area (Figure 12). Any actions that could impact this habitat require consultation with the NMFS, as defined by the Magnuson-Stevens Fishery Conservation and Management Act of 1976.

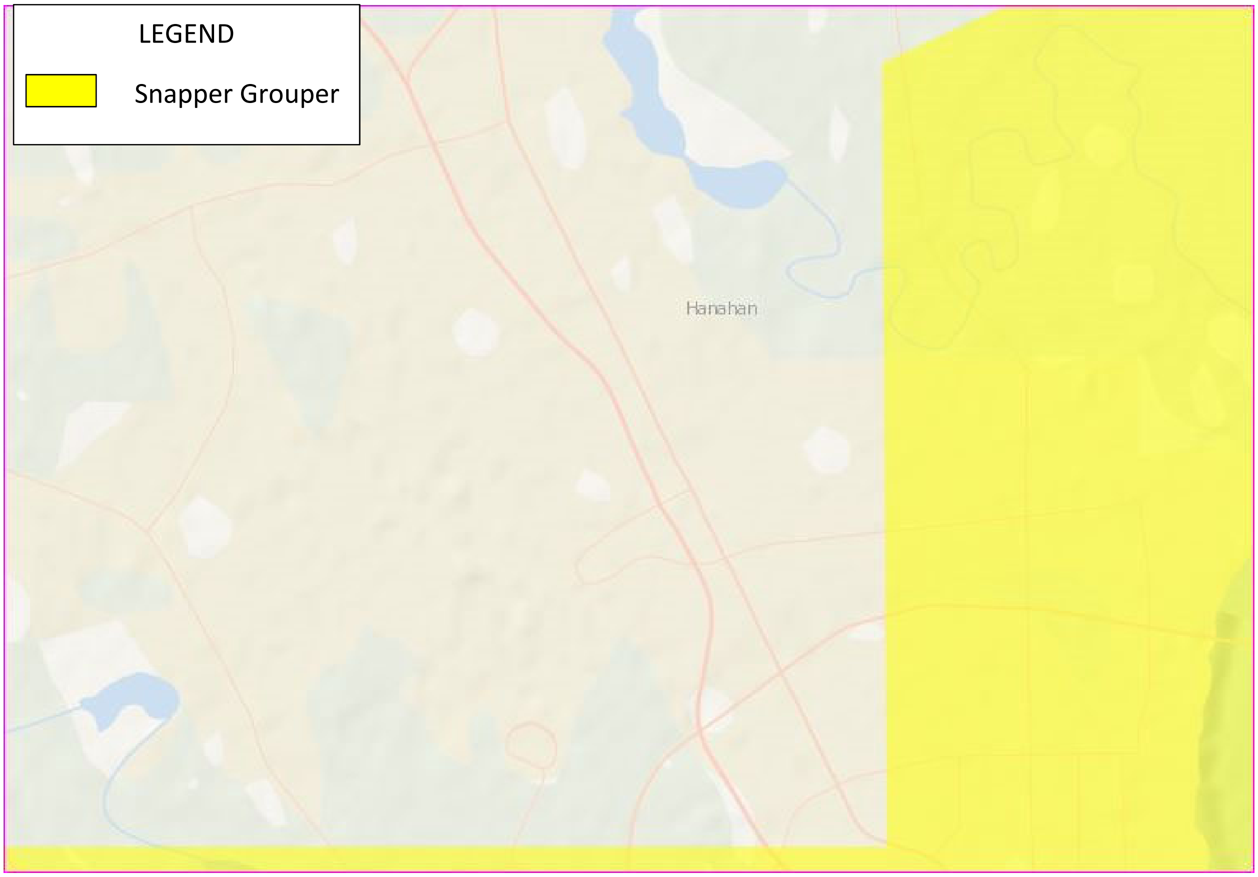


Figure 12. Essential Fish Habitat Map

4 Problems and Opportunities

Based on the inventory of existing conditions reviewed in the previous section, we can develop three problem statements that summarize flooding experienced in Turkey Creek. Flooding is complex due to the fact that it has contributions from both tidal flooding and flooding from rainfall induced stormwater runoff (i.e. compound flooding).

4.1 Problems

Problem #1 – Stormwater Runoff Flooding: Properties near Turkey Creek are flooded due to stormwater runoff flowing toward Turkey Creek from throughout the watershed.

Problem #2 – King tide Flooding: King tides produce overbank flooding that affects properties near Turkey Creek.

Problem #3 – Compound Flooding: Rainfall leading to stormwater runoff during king tides or storm surges produces compound flooding that affects properties near Turkey Creek.

Map books showing close ups of parcels under various flooding scenarios are provided as Appendix 5.

4.2 Opportunities

There may be opportunities to restore the natural environment along Turkey Creek for enhanced floodplain function and/or increased habitat.

5 Measures Considered

Typical USACE projects follow a thorough process referred to as plan formulation. Plan formulation is the process of developing management measures and plans that meet planning objectives and avoid planning constraints. Plan formulation consists of three phases which can be iterative: 1) identifying management measures; 2) formulating alternatives by combining the management measures; and 3) compare alternatives. The scope of this study included only the first phase, identifying management measures, which requires the understanding of the problem.

A management measure is a feature (structural) or activity (nonstructural) that can be implemented at a specific geographic site that is intended to cause a desirable change and results, preferably, in a positive output. There are three major categories of measures, including Structural, Nonstructural, and Natural or Nature-Based Features. Structural measures have historically been the technique most desired by the general public, as these modify flood patterns and “remove floods away from people” through measures such as floodwalls and levees. Structural flood risk management measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. This includes gates, levees, and flood walls that are implemented to protect people and property.

Nonstructural flood risk management measures basically “remove people from floods” leaving stormwater to pass unmodified. Nonstructural flood risk management measures are permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the probability of flooding. Relocation, flood-proofing, home elevation, and flood warning systems are examples of nonstructural measures.

Natural or nature-based flood risk management measures work with or restore natural processes with the aim of flood risk management. Floodplain restoration, habitat restoration, greenways, etc. can be considered.

This effort identified the measures shown in the table below, several of which merit further investigation.

Table 3: Conceptual measures and recommendations for further study

Measure	Description and Applicability	Further Study (Y or N)?
Structural		
Murray Bridge Modification	It is possible that the bridge crossing Turkey Creek is causing a blockage of the channel which is interfering with the flow of water downstream during rain events. This effect needs further analysis to verify if there is an impedance to flow, and how much it can be reasonably reduced. Potentially, additional drainage under the road will allow for increased flow, which could be accomplished by lengthening the bridge span, or placing box culverts within the earthen embankment beneath the road. This would require extensive design and construction.	Y
Deployable Dam	This is an event-based response. A "hydro-dam" could be installed downstream and north east of the Murray Bridge for king tide and surge events. The hydro-dam would require pumps (and fuel) to remove upstream storm water from the channel during the event. A crew would be needed to deploy the hydro-dam, and there would be risk to pumping equipment during the storm event.	Y
Tidal/Miter Gate	A tidal gate is a large, moveable structure that would close across a waterway prior to a storm and reopen to allow natural movement of tides. A miter gate serves the same function but on a smaller scale. Miter gates could be installed on or near the Murray Bridge. This solution would likely require mechanical pumping to remove upstream Stormwater rain water during high tide and surge events. For environmental considerations the gates would need to allow brackish water to flow up stream during non-storm or high tide events. The cost and maintenance of this measure would be high and complicated by upstream stormwater flooding due to rainfall associated with coastal storms.	Y
Levee	Levees are man-made barriers along a water course constructed for the primary purpose of providing flood, storm, and hurricane protection. Since the primary cause of the flooding is due to rainfall and not tidal or storm surge, the levee would likely prevent flow of rainwater to the creek and could increase flood damage due to rainwater. In addition, due to a levee's larger footprint, levees are only feasible where space allows and, in this instance, will require the acquisition of properties. This would leave few previously flooded properties, if any, protected by a levee. If a levee is located in an erosive shoreline environment, revetments may be needed on the waterfront side for more protection from erosion.	N

	A levee could consist of an earthen berm to an elevation of 7 feet or more above existing grade to accommodate the maximum flood stage observed in modeling outputs. This would require a substantial amount of land on either side of the structure, as well as block views of the creek. Table 4 displays the required widths for an earthen berm levee. A concern regarding levees is that they may entice people to seek shelter in a structure instead of evacuating, if a levee is present. This presents a life safety concern in the event a levee is overtopped or fails. This concern also applies to other structural features.	
I-Wall	I-Walls are a sheet pile flood control structure. Since the primary cause of the flooding is due to rainfall and not tidal or storm surge, the I-wall would likely prevent flow of rainwater to the creek and could increase flood damage due to rainwater. I-Walls require about a 30 ft wide footprint. This is primarily due to the 15 ft Vegetative Free Zone (VFZ) required on each side of the structure. Also, this will require the acquisition of properties and would leave few previously flooded properties, if any, protected by an I-Wall. However, due to the soil conditions in the area, the I-Wall would be limited to a height of 5 feet above existing grade. An I-Wall could adversely impact the effective floodplain, but generally, the wall is located in close proximity to the building(s) it is protecting, so that floodplain characteristics such as depth and velocity are not impacted. A concern regarding I-Walls are that they may entice people to seek shelter in a structure instead of evacuating, if an I-Wall is present. This presents a life safety concern in the event an I-Wall is overtopped or fails. This concern also applies to other structural features.	N
Deployable Floodwall	Rapid deployment floodwalls are structures that are temporarily erected along the banks of a river or estuary, or in the path of floodwaters. Deployable floodwalls are usually used in locations where space for a levee or I-Wall is limited.	Y
Stormwater Management Infrastructure (Grey)	Stormwater management infrastructure often consists of curb and gutter with an adequately piped system (grey). But, it can also incorporate bio-retention pond, bio-swales, and stormwater wetlands (green; discussed further under Natural and Nature-Based Features). To reduce runoff induced flooding, the overland flows need to be captured and detained during peak flows before they reach the creek. Two specific areas this may be useful are at Wedgewood Drive and Hillside Drive	Y
Detention Basins	A detention basin is an excavated area installed on or adjacent to water bodies to protect against stormwater flooding. This measure could be achieved by creating detention basins for short-term storage of stormwater.	Y

	To reduce runoff induced flooding, the overland flows need to be attenuated before they reach the creek.	
Underground Cisterns	Underground cisterns and tanks could temporarily store stormwaters. Industrial pumps would discharge the stormwater at a controlled pace after the danger of flooding has passed.	N
	Nonstructural	
Acquisition	This technique consists of buying the structure and the land. The structure is either demolished or is sold to others and relocated to a site external to the floodplain. Development sites, if needed, can be part of acquisition in order to provide locations where displaced people can build new homes within an established community.	Y
Relocation	This technique requires physically moving the at-risk structure and buying the land upon which the structure is located. It makes most sense when structures can be relocated from a high flood hazard area to an area that is located completely out of the floodplain.	Y
Elevating structures	This technique typically lifts an existing structure to an elevation which is at least equal to or greater than the 1% annual chance flood elevation. In many elevation scenarios, the cost of elevating a structure an extra foot or two is less expensive than the first foot, due to the cost incurred for mobilizing equipment. Elevation can be performed using fill material, on extended foundation walls, on piers, post, piles and columns. Elevation works well with structures that were built with crawl spaces, but can also be successful for slab on grade structures.	Y
Wet Flood proofing	This technique is applicable as either a stand-alone measure or as a measure combined with other measures such as elevation. As a stand-alone measure, all construction materials and finishing materials need to be water resistant and all utilities must be elevated above the design flood elevation. Wet flood proofing is applicable to residential homes as well as commercial and industrial structures when combined with a flood warning and flood preparedness plan. This measure is generally not applicable to large flood depths and high velocity flows.	Y
Dry flood proofing	This technique consists of waterproofing the structure. This can be done to residential homes as well as commercial and industrial structures. This measure achieves flood risk reduction but it is not recognized by the NFIP for any flood insurance premium rate reduction if applied to a residential structure. Based on laboratory tests, a "conventional" built structure can generally only be dry flood proofed up to 3-feet in elevation. A structural analysis of the wall strength would be required if it was desired to achieve higher protection. A sump pump and perhaps French drain system should be installed as part of the measure. Closure panels are used at openings. This concept does not work with basements nor does it work with crawl spaces. For buildings with basements and/or crawlspaces, the only way that dry flood proofing could be considered to work is for the first floor to be made impermeable to the passage of floodwater.	Y

Land Use Regulations	Land use regulations within a designated floodplain are effective tools in reducing flood risk and flood damage. The basic principles of these tools are based nationally in the National Flood Insurance Program (NFIP) which requires minimum standards of floodplain regulation for those communities that participate in the NFIP. For example, land use regulations may identify where development can and cannot occur, or to what elevation structures should locate their lowest habitable floor to.	Y
Flood Warning System	A flood warning system is a way of detecting threatening events in advance. This enables the public to be warned en masse so that actions can be taken to reduce the adverse effects of the event. As such, the primary objective of a flood warning system is to reduce exposure to coastal flooding.	Y (if one is not in place already)
Natural and Nature-Based Features		
Restore Floodplain	This measure would include acquiring property in the floodplain, removing structures, and restoring the floodplain.	Y
Stormwater Management Infrastructure (Green)	Stormwater management infrastructure often consists of curb and gutter with an adequately piped system (grey). But, it can also incorporate bio-retention pond, bio-swales, and stormwater wetlands (green). To reduce runoff induced flooding, the overland flows need to be attenuated before they reach the creek.	Y

Table 4. Levee Dimensions

Earthen Berm Height (ft) Above Existing Grade	**10 ft Top Width**		**8 ft Top Width**	
	3H : 1V	**4H : 1V**	**3H : 1V**	**4H : 1V**
	Total Width (ft)	**Total Width (ft)**	**Total Width (ft)**	**Total Width (ft)**
1	46	48	44	46
2	52	56	50	54
3	58	64	56	62
4	64	72	62	70
5	70	80	68	78
6	76	88	74	86
7	82	96	80	94
8	88	104	86	102
9	94	112	92	110
10	100	120	98	118
11	106	128	104	126
12	112	136	110	134
13	118	144	116	142
14	124	152	122	150

* Total Widths include a Vegetation Free Zone (VFZ) of 15 ft on each side of the berm

6 Preliminary Conclusions

This study has focused on the hydrology and hydraulics to understand the existing flooding problems, with attention also given to existing environmental conditions. Some measures to solve the flooding problems were introduced and professional judgment applied to determine whether they should be investigated further, towards developing alternative conceptual plans.

Modeling outputs reveal that Turkey Creek floods over its banks as a result of rain events, king tide events, and surge events. In the upstream portion of Turkey Creek, flooding is primarily influenced by stormwater, while further downstream tidal and surge influence flooding more strongly. Both modeling and in-person site visits revealed several areas that the City of Hanahan could investigate in the near term to improve flow through existing storm water structures. Numerous conceptual measures were presented to address flooding from tide and surge events, which could be pursued under a more extensive study. Modeled floods occur within the FEMA AE zone, and flood risk management guidance from USACE suggests avoiding development within the floodplain, reducing hazards and risk associated with floods, and restoring or preserving natural floodplain functions. The most effective way to reduce risk of first-floor flooding within the floodplain is to remove or elevate permanent structures.

7 Recommendations for Further Study

This study focused on the first phase of plan formulation, understanding the problem for the purpose of identifying of management measures. If further study is pursued, the focus would be on the second and third phases: formulating alternative plans by combining the management measures, and then comparing alternatives. To develop alternative conceptual plans, a full, multi-disciplinary PDT is recommended. To help ensure cohesiveness and thoroughness, it is recommended the team be under the leadership of an experienced water resources planner who can guide the various analyses conducted by engineering, economics, environmental, real estate and others.

Objectives and constraints weren't developed under this effort, but would be an important step towards ensuring formulation of alternative plans. Objectives are specific, flexible, measurable, realistic, attainable and acceptable statements about what an alternative plan should try to achieve. Constraints are restrictions that the recommended alternative plan should avoid, and similar to objectives, help with the formulation of alternative plans.

After developing objectives and constraints, the PDT would focus on a more thorough understanding of the existing conductions. To more fully understand the existing conditions, the following would be explored by the PDT

Hydrology and hydraulics

- The runoff contribution from individual sub-basin needs to be singled out and the developed HEC-HMS and HEC-RAS models can be used to perform that activity.
- The Murray Drive Bridge has been modeled assuming that flow is always open channel flow and there is no flow over the deck. It is recommended to do a sensitivity analyses to assess the effect of the bridge coefficient and the effect of debris blockage on the resulting stages at the bridge.
- A detailed survey of the local drainage structures and swales is required to address the overland flooding issues on Hillside Dr. and Wedgwood Dr. The 2D HEC-RAS grid needs to be extended to incorporate several drainage structures, lined canals, and swales.

- The city might also consider a storm drainage network assessment for where pipe size might be increased, additional culverts might be warranted. This would be done with a different type of H&H model than the one developed in this study.

Real estate

- Study of first floor flooding
- Inventory of values of impacted properties
- Survey of first floor elevations

Economics

- Assign cost value to flood damages
- Determine "benefits" - how much the damages will be reduced if different mitigation measures are chosen.

Another key step before alternative plans can be formulated is establishing the future without project condition (FWOP). The FWOP forms the basis from which alternative plans are formulated and impacts are assessed. It requires forecasts, which should be made for selected years over the period of analysis to indicate what physical, economic, social, environmental, and cultural changes are anticipated. The full multi-disciplinary PDT would be engaged in establishing the FWOP. Assumptions regarding forecasted FWOP conditions would be documented. As the FWOP is developed, additions and revisions may also be made to the documentation of existing conditions. The H&H engineer, civil and cost engineers all play key roles in conducting analyses, and together with the planner, biologist, economist and others, make recommendations for measures and alternative plans.

The third phase of plan formulation is comparing alternatives. In this phase, measures considered would be combined into alternatives. For each alternative, the cost of implementing would be compared to the benefits received. This comparison would result in the identification of the alternative that provides the greatest benefit at the least cost.

Appendices

Appendix A: Letter Requesting Support

MAYOR
MINNIE NEWMAN

CITY ADMINISTRATOR
JOHN P. CRIBB

CITY COUNCIL
MIKE DYSON, MAYOR PRO-TEM
JEFF CHANDLER
JOEL E. HODGES
DAN OWENS
CHRISTIE RAINWATER
MICHAEL SALLY

May 3, 2017

Lt. Colonel Matthew W. Luzzatto
Commander and District Engineer
69A Hagood Avenue
Charleston, SC 29403

Dear Lt. Col. Luzzatto:

The City of Hanahan is interested in obtaining Corps of Engineers assistance in addressing flooding problems in the City of Hanahan. Specifically, the location of concern is the area surrounding Turkey Creek.

This problem has been going on in our city for decades but has gotten significantly worse over the past several years. Our city sent a letter on August 4, 2010 requesting assistance and the recent historical rain events on October 1- 4, 2015 and October 8, 2016 resulted in significant damage and property loss with many homeowners still undergoing repairs.

The City of Hanahan would like for the Army Corps of Engineers, under Section 22 of the Water Resources Development Act, to provide assistance to the City in hopes of finding a solution to this ongoing problem. The city is aware of the cost sharing/in kind responsibilities associated with the Planning Assistance to States (PAS) Program and look forward to working with your staff to discuss the responsibilities and commitments involved.

Please note that if the Corps determines that another study would be more beneficial, the city is open to discussion. If you have any questions please contact me directly at 843-576-5250.

Sincerely,

John P. Cribb
City of Hanahan
City Administrator

CC: Diane Perkins
Charleston District, Chief Planning
69A Hagood Avenue
Charleston, SC 29403

PHONE (843) 554-4221 - FAX (843) 747-3220 - 1255 YEAMANS HALL ROAD - HANAHAN, SOUTH CAROLINA 29410

Appendix B: Site Visit Report

Turkey Creek Hanahan Field Report –3/5/2019

Attendees:

Sara Brown

Mikala Randich

Team did field inspection of bridges and culverts within the study area to assess efficiency in flow conveyance, need for maintenance or need for further study. While the Hydraulic analysis will only study the main stream, the tributaries were included the field assessment.

It was overcast drizzly kind of day, however, Charleston Airport rain gage did not document significant rainfall.

Charleston International Airport / Charleston AFB, South Carolina										
80 F Charleston International Airport / Charleston AFB Station | Report										
March Observations	View									
Time	at ure	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Precip Accum	Condition
Mon Mar 04 2019 20:56:00 GMT-0500	48 F	43 F	83%	NW	6 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Mon Mar 04 2019 21:56:00 GMT-0500	48 F	43 F	83%	NE	3 mph	0 mph	30.0 in	0.0 in	0.0 in	Mostly Cloudy
Mon Mar 04 2019 22:56:00 GMT-0500	47 F	42 F	83%	N	6 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Mon Mar 04 2019 23:56:00 GMT-0500	47 F	42 F	83%	N	6 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 00:56:00 GMT-0500	47 F	42 F	83%	NNW	6 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 01:56:00 GMT-0500	45 F	44 F	97%	CALM	0 mph	0 mph	30.0 in	0.1 in	0.0 in	Heavy Rain
Tue Mar 05 2019 02:56:00 GMT-0500	46 F	44 F	93%	NNW	9 mph	0 mph	30.0 in	0.1 in	0.2 in	Light Rain
Tue Mar 05 2019 03:02:00 GMT-0500	46 F	44 F	93%	NNW	10 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 03:22:00 GMT-0500	46 F	44 F	93%	N	8 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 03:56:00 GMT-0500	46 F	44 F	93%	N	7 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 04:02:00 GMT-0500	46 F	44 F	93%	N	7 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 04:56:00 GMT-0500	46 F	44 F	93%	N	7 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 05:27:00 GMT-0500	44 F	43 F	96%	N	5 mph	0 mph	30.0 in	0.0 in	0.0 in	Fog
Tue Mar 05 2019 05:52:00 GMT-0500	45 F	43 F	93%	N	8 mph	0 mph	30.0 in	0.0 in	0.0 in	Fog
Tue Mar 05 2019 05:56:00 GMT-0500	45 F	43 F	93%	NNE	7 mph	0 mph	30.0 in	0.0 in	0.0 in	Fog
Tue Mar 05 2019 06:28:00 GMT-0500	46 F	44 F	93%	N	7 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 06:49:00 GMT-0500	46 F	44 F	93%	N	6 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 06:56:00 GMT-0500	46 F	43 F	89%	N	8 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 07:56:00 GMT-0500	44 F	42 F	93%	NNW	9 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 08:16:00 GMT-0500	44 F	42 F	93%	NNW	9 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 08:56:00 GMT-0500	44 F	42 F	93%	NNW	12 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 09:08:00 GMT-0500	44 F	41 F	89%	NNW	12 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 09:11:00 GMT-0500	43 F	41 F	93%	NNW	10 mph	0 mph	30.0 in	0.0 in	0.0 in	Light Rain
Tue Mar 05 2019 09:37:00 GMT-0500	44 F	42 F	93%	NW	9 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 09:47:00 GMT-0500	44 F	41 F	89%	NW	12 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 09:56:00 GMT-0500	44 F	41 F	89%	NNW	13 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 10:49:00 GMT-0500	43 F	40 F	89%	WNW	12 mph	0 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 10:56:00 GMT-0500	43 F	39 F	86%	NW	15 mph	21 mph	30.0 in	0.0 in	0.0 in	Cloudy
Tue Mar 05 2019 11:48:00 GMT-0500	45 F	39 F	80%	NW	8 mph	0 mph	30.0 in	0.0 in	0.0 in	Mostly Cloudy
Tue Mar 05 2019 11:56:00 GMT-0500	45 F	37 F	74%	NNW	14 mph	0 mph	30.0 in	0.0 in	0.0 in	Mostly Cloudy
Tue Mar 05 2019 12:22:00 GMT-0500	46 F	35 F	66%	NW	14 mph	0 mph	30.0 in	0.0 in	0.0 in	Partly Cloudy
Tue Mar 05 2019 12:56:00 GMT-0500	45 F	35 F	68%	NW	13 mph	0 mph	30.0 in	0.0 in	0.0 in	Partly Cloudy

The closest USGS gage is Cooper River at Filbin Creek @ North Charleston 021720677. Tide elevation was 2.83 ft NAVD88 after a high tide of 3.38 ft NAVD88 one hour earlier.

Old Murray Court is the primary road crossing of the main stream prior to confluence with Goose Creek. The main channel is open but there is dense vegetation on either side of a main channel in the tidal floodplain. No obstructions were visible in front of the bridge.

It should be noted that the bridge was replaced in 2005. The previous RAS model being sued for this analysis was done in 2000. New bridge data will be needed to update the model, however, it is unlikely that the bridge has a significant impact.

Old Murray Ct. north side of bridge deck looking upstream, note vegetation in low tidal floodplain

We do know from previous site visits that there is a water/sewer line at/above low tidal floodplain on the downstream side of the bridge.

Old Murray Ct bridge looking downstream, note shoaling in primary channel.

Caution should be taken for any dredging of the primary channel in this area due to potential impacts on the sewer/water line and it supports.

Using Google earth for the upstream side, since the photo was taken at low tide, again shows the low tide channel, some shoals for meandering that is the preference of nature.

Old Murray Ct looking upstream, Google earth, taken near low tide.

Any dredging of the primary channel, as was done in the past would have no impact on tidal flooding elevations, which are the primary flooding mechanism for this tidal creek. However, there could be some benefit of timing of conveyance of rainfall flood waters at low tide. However, due to the tidal nature of the channel, these small shoals would continue to form, so maintenance would have to be a continuous challenge and the benefits may not be warranted.

A structure on the south side of the stream shows some but not much topographic change over the tidal floodplain vegetation. There is limited room for any berm/wall etc. to block tidal flooding.

Structure on old Murray Ct near Recess Rd.

On the Turkey Creek the next stream crossing is the railroad. Flow under the railroad has a primary archway culvert and a secondary circular culvert looks to be 36 or 42 inch CMP. Unfortunately the old HEC2 converted to a RAS in 2000 shows a 40" by 20" box culvert. This will affect the analysis. Based on the photos, it is unlikely that Atlantic Coast Railroad modified the culverts. Consider it was originally a HEC-2 which would not have coded arched culvert under the "SC-Special Culvert" option, so it would have been converted to a box culvert or circular culvert. They obviously choose a box culvert. The small circular culvert was likely added after the arch culvert but unknown if it was merely combined for open area in the "SC" option until we have the exact measurements of the culverts.

Note the large pipe (sewer line?) is also not in the RAS model. Google earth aerials show it was there prior to the RAS development in 2000. Perhaps it was combined with the railroad influence due to its proximity. Need to verify its elevations.

The small culverts and this pipeline crossing that partially blocks the culvert would result in backwater upstream when due to rainfall, and slow down and reduce flows into the downstream portion of Turkey Creek.

Arch culvert at railroad.

Circular culvert at Railroad

Pipeline upstream of Railroad, blocking culverts.

The next stream crossing is Hawthorne Dr. located within the mobile home park. It is merely a flat bridge from bank to bank, minimal impact on flows or water levels.

Upstream of Hawthorns Dr. to US52 has seen some major improvements in bank stabilization.

DS Highway 52 looing downstream toward Hawthorne Dr. Access via Schlotsky's Deli

DS Highway 52, standing on left bank looking Upstream Highway 52.

DS Highway 52 on left bank, looking at tributary.

Highway 52 on downstream side

Google Earth shows what it looked like previously.

Downstream of the Railroad, we looked at tributaries flowing into Turkey Creek. Water levels were high and channels were full as expected due to the tide level. Roadside ditches drain to the tributaries. Property owners would need to keep all ditches clear and culverts under driveways clear in order to not block flow. There is not much topographic change - it is a low-lying area.

Redeemer Rd Areas

We did not have permission to traverse the stream via people's yards. All observations were made from the road.

Redeemer DR looking Downstream toward Turkey Creek. (Note roadside ditches to the left and right)

Some Maintenance of the ditches and stream could be done by would likely have minimal impact.

Redeemer Dr. looking upstream toward Hillside Dr. Only saw two culverts.

Hillside Dr.

No obstructions of culverts or stream noted.

Standing upstream looking downstream toward Redeemer Dr. Note three culverts. Only saw two culverts on Redeemer DR. This would cause backwater towards Hillside and farther upstream.

Hillside Dr. Looking Upstream, stream banks bulk headed/armored

Upstream there isn't much room to widen channels if needed, due to bulkheads and armoring.
. Note constriction of the stream.

Hillside Dr looking downstream, note constriction of stream – would result in some backwater.

Hillside Dr looking upstream from downstream side.

From the aerial on Google earth it can be seen the tributary if channelize – straight lines and vertical walls.

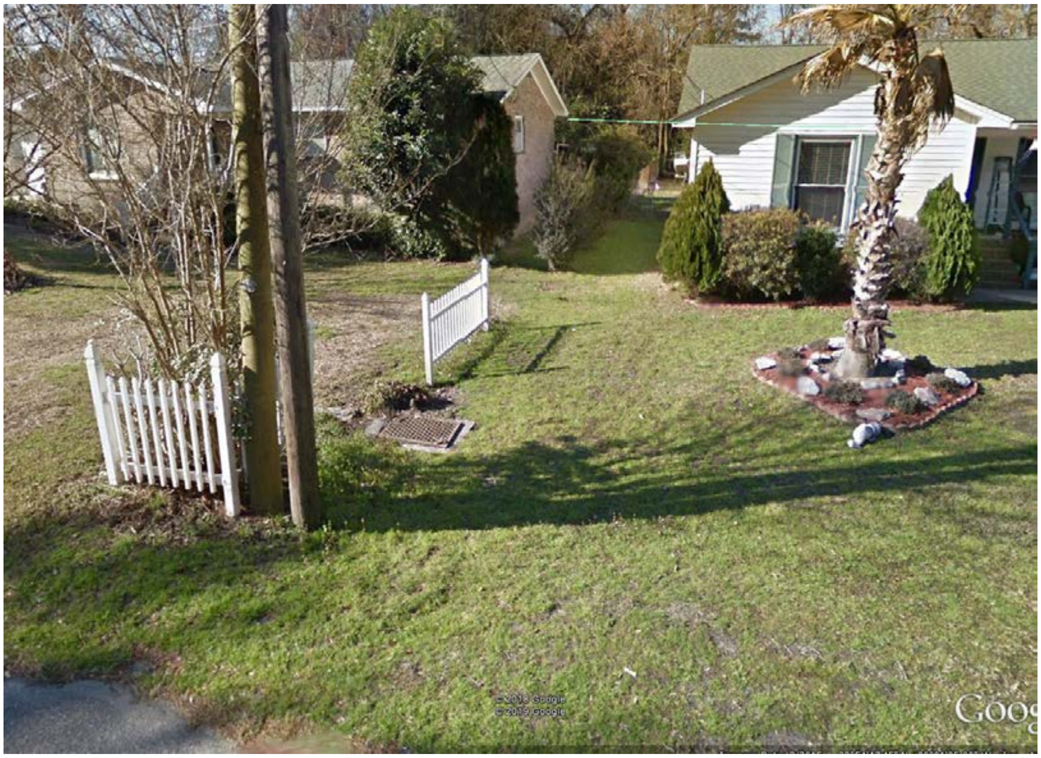
Ford St.

We noted it was a narrow reach that had wooden bulkhead on one side but did not extend the entire reach. A culvert under the road but no stream on the other side of the road. Some maintenance could be done here.

.

Ford St. looking downstream - note culvert.

Drop inlets were noted and assume to be the source of inflow to this tributary.



Drop inlet on upstream side of Ford St.

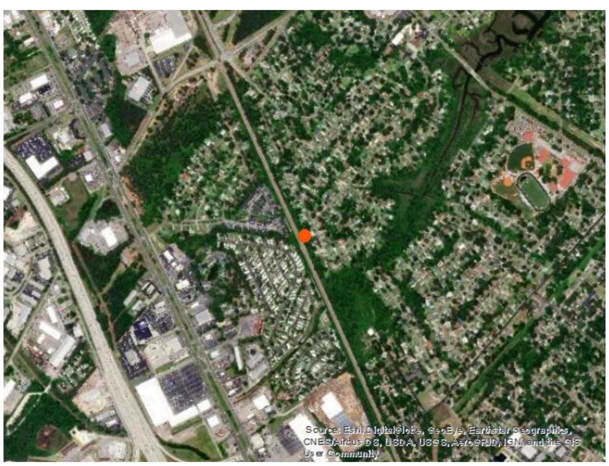
The question of where the tributary on the other side of the railroad near Lucille Dr (green line) was investigated. There was no sign of the culvert going under the railroad flowing to this tributary.

Map from North Charleston on flows to Turkey Creek – where did the green line go?

It was discovered that the tributary flows under the railroad via a bridge archway and the behind homes on Ford Dr. to flow into Turkey Creek.

Tributary under Railroad.

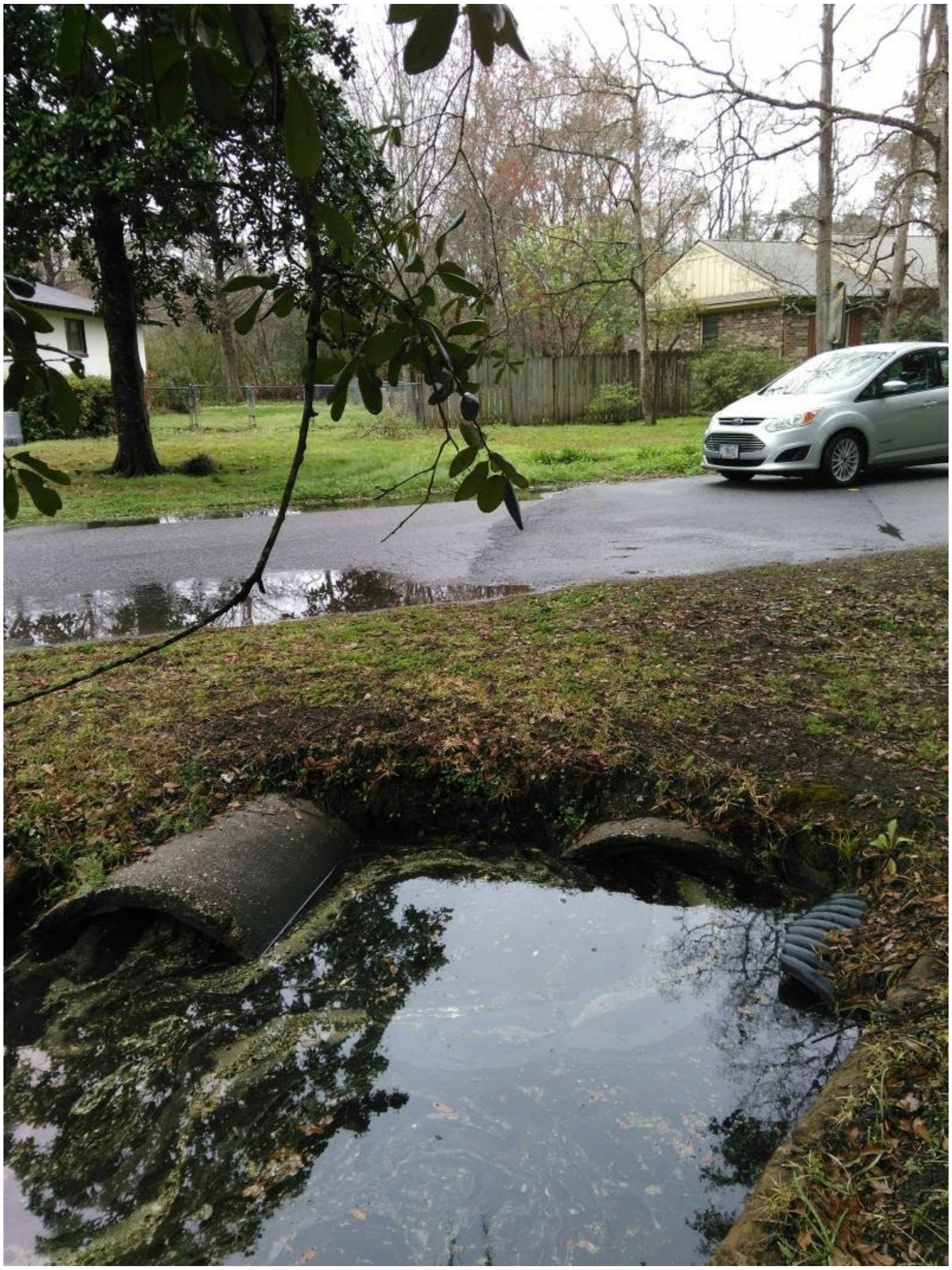
Stream behind home on Ford Dr.



Brookside Area:

Brookside Dr. Open tributary flows under road and stays via pipe to Turkey Creek. Note two culverts flowing under road.

Brookside Dr. Tributary looking upstream (road side ditch on right side of trib at an odd angle)



Same trib looking downstream, roadside ditch entering on right.

Note that pipes flow under the road and continue underground. There is an inlet located on the other side of the road (in front of the car), but the conveyance continues through/under/around (?) the side yard of this house toward Turkey Creek (according to aerial) . Stormwater drainage lines needed to be sure if this causes backwater into this area upstream.


Culvert under road- Brookside
Brookside Dr
© 2018 Google
Google

Inlet on downstrea side of road, observed to be full.

Brookside Dr. Roadside ditch – example.

Conclusions:

Did not see any appreciable maintenance issues. Did note there were some tributary constrictions that might alleviate rainfall driven flooding. If more flow conveyance area is needed in tributaries – city will be taking people's yard. There isn't much topography so it has to go wider. It is important to note that tidal flooding will inundate whatever areas is at the tide elevations, thus rainfall at high tide or tidal surges will not be alleviated by increasing channel size.

The city might also consider a storm drainage network assessment for where pipe size might be increased, additional culverts might be warranted. That is outside the scope of this study.

Appendix C
Hydrology and Hydraulic Modeling Appendix for Turkey Creek

Last Updated: 17 APRIL2020

US Army Corps of Engineers®
Jacksonville District

Table of Contents

1. Introduction

Flooding problems along Turkey Creek have been known for decades as reported in a 1975 USACE study performed by Water Resources Engineers, INC. In their letter of interest, the City of Hanahan reported that the area has experienced multiple flooding events with several properties being flooded and damaged on more than one occasion, and that these flooding problems have increased significantly in recent years. The City of Hanahan also reported that they believed augmented development of commercial establishments with large parking lots, occurring before state requirements for onsite stormwater detention, has intensified the problem. Tidal fluctuations and increase in frequency of King tide in recent years further complicate the natural drainage of the watershed by producing a backwater effect. The purpose of the present study is to update the hydrologic and hydraulic models incorporating the information from the 1975 USACE study with recent land use and LiDAR topographic LiDARdata. The models will be used as analysis tools to help identify the flooding problems along Turkey Creek.

1.1 Study Area

The Turkey Creek study area is located in the southern coastal region of South Carolina within the City of Hanahan and North Charleston areas. Hanahan is located within Berkeley County and the pertinent part of North Charleston is in Charleston County. Figure 1 shows the location of the study area with the orange line encompassing the Turkey Creek watershed boundary. The CSXT Railroad track (colored blue in Figure 1) represents the dividing line between Charleston (North Charleston) and Berkeley (City of Hanahan) counties. The study area is moderately urbanized consisting primarily of single family residential dwellings in the lower reach and mobile homes and commercial establishments in the upper portion of the watershed. Turkey Creek discharges into the tidally influenced Cooper River and then into the Charleston Harbor.

Tidal effects on Turkey Creek are pronounced and vary with the force, direction, and duration of winds and storm surges generated from the Atlantic Ocean and propagating from Charleston Harbor upstream along the Cooper River and its floodplain. Generally, tidal stages in Turkey Creek have a departure of 1.5 to 2.0 feet above normal tide experienced in Charleston Harbor and a lag time of about 3 to 4 hours. Normal tides in Charleston Harbor range from -0.95 feet NAVD 88 to 4.16 feet NAVD 88 with a mean range of 5.22 feet and diurnal range of 5.76 feet [3]. The king tide is a higher than predicted high tide and is above the highest water level reached at high tide on an average day. In Charleston, the average high tide range is about 5.5 feet, whereas during a King Tide event the high tide range may reach 7 feet or higher [4].

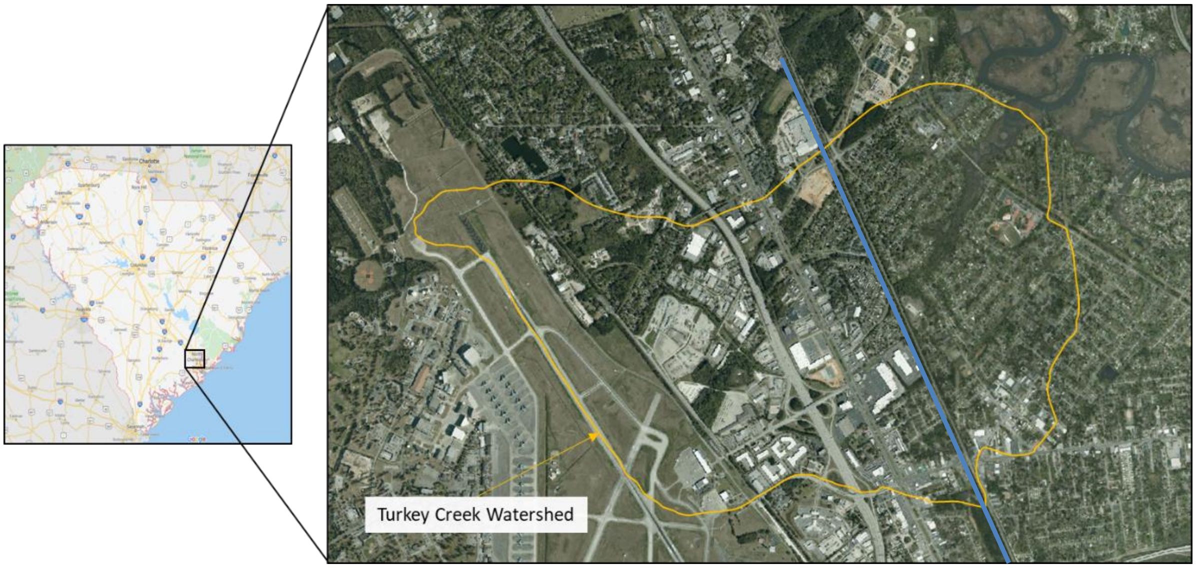


Figure 1: Location Map

1.2 Purpose of Hydrologic and Hydraulic Analyses

The objectives of the hydrologic and hydraulic analyses were to develop hydrologic and hydraulic models for the Turkey Creek watershed using recent information (e.g. landuse, LiDAR) and hydrologic and hydraulic information from previously developed HEC-1 and HEC-RAS models. These models were then used to evaluate possible causes of flooding, sources of surface water runoff, and develop conceptual level recommendations for flood risk management for residents near Turkey Creek, in Hanahan, SC.

Hydrologic and hydraulic modeling was performed for the 0.5, 0.2, 0.1, 0.04, 0.02, and 0.01 Annual Exceedance Probability (AEP) design storm events. AEP has replaced return period in the USACE terminology for characterizing the frequency of a storm event; previously the above storms would have been described as the 2-, 5-, 10-, 25-, 50-, and 100-year return period events, respectively.

The objectives were established as follows:

1. Define the existing conditions of flood extents to determine the sources of flooding.
2. Develop Hydrologic and Hydraulic Models, adopting information from previously developed HEC-1 and HEC-RAS models and incorporating up-to-date available data along Turkey Creek within the jurisdiction of the City of Hanahan.

3. Develop HEC-HMS model for Turkey Creek watershed.
4. Develop HEC-RAS 2D model for Turkey Creek and part of Cooper River.
5. Generate and simulate 17 different RAS modeling scenarios for the purpose of developing a probable extreme condition that would occur from the combination of extreme rainfall event and a King tide event.
6. Analyze model results with respect to reported flooding in extreme events.
7. Develop conceptual level recommendations.

2. Hydrologic Modeling

This section includes the description of the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model set-up and development for the Turkey Creek watershed. HEC-HMS was used to simulate the Turkey Creek watershed for estimation of runoff volumes and flow hydrographs for subsequent use as inputs to the Hydrologic Engineering Center River Analysis System (HEC-RAS) model. The subsequent sections will describe the various components necessary for construction of the HEC-HMS model.

2.1 Sub-basin Elements

A sub-basin element describes a hydrologic area that is drained by a single stream or group of streams that converge to a single outfall location. The sub-basins for the HEC-HMS model were delineated from recent Light Detection and Ranging (LiDAR) elevation data using the ArcMap Geographic Information System (GIS) software to represent the change in land use and flow pattern.

A sub-basin element was added for each sub-basin identified in the model domain. HEC-HMS computes outflow by subtracting the losses, transforming excess rainfall, and adding baseflow to the rainfall data that is applied to each sub-basin. Figure 2 shows the sub-basin map with corresponding model elements (sub-basins, routing reaches, reservoirs, and junctions) used in the HEC-HMS model. The following sections explain how the various input parameters for the sub-basin elements were computed. Total drainage area of the Turkey Creek watershed was computed to be 3.26 square miles. The computed area of each sub-basin is tabulated in Table 1.

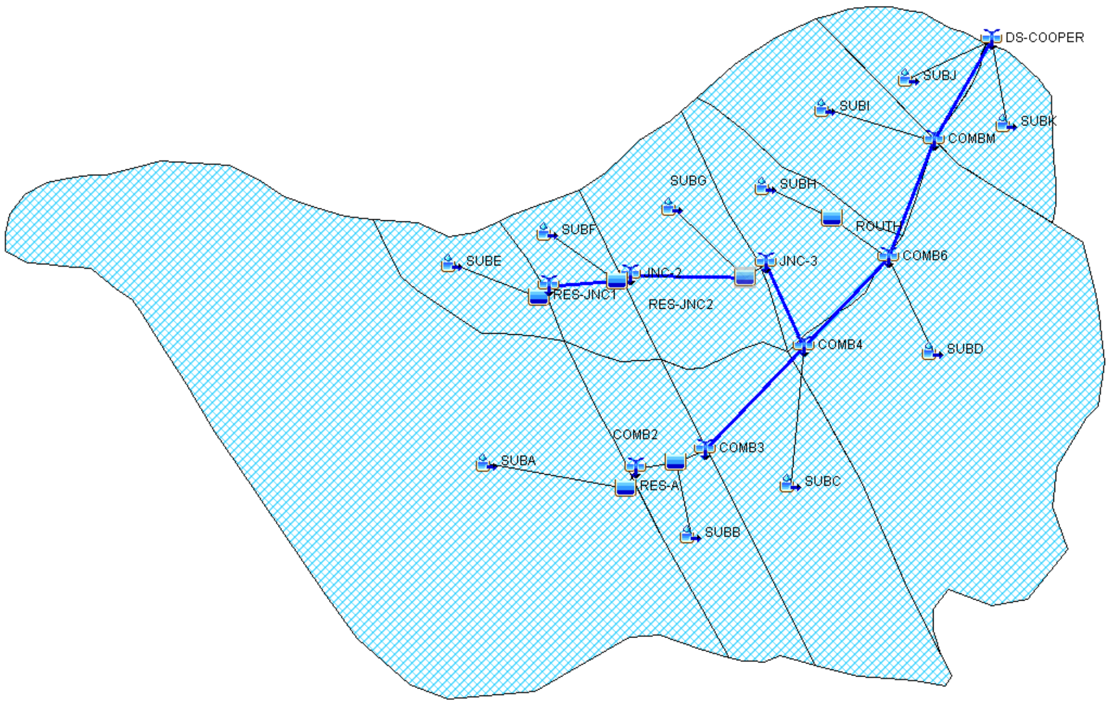


Figure 2: HEC-HMS Basin and 11 Sub-basin (A-K) elements

2.2 Loss Method

The loss method for the sub-basin determines the infiltration calculations used for that sub-basin. The Soil Conservation Services (SCS) Curve Number Loss was selected as the loss method for the HEC-HMS model set-up because land use and soil property data were available for the watershed. The Soil Conservation Services, now the NRCS, curve number method implements the curve number method for incremental losses. The method was used to estimate the amount of runoff potential from the rainfall event based on the relationship between soil type, land use, and hydrologic soil conditions.

Curve numbers were derived from the relationship between soil type (coverage), land use, and the antecedent moisture condition (AMC) in the basin. The land use data was

Table 1: Composite Curve Number

Sub-basin	Area (sq mi)	CN
SUB-A	1.258	79.43
SUB-B	0.187	80.44
SUB-C	0.300	79.35
SUB-D	0.627	79.48
SUB-E	0.092	79.57
SUB-F	0.093	80.25
SUB-G	0.201	79.80
SUB-H	0.149	78.99
SUB-I	0.180	79.02
SUB-J	0.082	81.28
SUB-K	0.089	84.17

expressed using the South Carolina Land Cover (NLCD 2011), with multiple different land cover types included. The State Soil Geographic dataset (STATSGO) soil coverage was used to determine soil types and total area for each soil classification using GIS. The soil type number represents a large number of individual soil types with similar characteristics. The soil group data expresses the soil group behavior as an A, B, C, D, or as a dual hydrologic soil group type.

Composite curve numbers that represent the different soil type and land use combinations were developed for each sub-basin. Table 1 shows the composite curve number for different sub-basins.

2.3 Transform Method

The transform method for the sub-basin controls the runoff calculations used for a particular sub-basin. The Soil Conservation Services (SCS) dimensionless unit hydrograph was selected as the transform method. A Peak Rate Factor (PRF) needed to be applied to the ordinates of the unit hydrograph to alter the hydrograph's shape while maintaining the total runoff volume. Considering flat coastal areas, disconnected pockets, and other variability, the Delmarva graph type with PRF of 284 was utilized to shape the outflow hydrograph. In addition to the PRF, the SCS unit hydrograph method requires lag time as an input. A computed outflow hydrograph for each sub-basin is the representation of the response of the sub-basin to the rainfall event based on the time of concentration and lag time. The time of concentration is defined as the time it takes water to travel from the hydraulically furthermost point in the watershed to the outlet. The lag time is defined as the time interval between the center of mass of the excess rainfall and the peak of the discharge hydrograph. Within the hydrologic modeling platform, the lag time is used to create the resulting hydrographs. A common relationship between lag time and time of concentration is that the lag time is 60% of the time of concentration. Table 2 presents the time of concentration and corresponding lag time for different sub-basins.

Table 1. Lag Time (min).

Sub-basin	Time of Concentration (min)	Lag Time (min)
SUB-A	208.82	125.29
SUB-B	71.94	43.16
SUB-C	96.99	58.20
SUB-D	122.54	73.52
SUB-E	75.02	45.01
SUB-F	65.21	39.12
SUB-G	69.49	41.70
SUB-H	64.05	38.43
SUB-I	60.66	36.39
SUB-J	58.24	34.95
SUB-K	58.48	35.09

2.4 Baseflow Method

The recession method was selected as the baseflow method. The precipitation that is infiltrated and not lost from the system to deep aquifer storage eventually is discharged as streamflow. This volume of water is typically described as baseflow and can be estimated as a function of surface water response. Base flow is derived from precipitation that has infiltrated into the soil and drained beyond the rooting zone and is used to model the interflow/groundwater contributions from the shallow aquifer that end up as stream flow. The recession baseflow method is designed to approximate the typical behavior observed in watersheds when channel flow recedes exponentially after an event. The exponential recession baseflow is a function of the surface water runoff hydrograph, and consists of three parameters: 1) an initial discharge; 2) a recession constant that describes the rate of baseflow decay; and 3) a threshold to peak, which defines the time at which the recession defines the total flow following the peak of a direct runoff event. Because there is not any calibration data available, the initial type and threshold type with respective values were kept unchanged from the previously developed model.

2.5 Routing Method

The Modified Puls and Kinematic Wave routing methods were both selected as routing methods for the model. A reach element has one or more sources of inflow from another element and computes one combined outflow. It represents a segment of the channel or surface flow way and simulates the movement of water by using a user-selected routing method. The Modified Puls routing method was adopted from previously developed model for most of the reaches. The routing method selected for the newly added reaches was the Kinematic Wave routing method. The Kinematic Wave method is based on physical parameters such as reach length, Manning's roughness coefficient, channel geometry, and slope. The GIS software was utilized to determine the routing parameters such as reach length and channel bed slope. Aerial photography, literature values, and engineering judgment were used to determine appropriate manning coefficients.

2.6 Meteorological Model

For all of the 2-, 5-, 10-, 25-, 50-, and 100-year return period events, the 24-hr storm with SCS Type III distribution was selected. Figure 3 shows the 24 hour temporal distribution. The SCS Storm applies the same total rainfall depth to all sub-basins. The Type III distribution was designated for the Turkey Creek Watershed as per the recommendation in Stormwater Design Standard Manual for Berkeley County, SC. The NOAA Atlas 14 was used to estimate rainfall depths. The precipitation depths corresponding to various return periods are shown in Table 3.

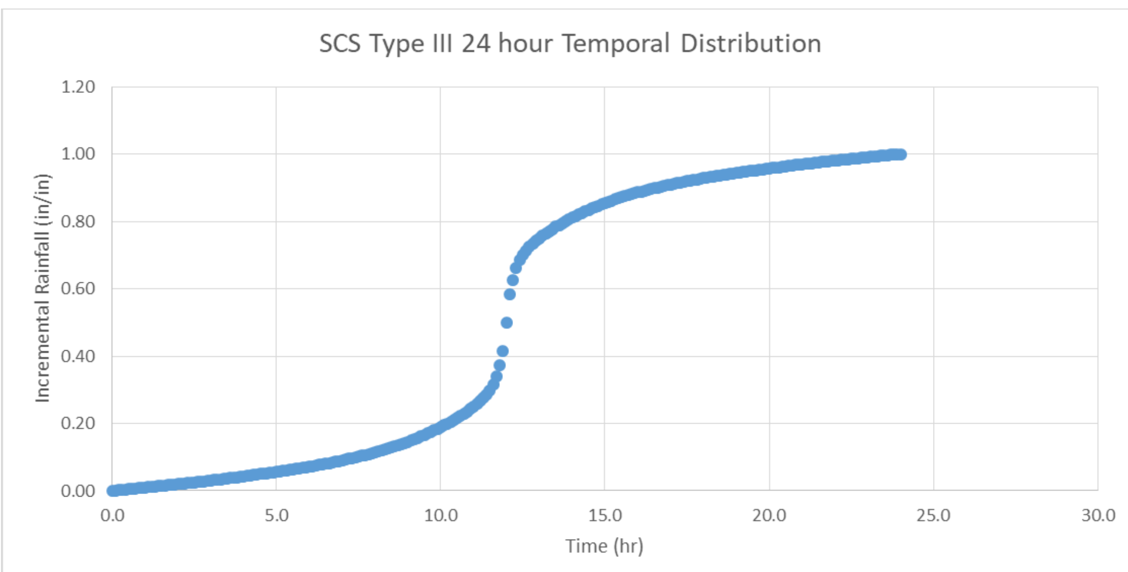


Figure 3: SCS Type III Temporal Distribution

Table 3: Precipitation Depths and Return Frequency

Recurrence Interval (yr)	Rainfall Depth (in)
2	4.16
5	5.37
10	6.36
25	7.75
50	8.88
100	10.10

2.7 Control Specification

The control specifications were used to specify the start date and time as well as the end date and time. The synthetic storms time windows are hypothetical and were run at a time interval of 10 minutes. The duration of the design storms was 36 hours to ensure the receding limb of the hydrograph was captured.

2.8 Model Assumptions

The model input parameters were estimated using best available data and common engineering practices and judgment. Model assumptions were necessary as no flow gages were available within the watershed. The Turkey Creek watershed's natural flow pattern has been greatly altered by urban development over the years; therefore, certain sub-basins may not produce runoff temporally and spatially similar to that of a natural physical watershed. Examples of this would be runoff being collected or diverted in small canals or ditches, interruption of runoff due to roadways, or other manmade structures, storm drains, sewer systems and retention ponds. The required input parameter data must take into account these disruptions in the natural flow process and subsequent increases in retention time in order to properly simulate the hydrologic processes present. Each sub-basin element and its associated loss and transform methods were reviewed and modified to produce a runoff hydrograph that was reasonable for the particular physical conditions.

2.9 Simulating Scenarios/Model Application

All six design rainfall events presented in Table 3 were simulated using the updated HEC-HMS model. The spatial distribution of the rainfall in the Turkey Creek watershed was determined by applying the Atlas 14 precipitation-frequency estimates equally to each sub-basin. Areal reduction was not applied, as it was considered negligible due to the small size basin and gives a slightly more conservative approach. Figure 4 presents the flow hydrograph from 100 year event at point 'COMB3' that is the upstream end of the hydraulic model domain.

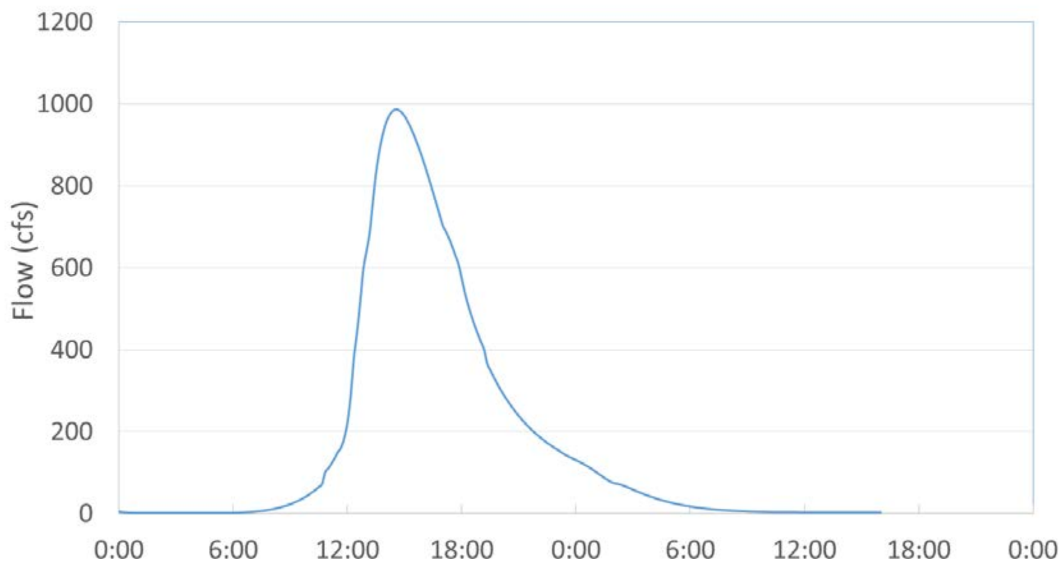


Figure 4: 100yr Flow hydrograph at point 'COMB3'.

3. Hydraulic Modeling

This section includes the description of the Hydrologic Engineering Center River Analysis System (HEC-RAS) model application and model set-up to perform hydraulic analyses.

The two dimensional (2D) hydraulic generic model for the area of concern was developed using HEC-RAS version 5.0.7 (2019). HEC-RAS is a hydraulic numerical model platform developed and distributed by the USACE that uses standard step mathematical analysis to provide steady and unsteady water surface profile computations. `

The HEC-RAS platform allows the modeler to formulate different alternative plans based on modifications to plan geometry and specification of hydraulic parameters, such as chan nel roughness. Results from several simulations can be compiled in tabular and graphical form for comparison.

3.2 Model Setup and Application

Model setup and application comprise development of a model grid incorporating topographic information and bathymetry, incorporating physical features like structures, specifying bed roughness, setting up boundary conditions, and simulating different scenarios. The following sub-sections explain the different component of model setup.

3.2.1 HEC-RAS Model Geometry

A Digital Elevation Model (DEM) was generated from LiDAR data and bathymetric data using RAS-MAPPER within HEC-RAS. HEC-RAS was utilized to generate a 2D computational mesh for the entire domain of the area of concern. The mesh was refined in the channel to represent the narrow channels properly in the model. In Figure 5, the left panel shows the 2D mesh on top of the terrain and right panel shows the mesh refinement representing the channel details in the mesh.

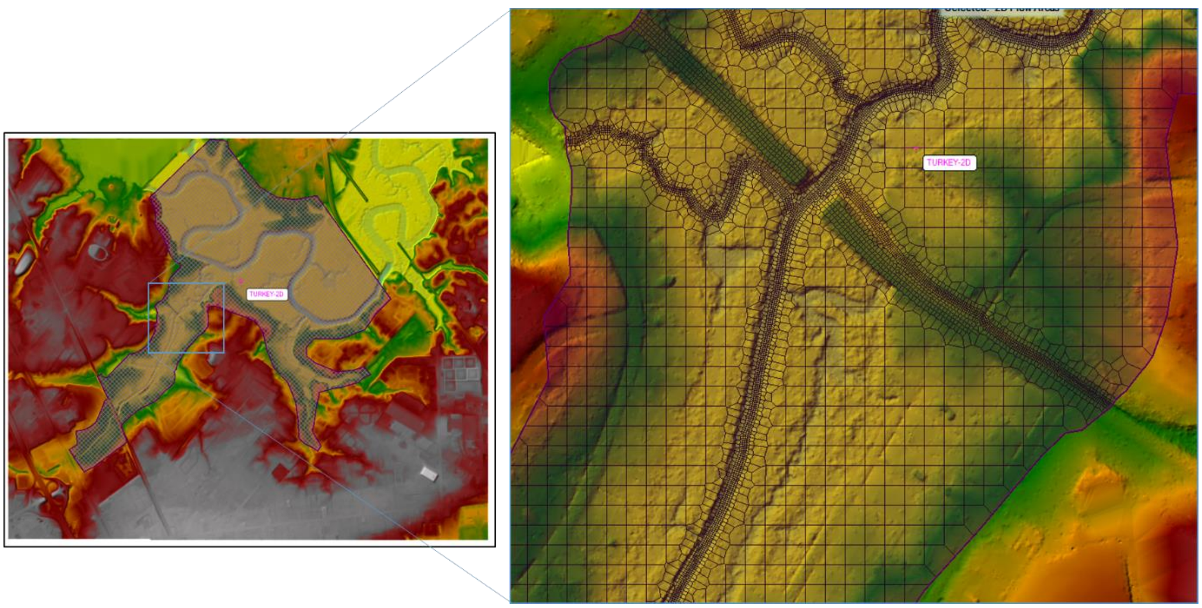


Figure 5: Terrain and 2D Mesh

Two hydraulic structures were included in the HEC-RAS model: the CSXT railroad culvert, an 8ft by 12ft elliptic pipe, and Murray Avenue Bridge, a three-span structure. Information from the topographic survey and the South Carolina Department of Transportation (SCDOT) was used for the culvert and bridge geometry. HEC-RAS currently does not allow to the modeling of a bridge structure in the 2D mesh. Because the historical maximum flow never reached the bridge deck, the representation of the bridge in the 2D was simplified using a user defined weir/spillway structure as in Figure 6.

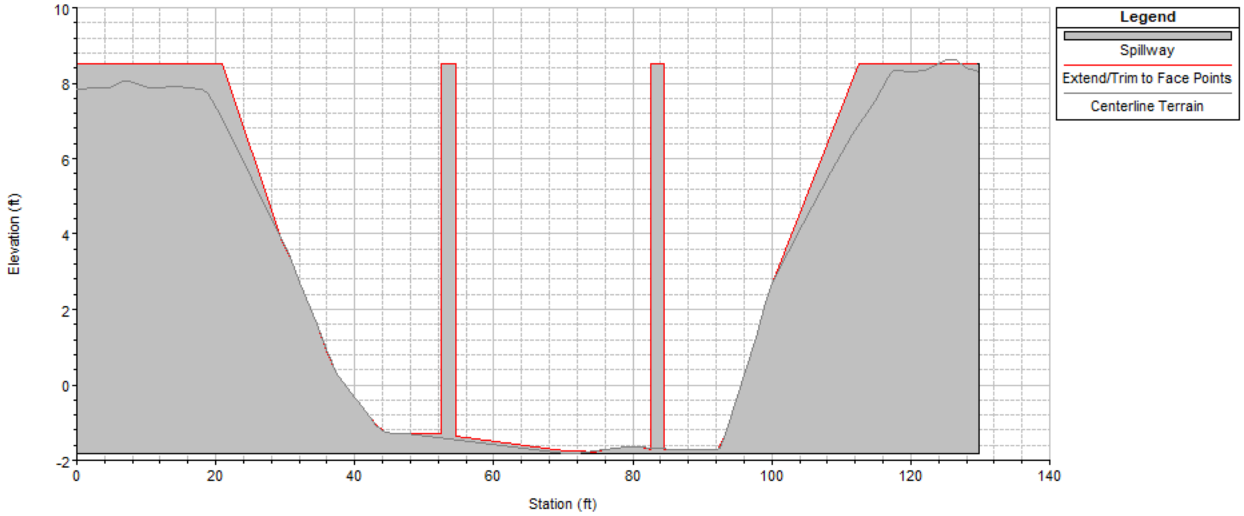


Figure 6: Representation of Murray Bridge in 2D Mesh.

3.2.2 Bed Roughness Coefficients

Three different Manning's n roughness coefficient were used to represent the area specific bed roughness in the model. A value of 0.05 was used for the main overland and overbank flow areas. The value corresponds to medium to dense bush. A value of 0.025 was used for the coastal floodplain and channel. An override regions with a value of 0.035 was provided to represent the channel roughness, which corresponds to sluggish reaches, weedy and deep pools as observed in Turkey Creek. Figure 7 shows the area specific manning's n in different colors.

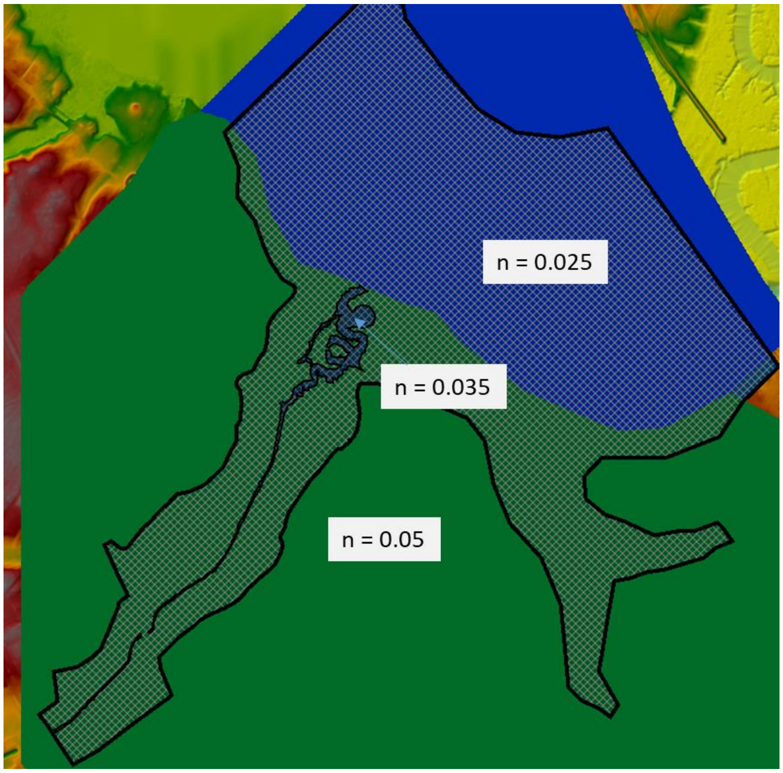


Figure 7: Area Specific Manning's n

3.2.3 HEC-RAS Model Boundary Conditions

The upstream and lateral flow boundary conditions were established using the output runoff hydrograph from HEC-HMS. The downstream stage boundary condition, located at Cooper River near N Rhett Avenue, used the tide gauge data collected by USGS (Site: 021720677, Cooper River at Filbin Creek).

The upstream boundary conditions for Turkey Creek, located west side of CSXT railroad, applied the flow hydrographs extracted from the HEC-HMS simulations. Other HEC-HMS runoff hydrographs from the basins draining to Turkey Creek were added as lateral inflows into the HEC-RAS model. Runoff locations were established using the hydrologic model sub-basins as modeled in HEC-HMS. Figure 8 shows the interaction of HEC-HMS and REC-RAS models and hence the corresponding lateral flow boundary locations.

A scenario of Goose Creek dam release (9" over main weir) was also considered as lateral inflow boundary to assess the effect of release on Turkey Creek flooding. Figure 9 shows the schematic diagram of the weir and the release scenario.

The downstream stage boundary condition, where the model domain ends at Cooper River, was set to the tide gauge data. Three different scenarios of tidal gauge data were used at the downstream end that represent i) Normal Tide, ii) King Tide, and iii) Surge level during Hurricane Matthew. Figure 10 through 12 show the downstream boundary stages.

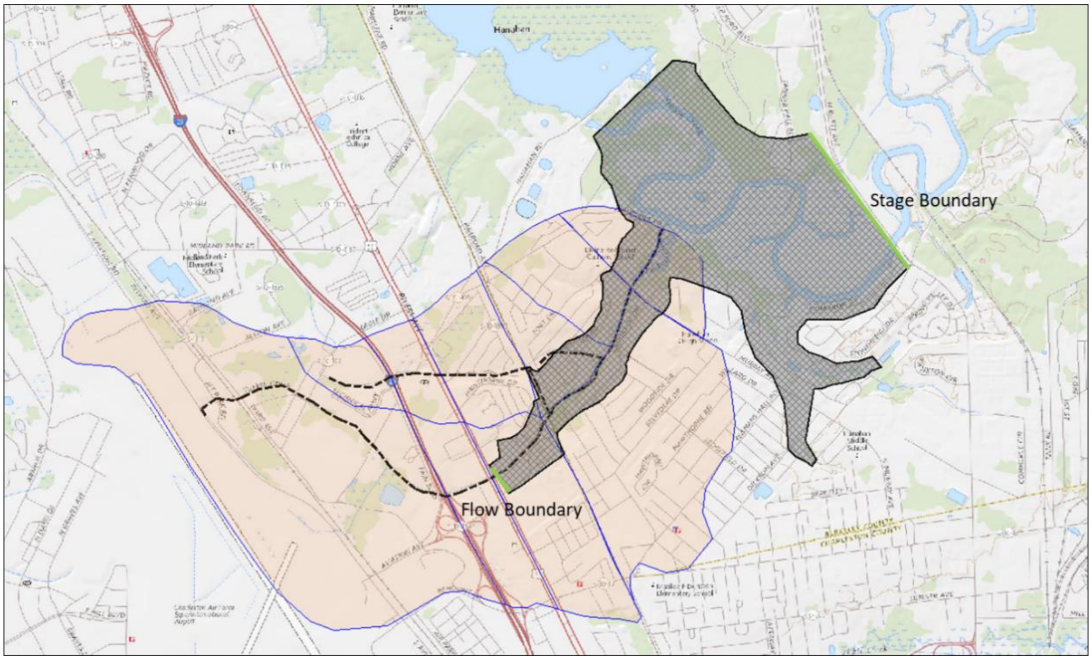


Figure 8: Interaction of HEC-HMS and HEC-RAS Models

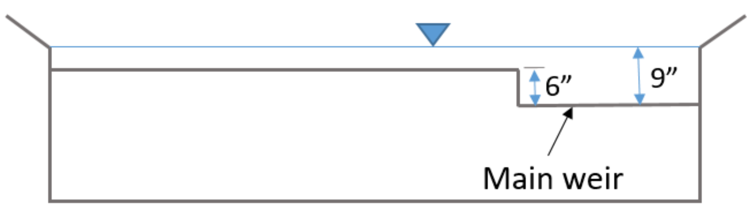


Figure 9: Goose Creek Weir Scematic Diagram

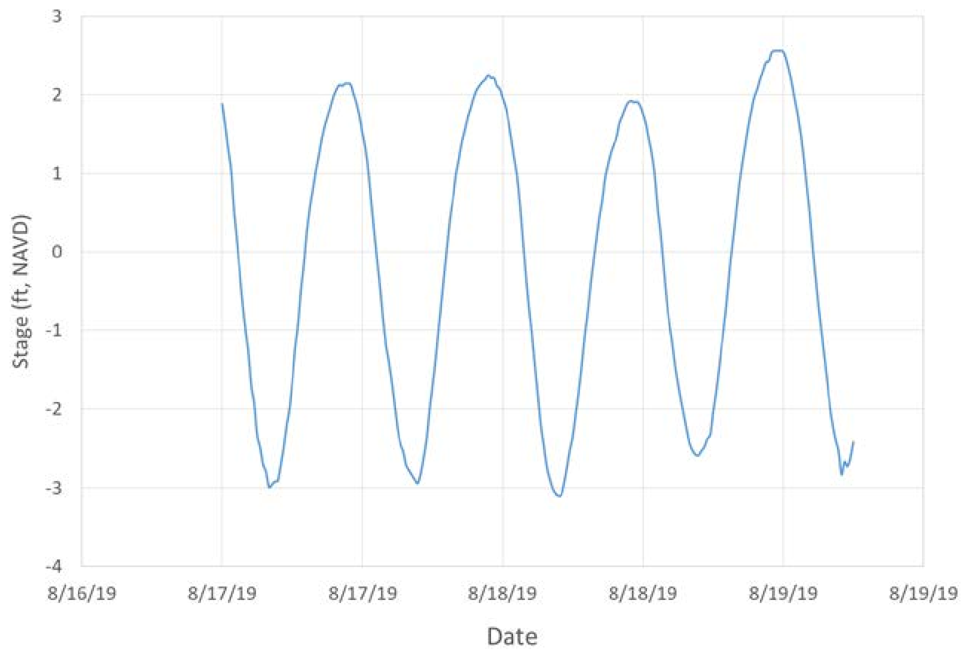


Figure 10: Normal Tide

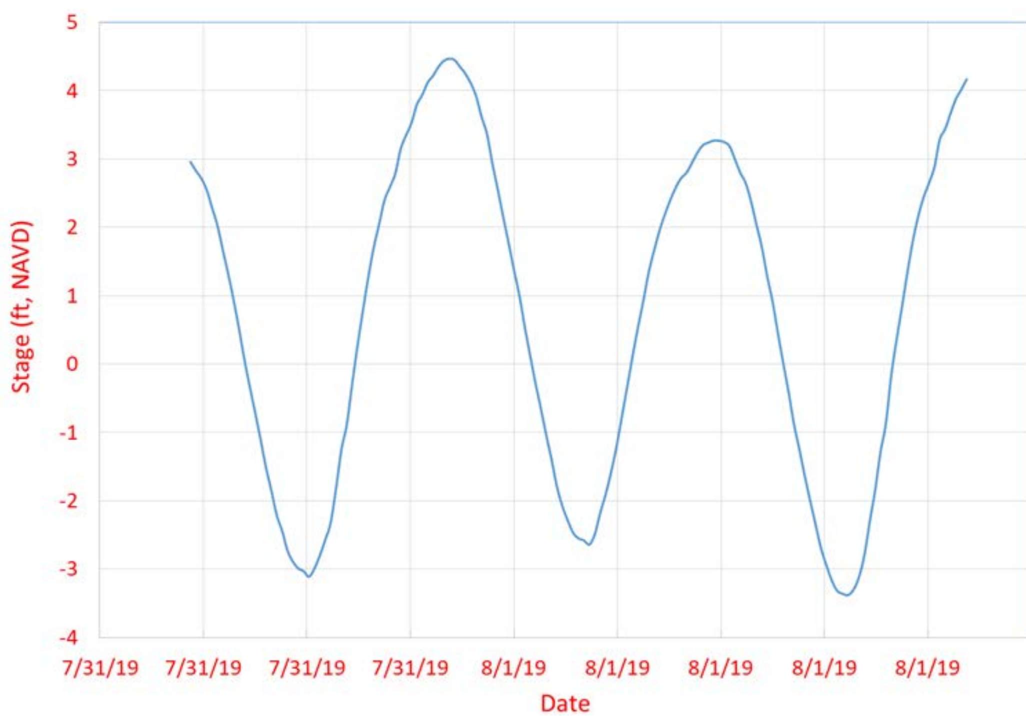


Figure 11: King Tide

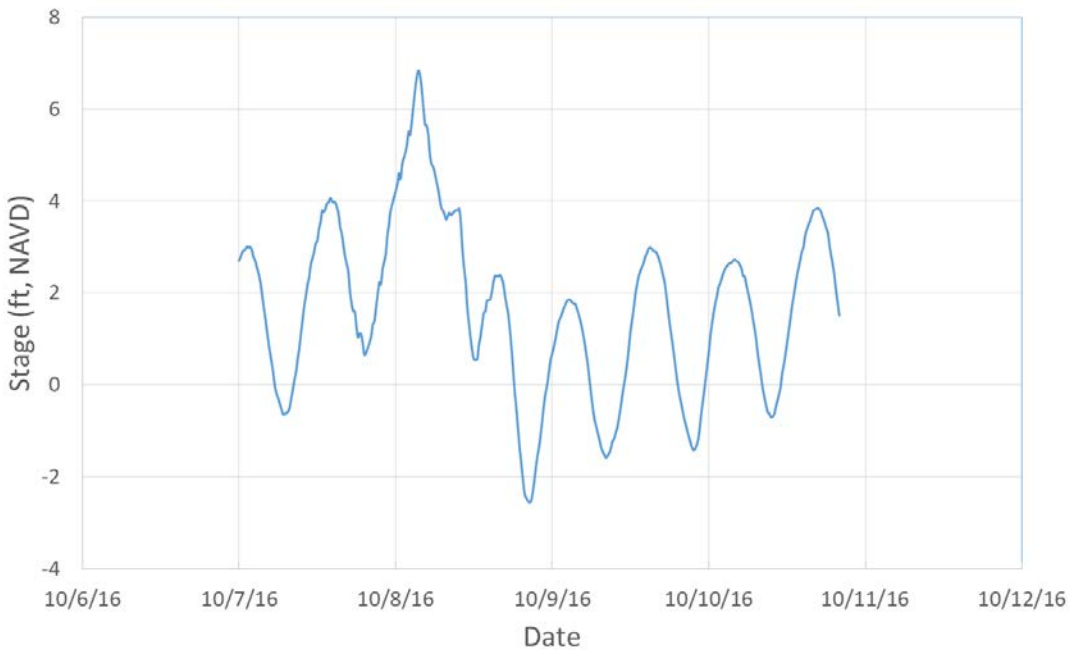


Figure 12: Storm Surge (Hurricane Mathew)

3.2.4 Model Calibration

Due to unavailability of gage data, the model was not calibrated but engineering judgment was applied to specify parameters and boundary conditions and to justify modeled flood inundation results with reported data. Specifically, observed rainfall and tidal stage data from the Hurricane Matthew event in October 2016 were applied to the HMS and RAS models in order to generate modeled flood inundation maps. The results of the Hurricane Matthew scenario are described by the output from the model run “RAINY-DSSURGE-50YRNGC”.

3.2.5 Storm Event Modeling

Seventeen different scenarios were developed to simulate combining different event runoff hydrographs, stages, and dam release from the Goose Creek. The purpose of combining was to synthesize a worst case flooding scenario and to find out the influences of different components in flooding issues. Table 4 presents the developed scenarios and their descriptions.

Table 4: Modeling Scenarios

Scenario	***Description***
SUNNY-NT	No rain with normal tide
SUNNY-KT	No rain with king tide
RAINY-DSNT-2YRNGC	2yr rain with normal tide and no Goose Creek Flow
RAINY-DSNT-5YRNGC	5yr rain with normal tide and no Goose Creek Flow
RAINY-DSNT-10YRNGC	10yr rain with normal tide and no Goose Creek Flow
RAINY-DSNT-25YRNGC	25yr rain with normal tide and no Goose Creek Flow
RAINY-DSNT-50YRNGC	50yr rain with normal tide and no Goose Creek Flow
RAINY-DSNT-100YRNGC	100yr rain with normal tide and no Goose Creek Flow
RAINY-DSKT-2YRNGC	2yr rain with king tide and no Goose Creek Flow
RAINY-DSKT-5YRNGC	5yr rain with king tide and no Goose Creek Flow
RAINY-DSKT-10YRNGC	10yr rain with king tide and no Goose Creek Flow
RAINY-DSKT-25YRNGC	25yr rain with king tide and no Goose Creek Flow
RAINY-DSKT-50YRNGC	5yr rain with king tide and no Goose Creek Flow
RAINY-DSKT-100YRNGC	100yr rain with king tide and no Goose Creek Flow
RAINY-DSNT-25YR9"GC	25yr rain with normal tide and 9” Goose Creek Weir Flow
RAINY-DSKT-25YR9"GC	25yr rain with king tide and 9” Goose Creek Weir Flow
RAINY-DSSURGE-50YRNGC	50yr rain with Mathew surge and no Goose Creek Flow

4. Results and Discussion

The water surface elevation (WSE) from hydraulic modeling analyses of different scenarios are compared at three different locations and are presented in Table 5. The three different point locations along Turkey Creek are depicted in Figure 13. Point-A is located on the upstream side of Murray Drive Bridge; Point-B is located on the downstream side of the Murray Drive Bridge, and Point-C is located near the upstream terminus of the study area being evaluated for flood impacts. Point C is located downstream of the CSXT Railroad crossing of Turkey Creek. This railroad also forms the boundary between the City of Hanahan and the City of North Charleston.

Table 5: Comparison of WSE

Scenario	WSE at Point-A, ft NAVD	WSE at Point-B, ft NAVD	WSE at Point-C, ft NAVD
SUNNY-NT	2.25	2.25	2.24
SUNNY-KT	4.47	4.47	4.47
RAINY-DSNT-2YRNGC	2.52	2.26	4.57
RAINY-DSNT-5YRNGC	3.50	2.54	5.20
RAINY-DSNT-10YRNGC	4.06	2.92	5.53
RAINY-DSNT-25YRNGC	4.75	3.33	5.96
RAINY-DSNT-50YRNGC	5.26	3.52	6.29
RAINY-DSNT-100YRNGC	5.77	3.72	6.61
RAINY-DSKT-2YRNGC	4.61	4.51	5.09
RAINY-DSKT-5YRNGC	4.81	4.57	5.51
RAINY-DSKT-10YRNGC	5.00	4.63	5.79
RAINY-DSKT-25YRNGC	5.32	4.68	6.15
RAINY-DSKT-50YRNGC	5.61	4.74	6.42
RAINY-DSKT-100YRNGC	5.95	4.83	6.70
RAINY-DSNT-25YR9"GC	4.75	3.33	5.96
RAINY-DSKT-25YR9"GC	5.33	4.70	6.15
RAINY-DSSURGE-50YRNGC	6.22	6.33	6.45

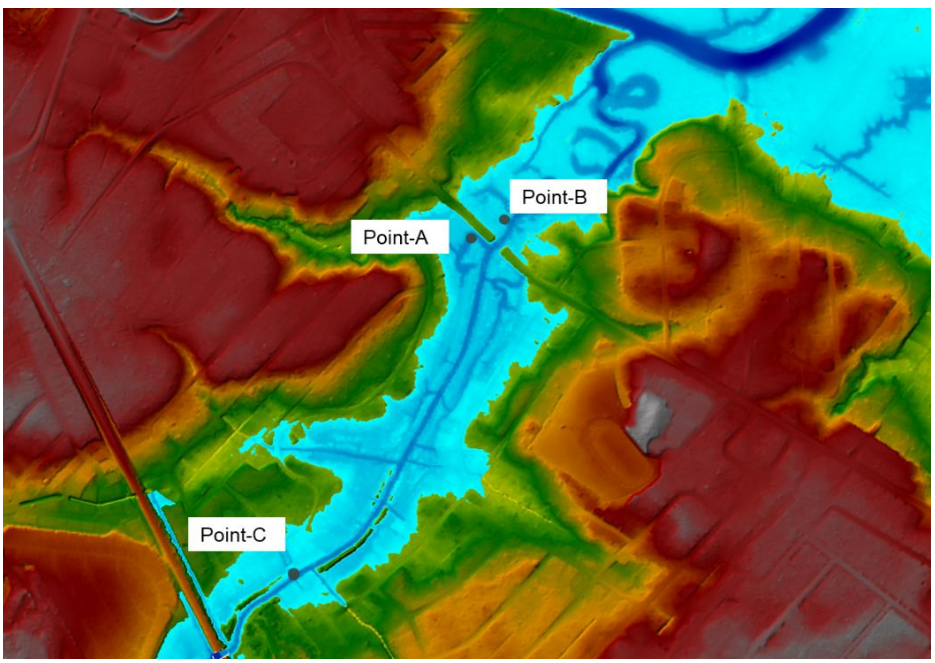


Figure 13: Locations of three observation points.

Hydraulic modeling results from different scenarios show that the effect of rainfall runoff on the upstream end of the study reach (Point C) is more noticeable than that from the king tide. The simulated water surface elevation (WSE) from the Sunny Day king tide at Point-C is found to be

4.47 ft NAVD (no rainfall, no Goose Creek Reservoir discharge) whereas at the same point the simulated WSE from a frequent rainfall event and normal tide is shown to be 4.57 ft NAVD (normal tide, 2-yr rainfall, no Goose Creek Reservoir Discharge). Flooding at the Point C location is most affected by the magnitude of the rainfall event and to a much lesser degree by the magnitude of the tidal stage. This is illustrated best when comparing the peak flood stage from the 100-yr rainfall event / king tide with the peak flood stage from the 100-yr rainfall event / normal tide and with the Hurricane Matthew event. At Point C, the effect of the king tide only increases the peak 100-yr flood stage from el. 6.61 ft NAVD up to el. 6.70 ft NAVD88. Under a more severe tidal event such as Hurricane Matthew, the peak flood stage at Point C is predicted to be el. 6.45 ft NAVD – lower than the above 100-yr events because the rainfall associated with Matthew was a lesser amount, approximately 50-yr. However, as one moves downstream Turkey Creek and closer to the Cooper River, the effect of the tidal stage on peak flood stages in Turkey Creek (Points A and B) will increase.

The flood stages at the downstream side of the Murray Drive bridge are dominated by the tidal signal regardless of the size of the upstream watershed storm event. The latter is most evident based on a peak flood stage of el. 4.47 ft NAVD88 (sunny day King Tide) at Point B whereas the same location only peaks at el. 3.72 ft NAVD under a 100-yr rainfall event / normal tide and at el. 4.83 ft NAVD under a 100-year rainfall event / king tide / Goose Creek Reservoir discharge. Note that an even more severe tidal storm surge condition associated with the passage of Hurricane Matthew would have produced peak stages of el. 6.22 ft NAVD at the upstream side of the Murray Drive Bridge.

The effect of rainfall runoff on the upstream end of the Murray Drive Bridge (Point-A) begins exceeding the effect of the king tide (4.47 ft. NAVD) at the 2-yr rainfall event under king tide conditions (4.61 ft NAVD) and at the 25-yr rainfall event under normal tide conditions (4.75 ft NAVD).

Simulated model results have revealed the reasons for several reported flooding issues. For example, there are several reported locations of flooding along Hillside Drive indicated as deep blue dots (numbers 1-4) in Figure 14. The simulated WSE from an extreme event i.e., Hurricane Mathew with 50yr-24hr rainfall, is found to be 6.22ft NAVD in the vicinity whereas the ground elevation in between points 2 and 3 is 7.5ft NAVD. It is unlikely for this location to be flooded due to direct effects of the water stage in Turkey Creek. This area might have been flooded from local drainage congestions as the size of pipe culvert on Hillside Drive may be inadequate and the lined canal that carries flow through the pipe is narrow, moreover the elevated tail-water during a rainfall-event further reduces the efficiency of the culvert. At this point, the pipe culvert has not been modeled incorporating it with HEC-RAS 2D mesh. The lined canal geometry could not be integrated into the mesh due to data unavailability.

A similar reported flooding issue can be observed on Wedgewood Dr. (Deep blue dot on Figure 15) where average ground elevation is 9 ft NAVD and the nearest simulated WSE from same event is found to be 6.6 ft NAVD. The adequacy of the culvert has not been

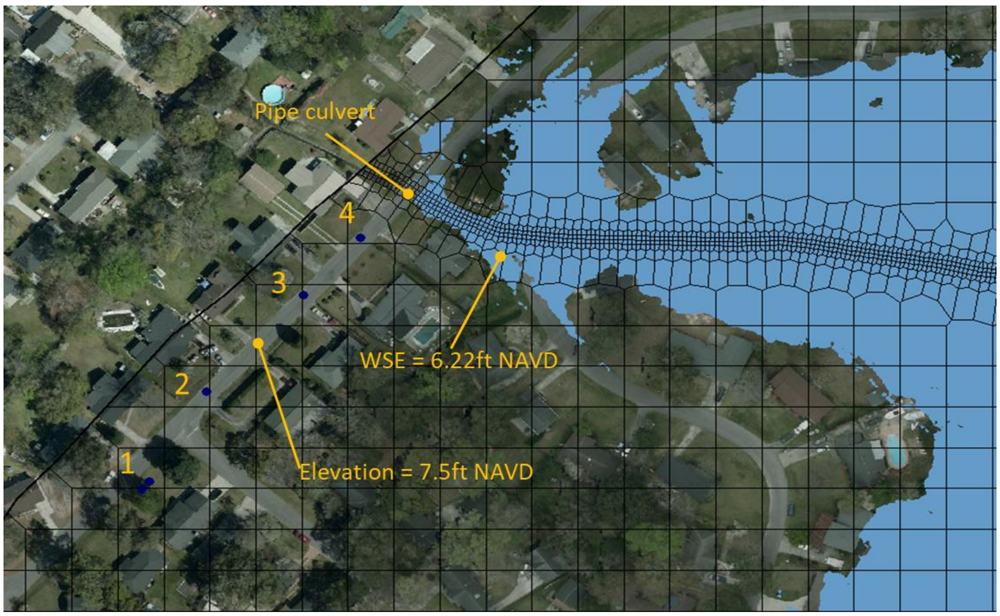


Figure 14: Reported flooding locations on Hillside Dr.

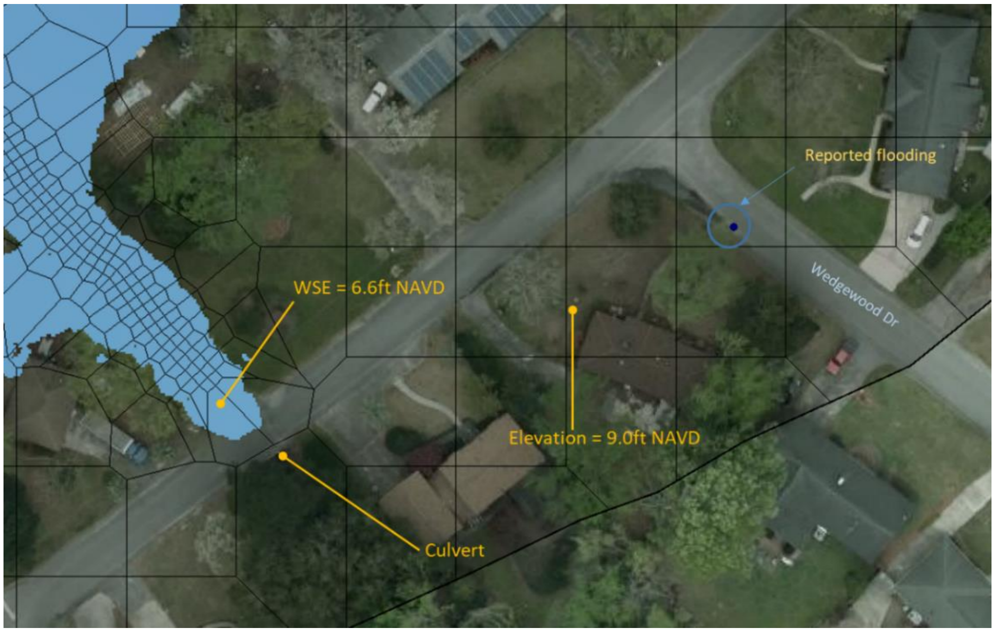


Figure 15: Reported flooding locations on Wedgewood Dr.

checked or incorporated into the model mesh because of data unavailability, but the reported area was likely not flooded due to the backwater effect of the Turkey Creek stages, but more likely due to drainage congestion and from overland flow.

The simulated results with and without Goose Creek dam release indicate that the contribution of release to Turkey Creek flooding is not significant. We have considered both typical and significant dam releases for the Goose Creek reservoir based on conversations with the reservoir operators. The main portion of Goose Creek weir has a crest elevation 6 inches below the crest elevation of the higher (wider) part of the weir (Figure 9). A typical release would be 6 inches of flow over the lower weir and no discharge over the top weir. According to staff at the Goose Creek Reservoir, a significant release would be 9 inches of flow over the lower weir and 3 inches of flow over the top weir.

The intensity of stormwater runoff induced flooding can be reduced by managing the runoff using storm water management facilities. In this regard, the runoff contribution from individual sub-basins and existing pipe culverts needs to be singled out and the developed HEC-HMS and HEC-RAS models can be used to perform that activity. The purpose of the storm water management facilities is to attenuate the flow by detaining it and then releasing it over a certain period of time considering the tidal cycle.

The Murray Drive Bridge has been modeled assuming that flow is always open channel flow and there is no flow over the deck. It is recommended to do a sensitivity analyses to assess the effect of the bridge coefficient and the effect of debris blockage on the resulting stages at the bridge.

5. Conclusions

The following conclusions can be made from the hydrologic and hydraulic analyses based on the data available at the time of study:

- ❑ Moving upstream along Turkey Creek, the flooding is more influenced by the watershed runoff than it is by the normal or King Tides.
- ❑ The contribution of the Goose Creek Reservoir release to Turkey Creek flooding is not significant.
- ❑ To reduce runoff induced flooding, the overland flows need to be attenuated before they reach the creek.
- ❑ Additional refinement of the HEC-HMS watershed and sub-basin model will be necessary to develop and single out flows for detailed analysis of stormwater features Developed hydrologic HEC-HMS model can be used to optimize the design of storm water management facilities/detention ponds and outfall control structures.
- ❑ A detailed survey of the local drainage structures and swales is required to address the overland flooding issues on Hillside Dr and Wedgwood Dr. The 2D HEC-RAS grid needs to be extended to incorporate several drainage structures, lined canals, and swales.
- ❑ Some sensitivity analyses are required to assess the stage/flow effect of varying bridge coefficients at the Murray Dr. Bridge.
- ❑ The flooding problem of Turkey Creek is complex due to the contribution from multiple factors. Any solution to reduce the effects of the downstream tidal flooding may have an adverse impact to the watershed runoff induced flooding.

6. References

- Flood Insurance Coverage Assessment and Coverage Improvement Plan, 2017; City of Hanahan, SC. [1]
- Phase I Project Report: Turkey Creel Watershed for USACE Charleston District by Water Resources Engineering, INC. 1975. [2]

- https://tidesandcurrents.noaa.gov/stationhome.html?id=8665530 as of 3/22/2020. [3]

- https://www.scdhec.gov/environment/your-water-coast/ocean-coastal-management/coastal-zone-management/coastal-hazards/king as of 3/27/2020. [4]

7. Simulation Tools

- HEC-HMS Version 4.3
- HEC-RAS Version 5.0.7
- ArcMAP 10.7
- SMS 13.0

Appendix A
Hydrologic Modeling Results

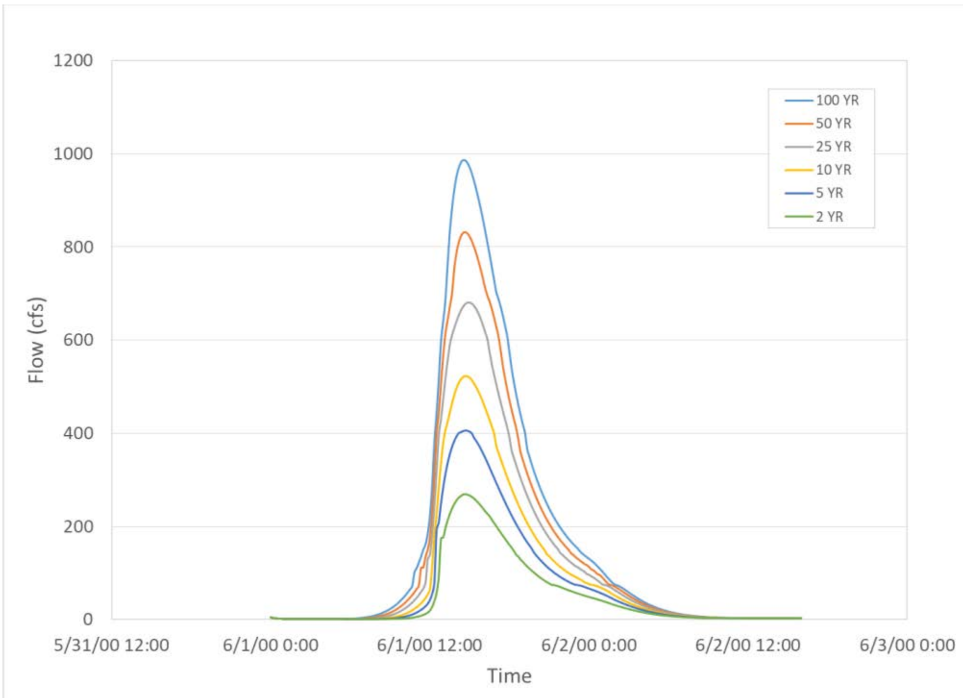


Figure A1: Runoff Hydrographs at 'COMB3'

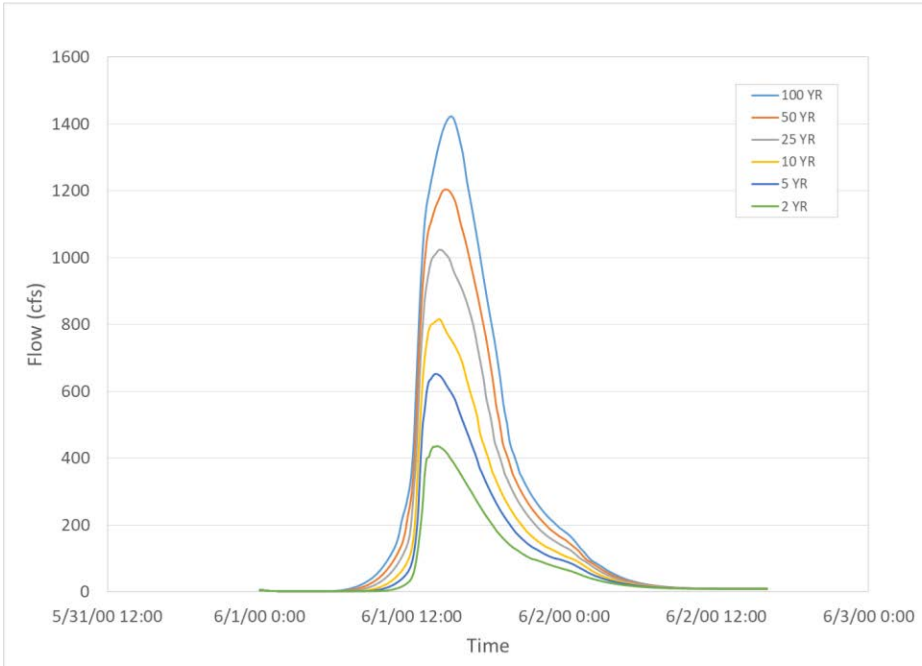


Figure A2: Runoff Hydrographs at 'COMB4'

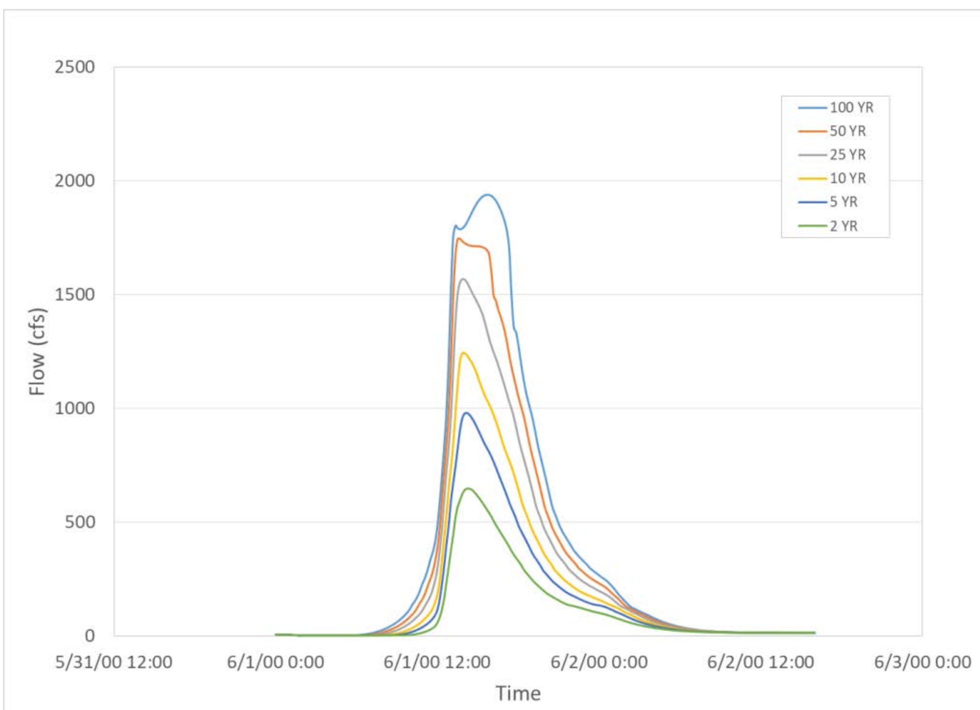


Figure A3: Runoff Hydrographs at 'COMBM'

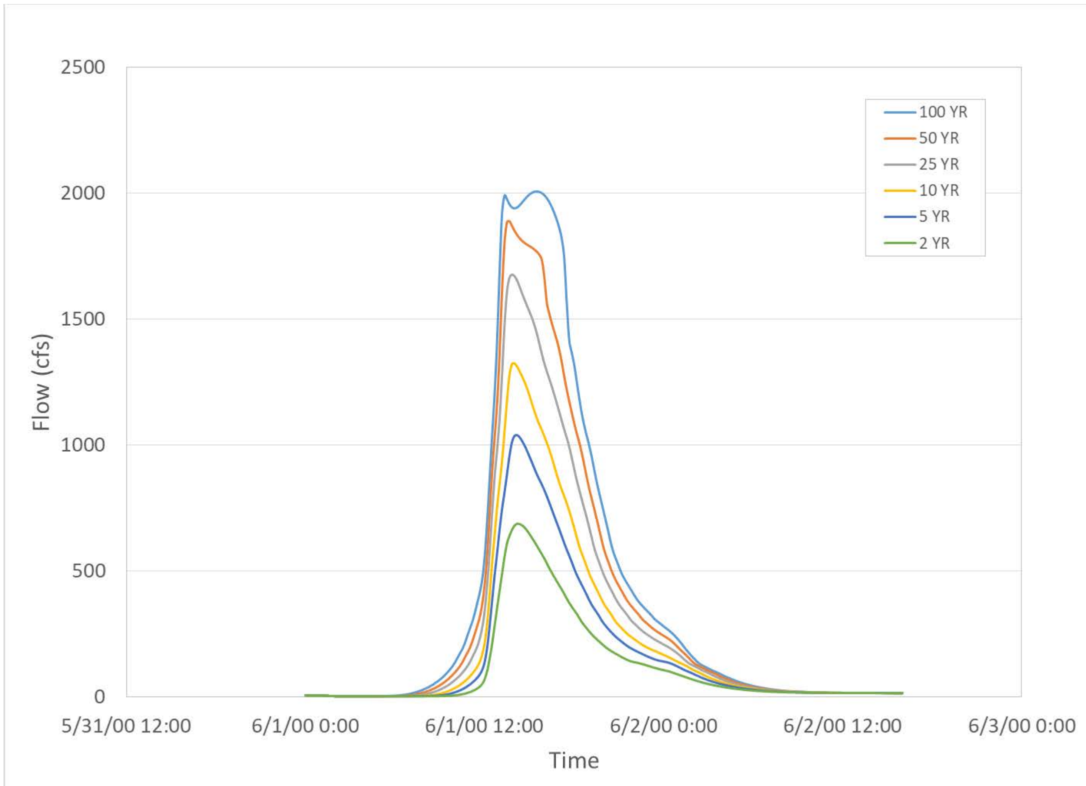


Figure A4: Runoff Hydrographs at 'DS-COOPER'

Appendix B
Hydraulic Modeling Results

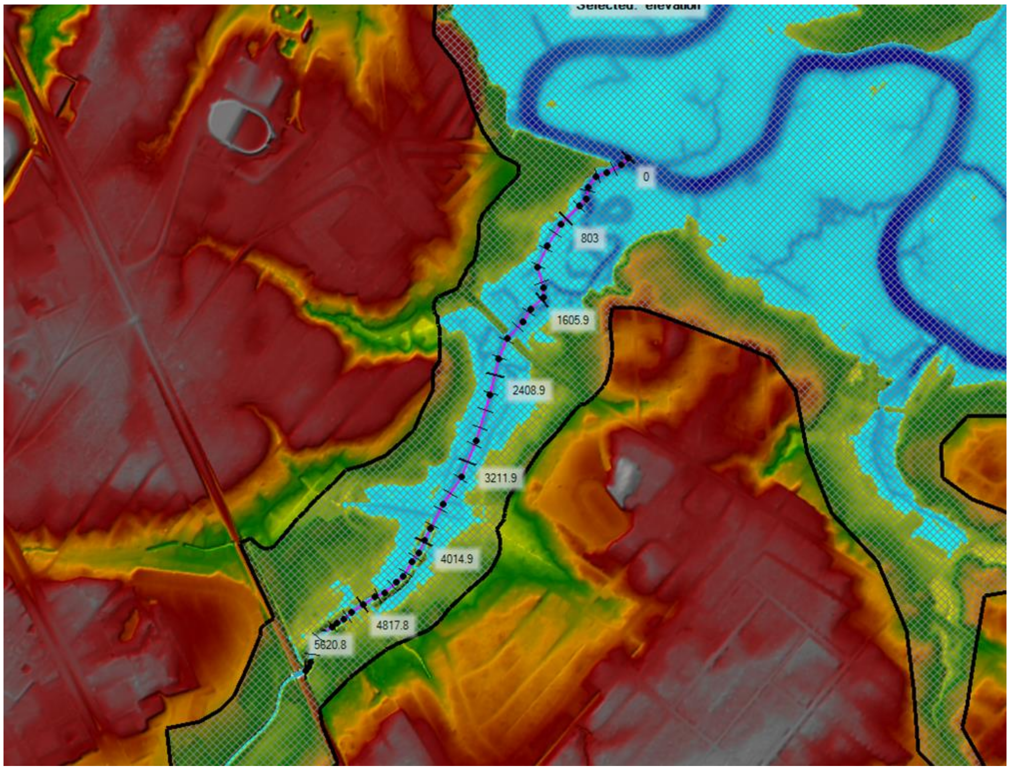


Figure B1: Longitudinal Profile

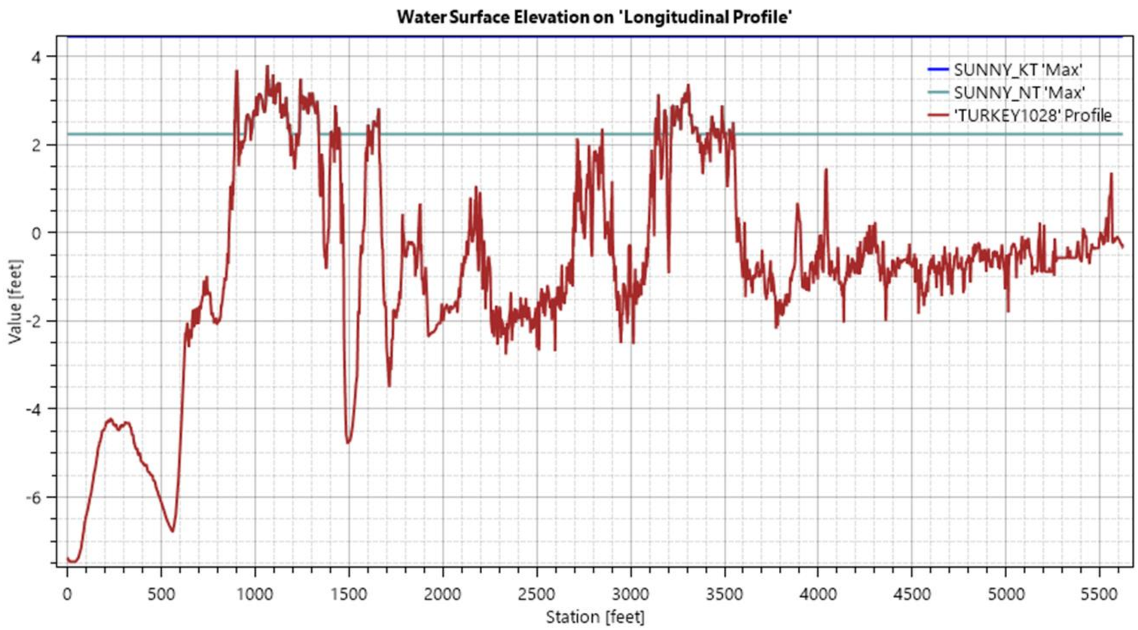


Figure B2: Water Surface Profiles of sunny day king tide and sunny day normal tide

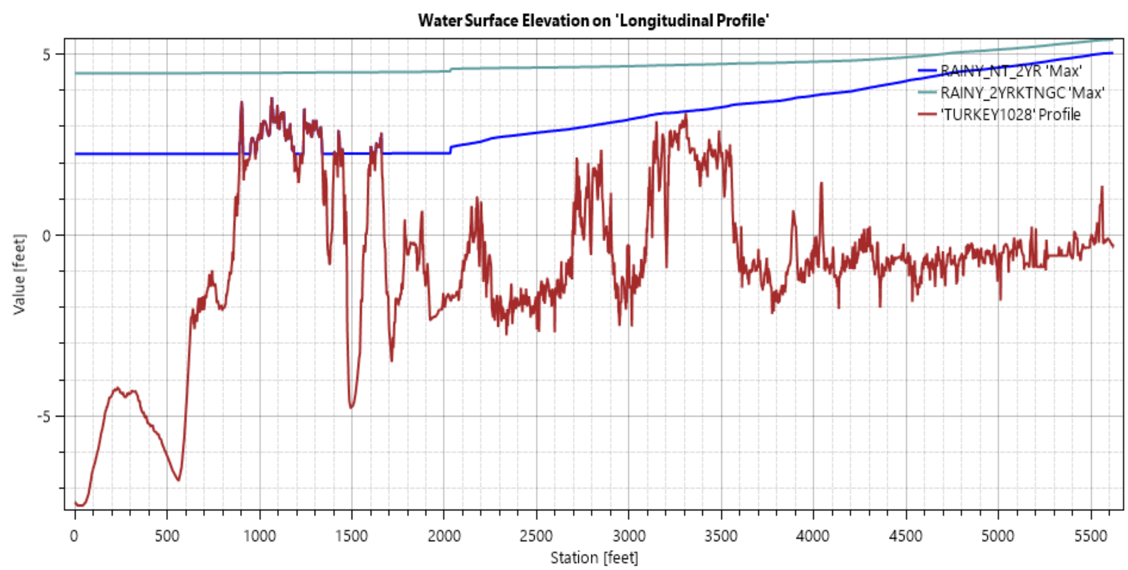


Figure B3: Water Surface Profiles of 2-YR event with king tide and normal tide

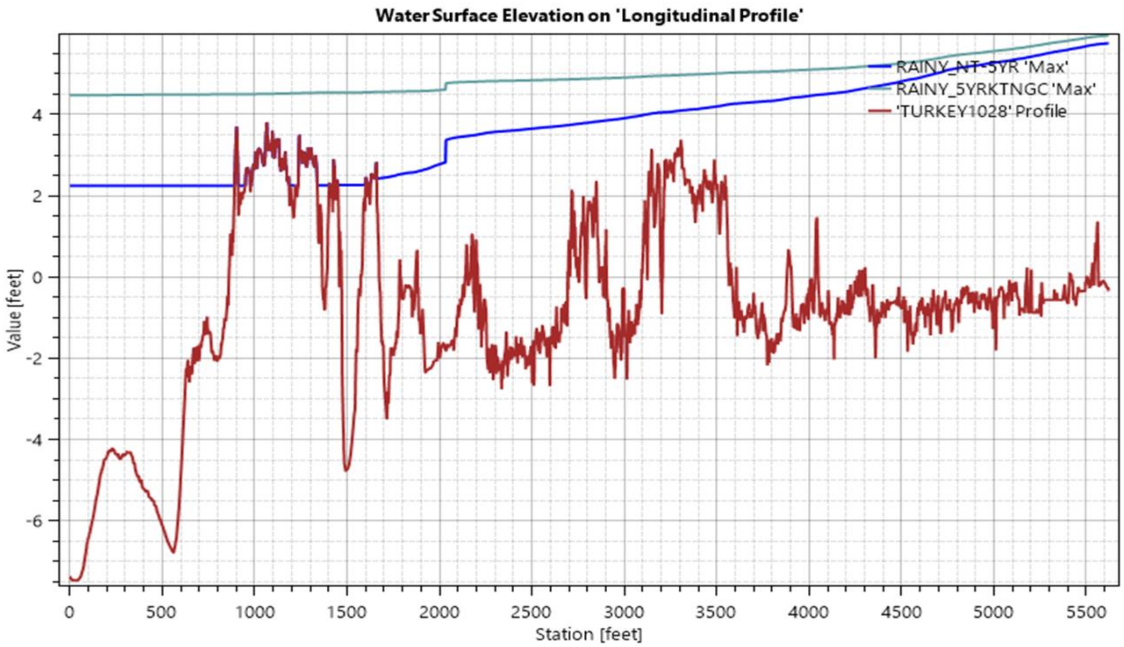


Figure B4: Water Surface Profiles of 5-YR event with king tide and normal tide

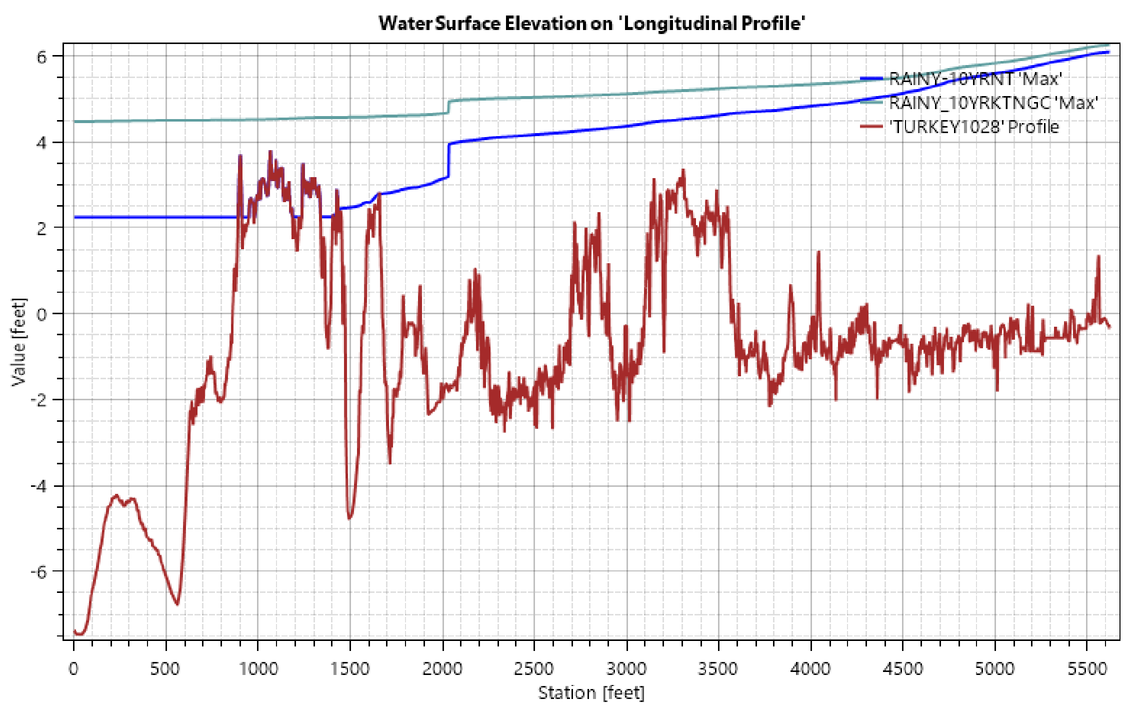


Figure B5: Water Surface Profiles of 10-YR event with king tide and normal tide

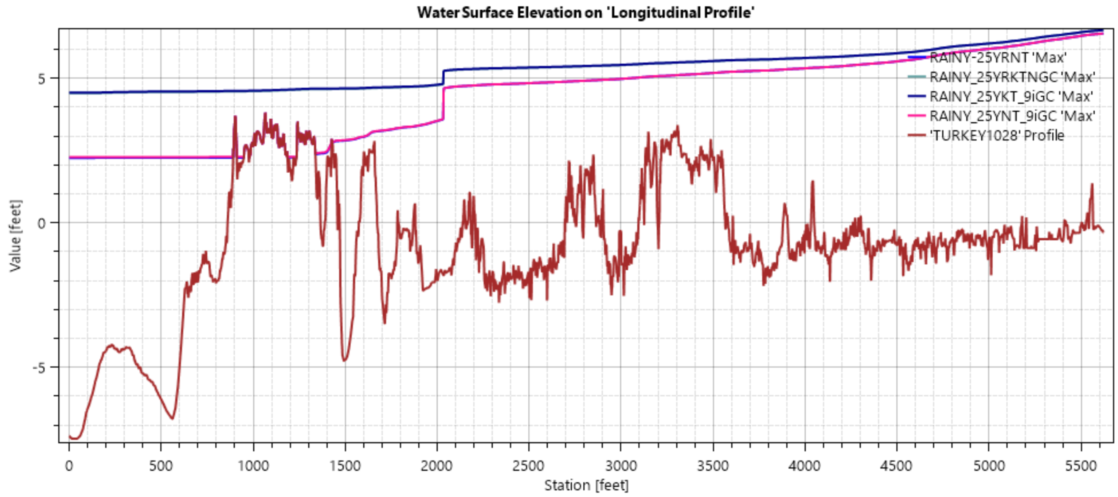


Figure B6: Water Surface Profiles of 25-YR event with king tide, normal tide, and with Goose Creek dam release.

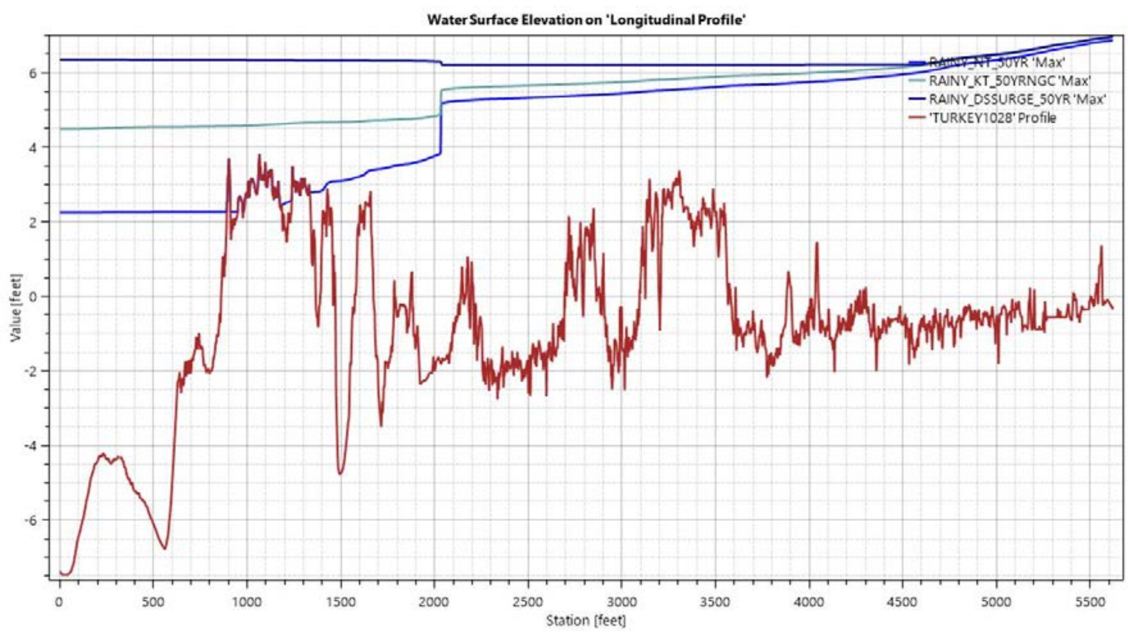


Figure B7: Water Surface Profiles of 50-YR event with king tide, normal tide, and with storm surge

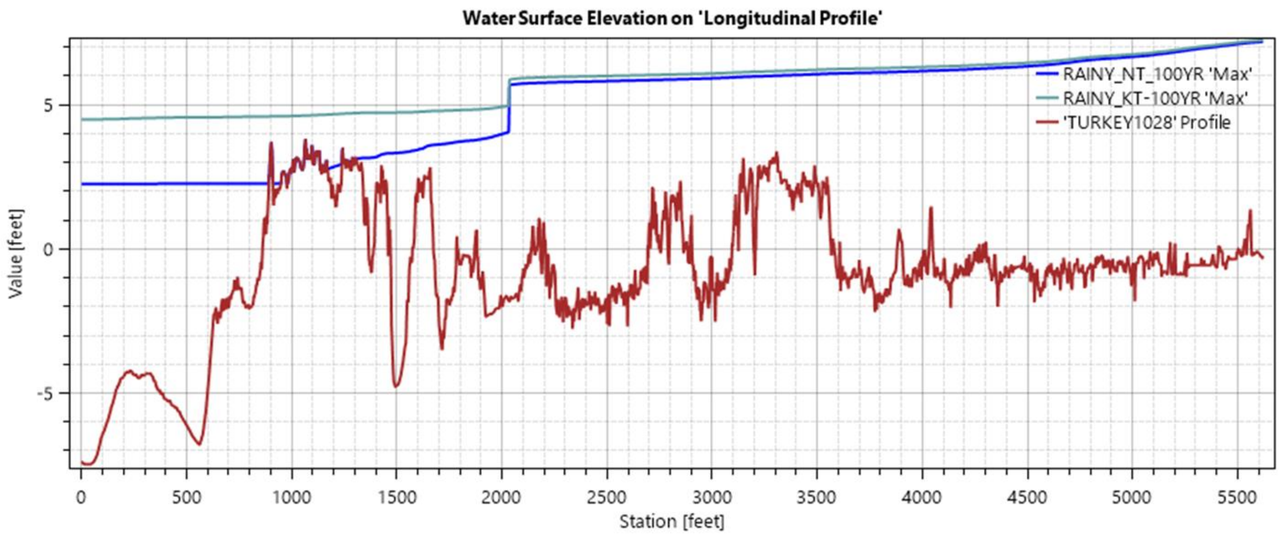


Figure B8: Water Surface Profiles of 100-YR event with king tide and normal tide

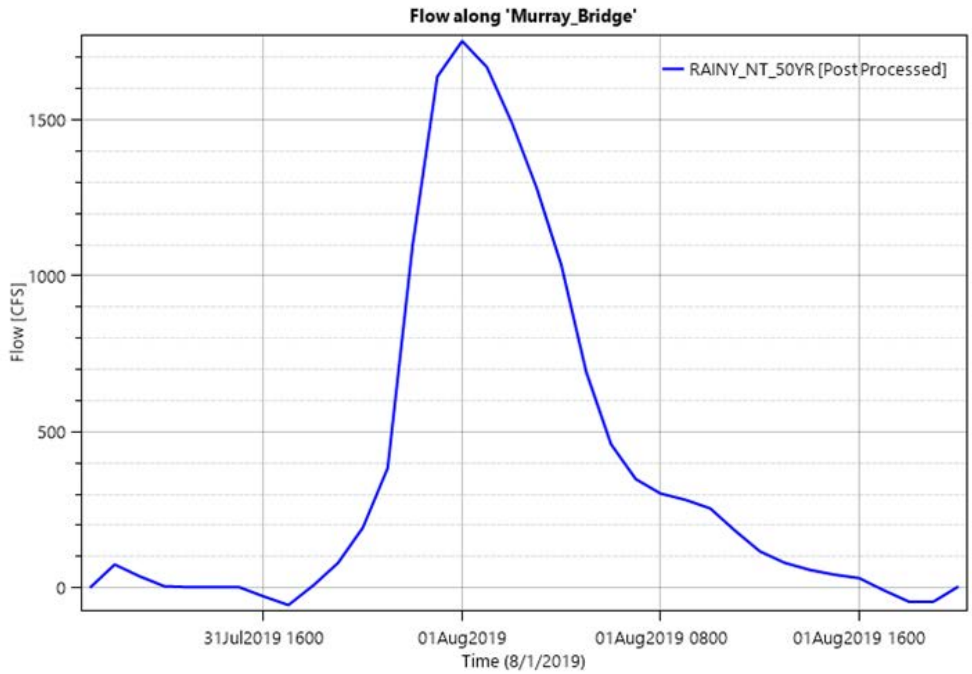


Figure B9: Flow along Murray Bridge at 50-YR event with normal tide

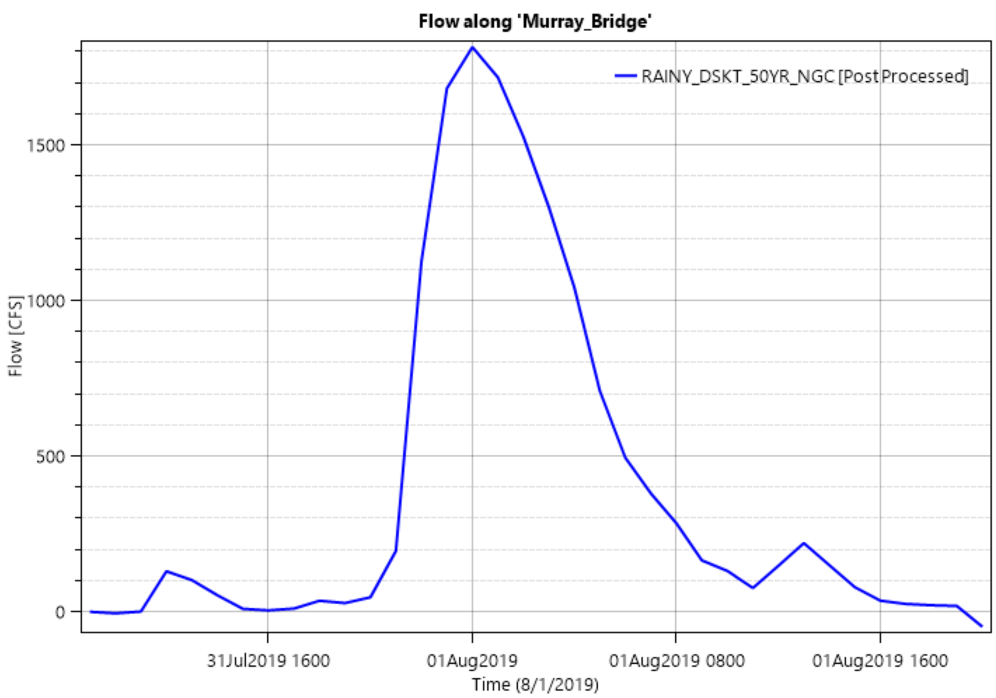


Figure B10: Flow along Murray Bridge at 50-YR event with king tide

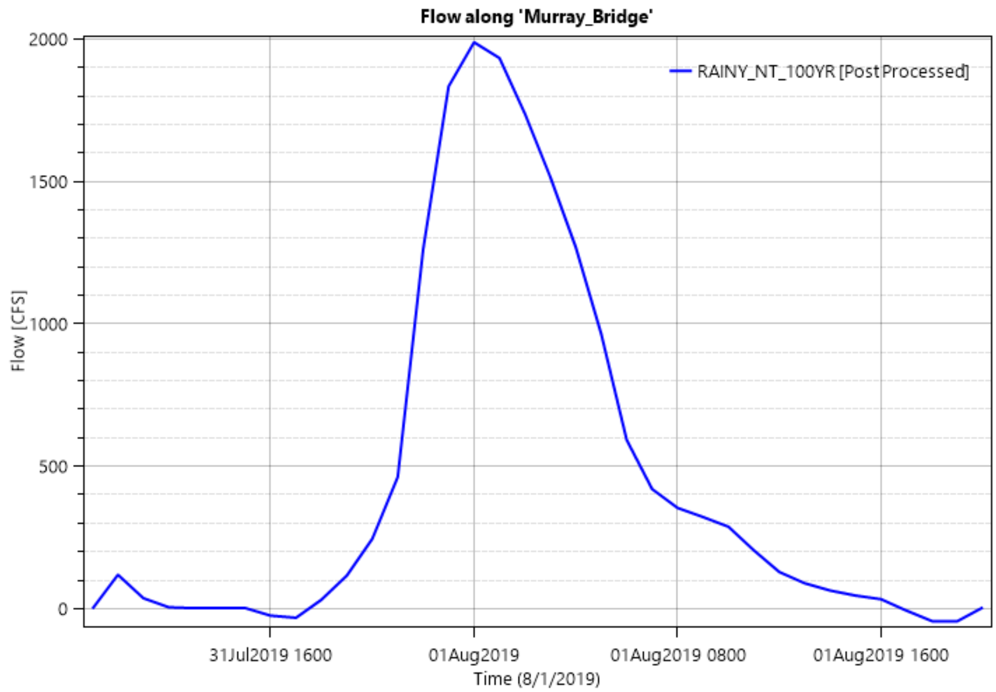


Figure B11: Flow along Murray Bridge at 100-YR event with normal tide

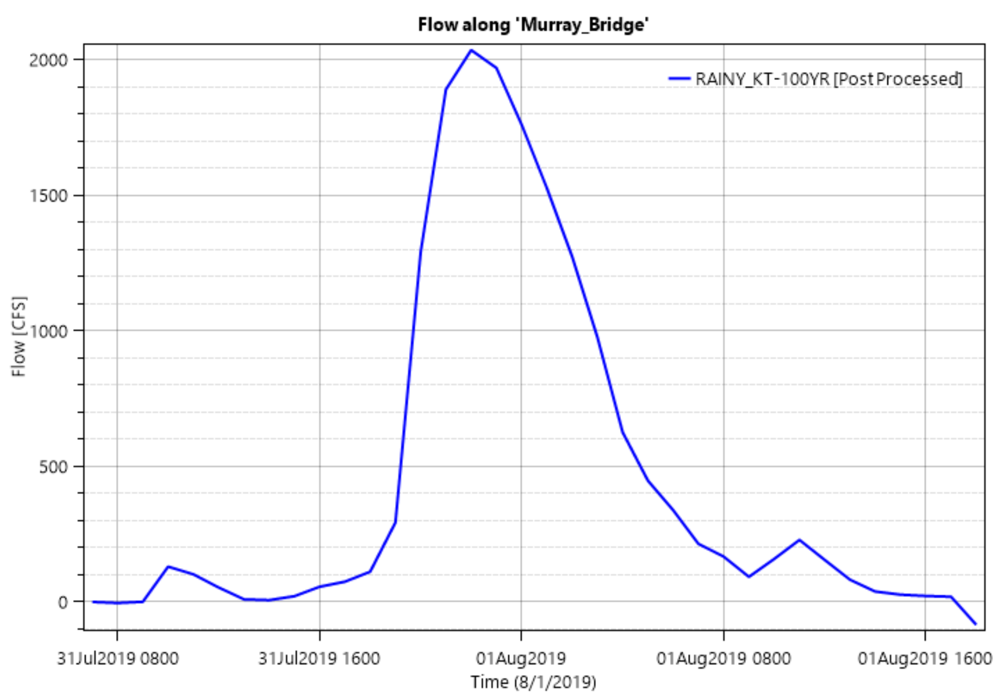


Figure B12: Flow along Murray Bridge at 100-YR event with king tide

Appendix D:
Assessment of current environmental conditions

Contents

1 Introduction

This document inventories a wide array of information in accordance with federal regulations. This information will be pertinent if the NFS independently pursues any potential measures for which a permit is needed.

2 Hazardous and Toxic Waste

There are no known hazardous or toxic waste sites located in the study area.

3 Wetlands

Wetlands are ecosystems that are inundated or flooded by water at a frequency and duration that results in anaerobic soil conditions and supports hydrophytic vegetation. Wetlands provide many ecological functions such as flood storage, nutrient transformation, and clean water and are provided protection under federal and state regulations. According to Executive Order 11990 Protection of Wetlands, Federal agencies must consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. According to the National Resources Conservation Service website, the majority of the study area is mapped as Capers Association soils. The Capers Association soils consist of very deep, very poorly drained, and very slowly permeable soils located in tidal marsh. According to the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), the study area includes approximately 50 acres of Palustrine Emergent Persistent Seasonally Flooded Fresh Tidal (PEM1R) wetlands (Figure 1). A wetland delineation of the study area should be performed prior to any project undertakings.

Figure 1. National Wetlands Inventory

4 Cultural Resources

NEPA requires an inventory of cultural resources when applying for permits. The National Historic Preservation Act of 1966, as amended (NHPA), defines cultural resources as prehistoric and historic sites, structures, districts, or any other physical evidence of human activity considered important to a culture, a subculture, or a community for scientific, traditional, religious, or any other reason. Several federal laws and regulations protect these resources, including the NHPA of 1966, the Archaeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act of 1978, the Archaeological Resources Protection Act of 1979, and the Native American Graves Protection and Repatriation Act of 1990. Section 106 of the NHPA and its implementing regulations, 36 CFR Part 800, requires Federal agencies to evaluate the effects of their activities on historic properties.

According to the South Carolina Institute of Archaeology and Anthropology (SCIAA) and the South Carolina Department of Archives and History (SCDAH), there are no known eligible historical or cultural resources located within the identified study area (Figure 2). There are six structures located within study boundaries along Old Murray Court at Eastwood Avenue in the Highland Park subdivision. However, these structures were previously evaluated and determined ineligible for inclusion in the National Register of Historic Places (NRHP). Located just outside the study area and adjacent to the Goose Creek reservoir, there are five potentially eligible structures associated with Charleston Waterworks. The Goose Creek Reservoir and the Saxon pumping station were constructed in 1903 and later purchased by the City of Charleston to establish the first public water system. The five structures include the pumping station, chemical storage building, filter building, steam generating station, and a tunnel/shaft.

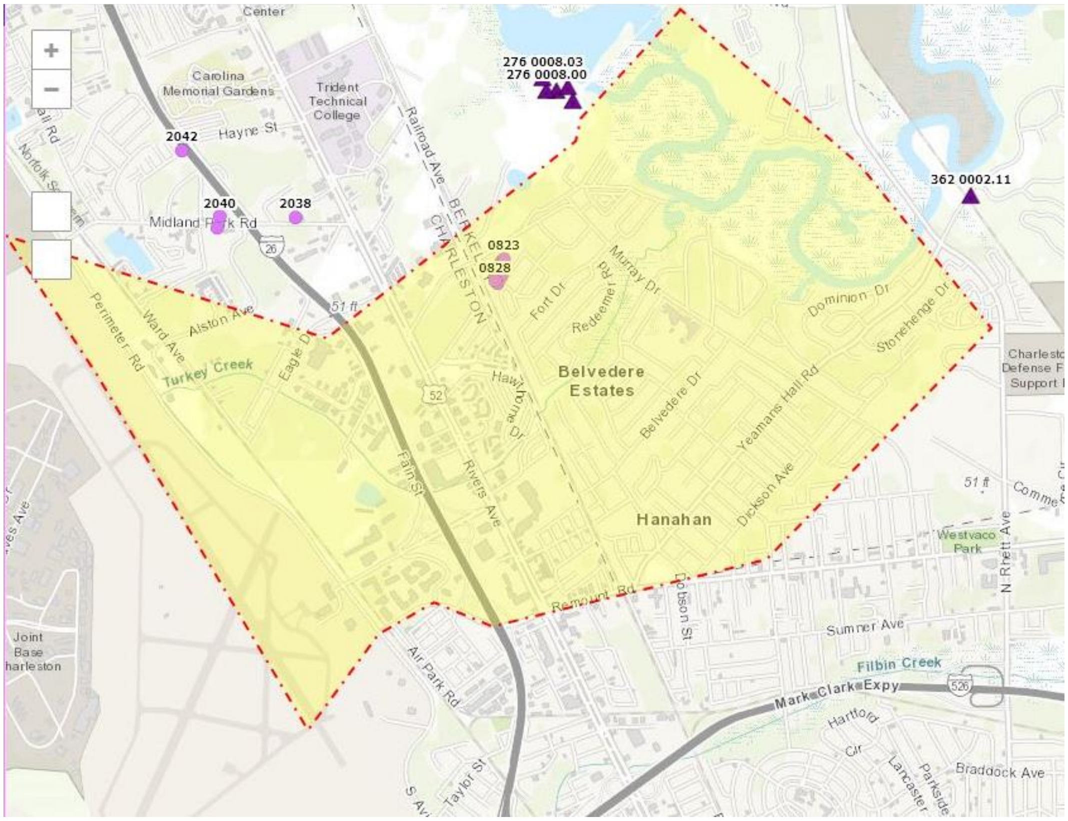


Figure 2. South Carolina Archsite Map

5 Biological Resources

The Endangered Species Act of 1973, as amended (ESA), requires federal agencies to ensure that the actions they fund, authorize, or perform are not likely to jeopardize the survival of listed species or result in the destruction or adverse modification of designated critical habitat. Table 1 below lists the plant and animal species that are protected under ESA, and which may be found in Berkeley County based on their geographic habitat range. This list includes species that are under the jurisdiction of the USFWS and/or the National Oceanic and Atmospheric Administration (NOAA), as well as state listed species.

Table 1. Berkeley County Federal and State Listed Threatened and Endangered Species

Common Name	Scientific Name	Federal Status	State Status
Mammals			
West Indian Manatee	*Trichechus manatus*	T	E
Northern Long-eared Bat	*Myotis septentrionalis*	T	n/a
Rafinesque's Big-eared Bat	*Corynorhinus Rafinesque*	n/a	E
Marine Turtles			
Kemp’s Ridley sea turtle	*Lepidochelys kempii*	E	E
Leatherback sea turtle	*Dermochelys coriacea*	E	E

Loggerhead sea turtle	*Caretta*	T	T
Green sea turtle	*Chelonia mydas*	T	T
Fish			
Shortnose sturgeon	*Acipenser brevirostrum*	E	E
Atlantic sturgeon	*Acipenser oxyrhynchus*	E	n/a
Birds			
American wood stork	*Mycteria americana*	E	E
Red-cockaded woodpecker	*Picoides borealis*	E	E
American Swallow-tailed Kite	*Elanoides forficatus*	n/a	E
Bald Eagle	*Haliaeetus leucocephalus*	n/a	E
Least Tern	*Sterna antillarum*	n/a	T
Amphibians			
Frosted flatwoods salamander	*Ambystoma cingulatum*	T	E
Gopher Frog	*Lithobates capito*	n/a	E
Reptiles			
American Alligator	*Alligator mississippiensis*	n/a	T
Southern Hognose Snake	*Heterodon simus*	n/a	T
Spotted Turtle	*Clemmys guttata*	n/a	T
Plants			
American chaffseed	*Schwalbea Americana*	E	n/a
Canby's dropwort	*Oxypolis canbyi*	E	n/a
Pondberry	*Lindera melissifolia*	E	n/a
E – Federal and/or State endangered T – Federal and/or State threatened			

According to the South Carolina Heritage Trust (SCHT) database, there are no Federal ESA listed species or Federally-designated critical habitat located within the study area. However, the SCHT database indicates the presence of bald eagle species within the study area boundary. While this species is no longer listed under the ESA, it is designated as a state listed species and is federally protected by the Bald & Golden Eagle Protection Act of 1940, as amended (BEGPA). BEGPA prohibits the "take" of a bald or golden eagle, including their parts, nest, or eggs, without a permit issued by the Secretary of the Interior. Take is defined as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb". "Disturb" includes interference with normal breeding, feeding, or sheltering behavior that could result in a decrease in productivity, nest abandonment, or injury. Any measures that have the potential to adversely affect this species will require coordination with the USFWS.

6 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act of 1976, as amended (ACT), defines Essential Fish Habitat (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity". Under the ACT, federal agencies are required to consult with the National Marine Fisheries Service (NMFS) for any action or proposed action that is authorized, funded, or undertaken by the agency which could adversely affect EFH.

According to the NMFS EFH Mapper, resources that may be found in the study area include the Snapper Grouper species (Figure 3). Any measures that have the potential to adversely affect EFH resources will require consultation with NMFS prior to implementation.

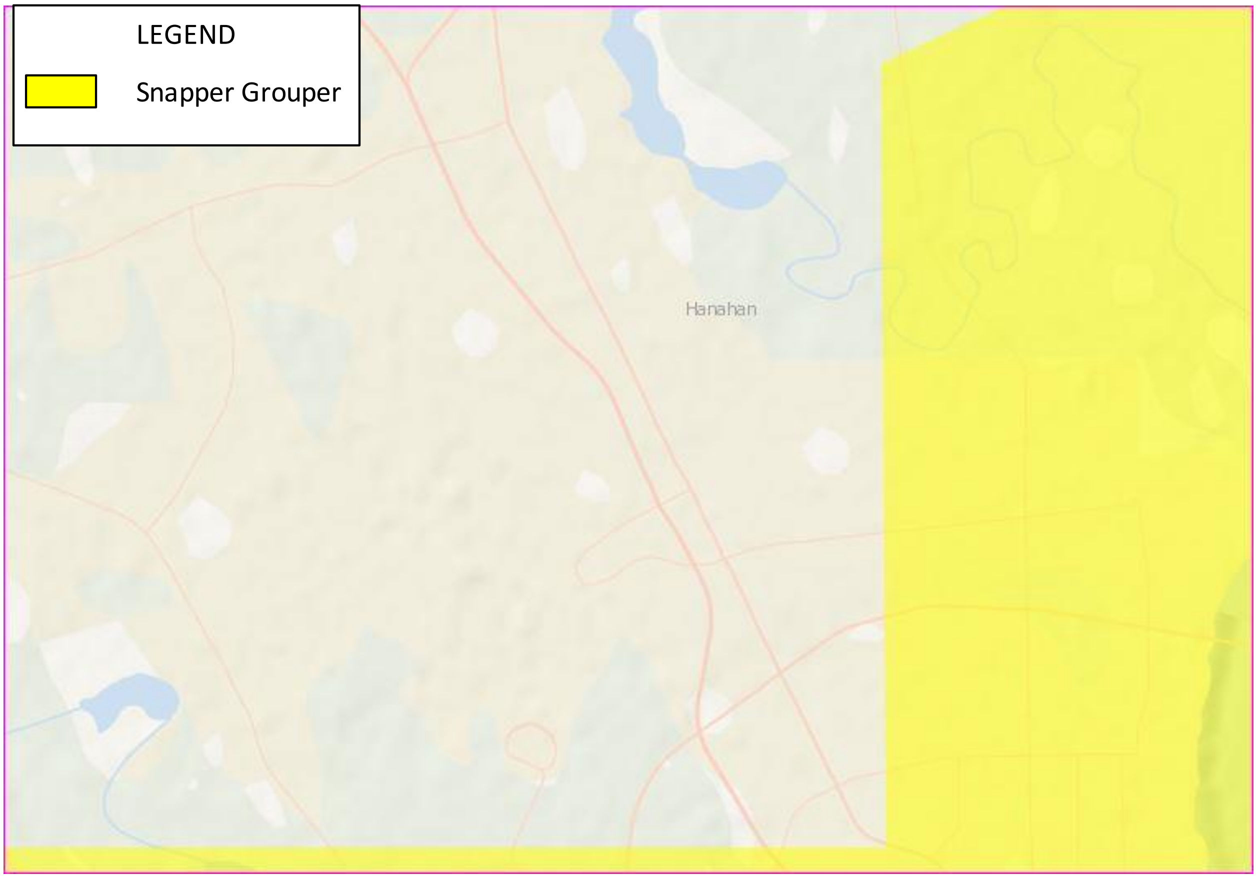
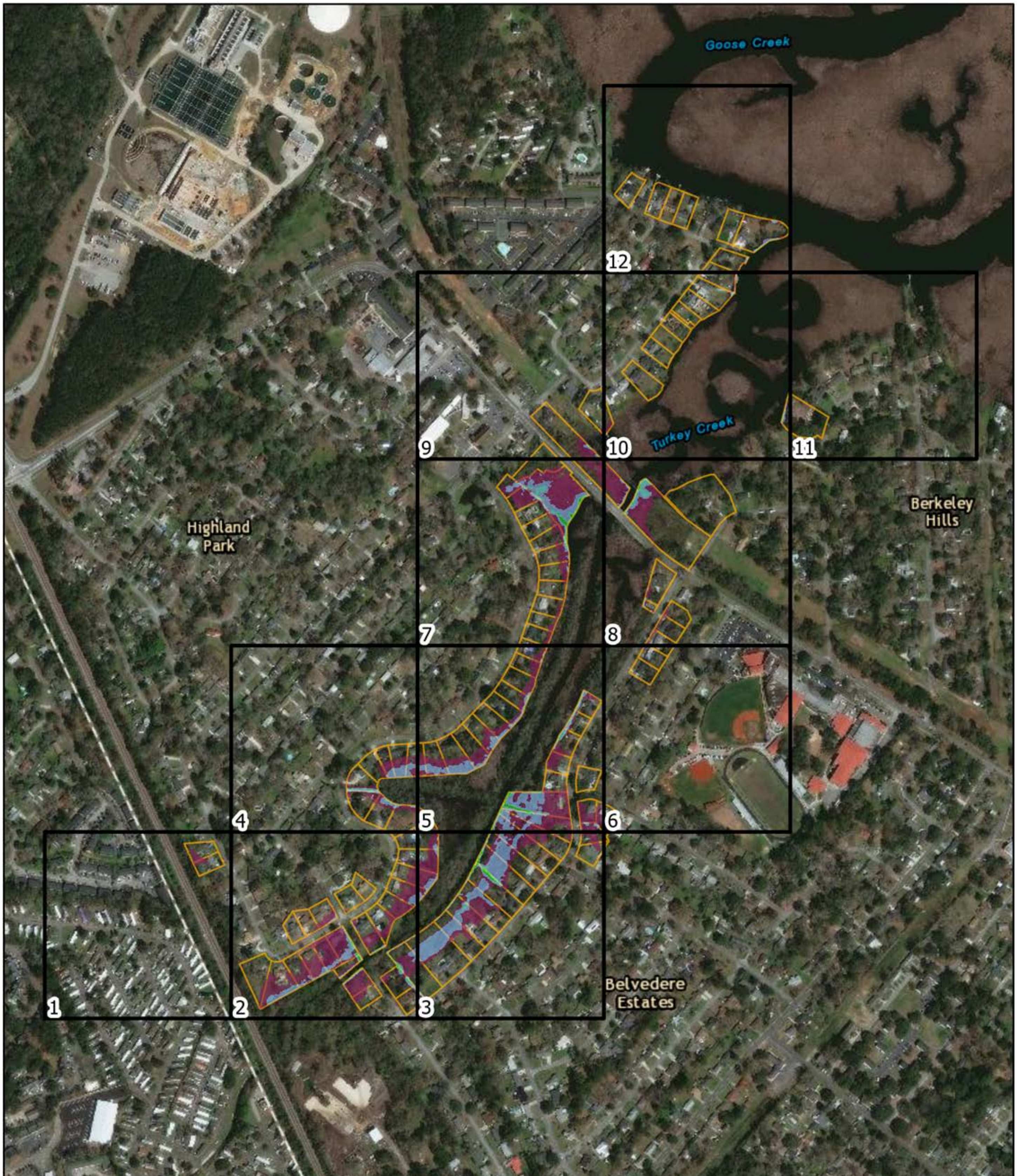


Figure 3. Essential Fish Habitat Map

Appendix E: Parcel flood risk map books

Modeled Scenario:
RAINY DSNT 10YR NGC



Legend

Parcels

N
W
E
S

0 250 500 1,000
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:8,667

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W
E
S

0 50 100 200

US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study	Created: March, 2020
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US Army Corps of Engineers
Charleston District
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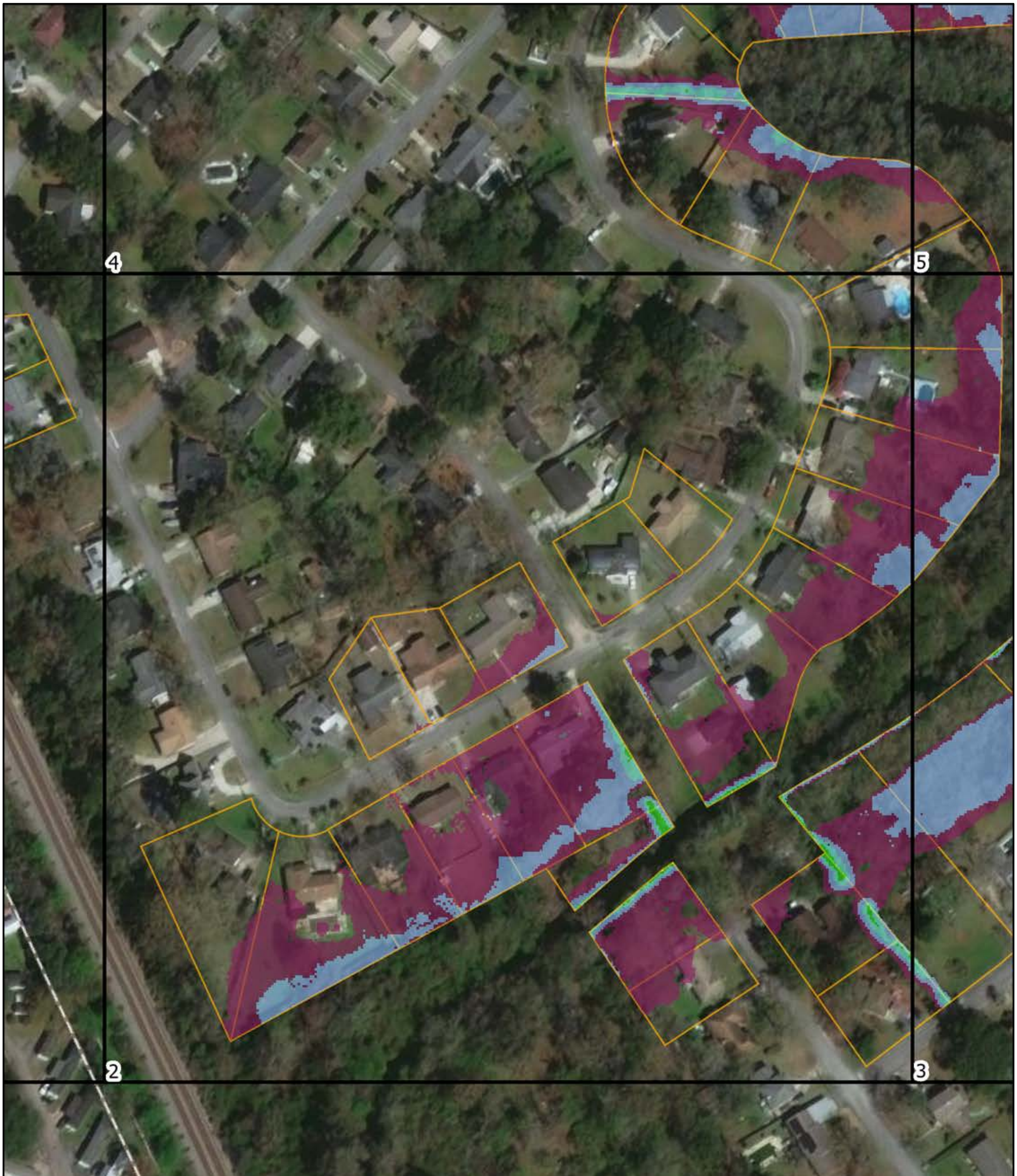
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
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Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
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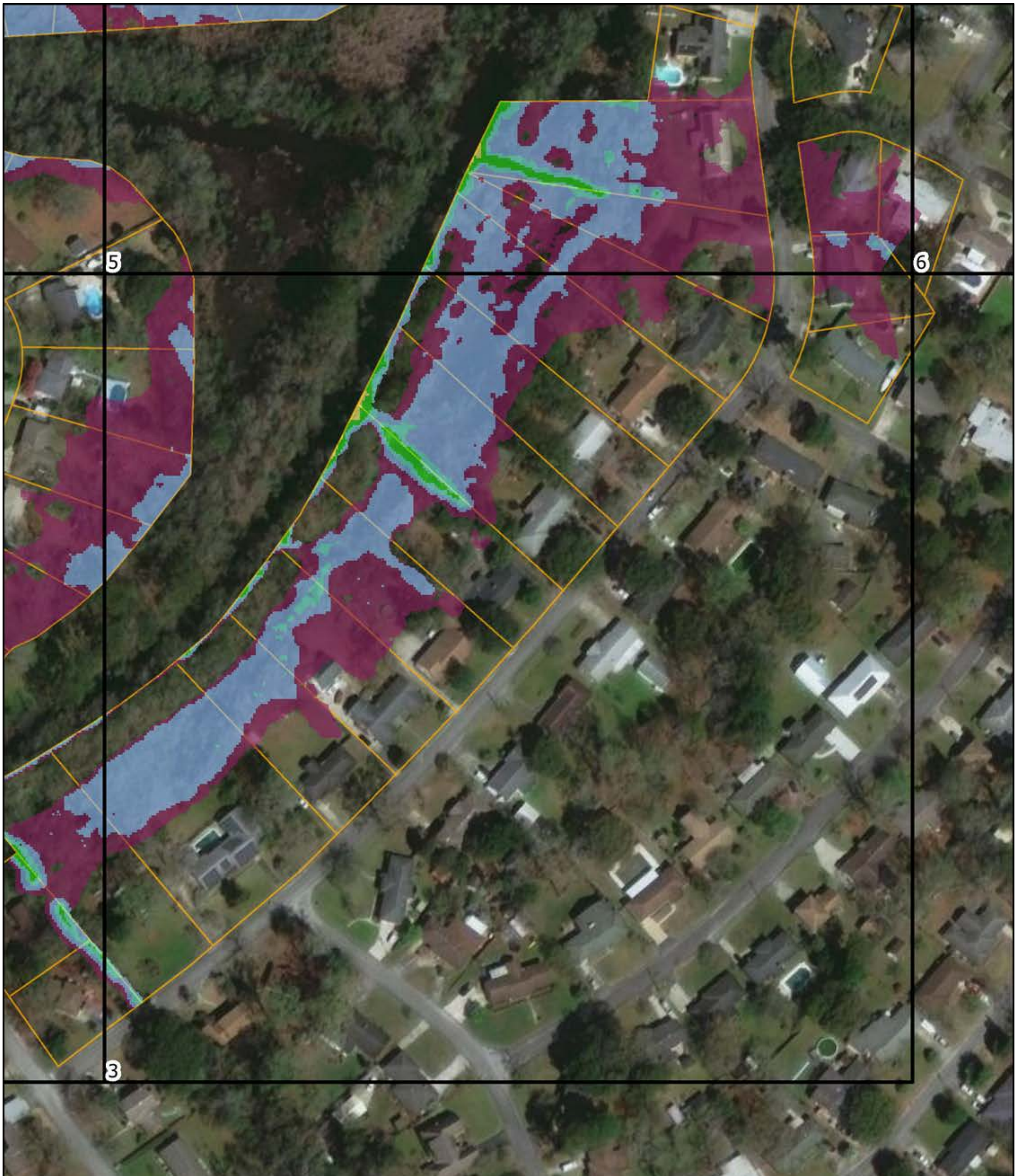

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W
E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
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Datum: NAD 1983 NSRS2007

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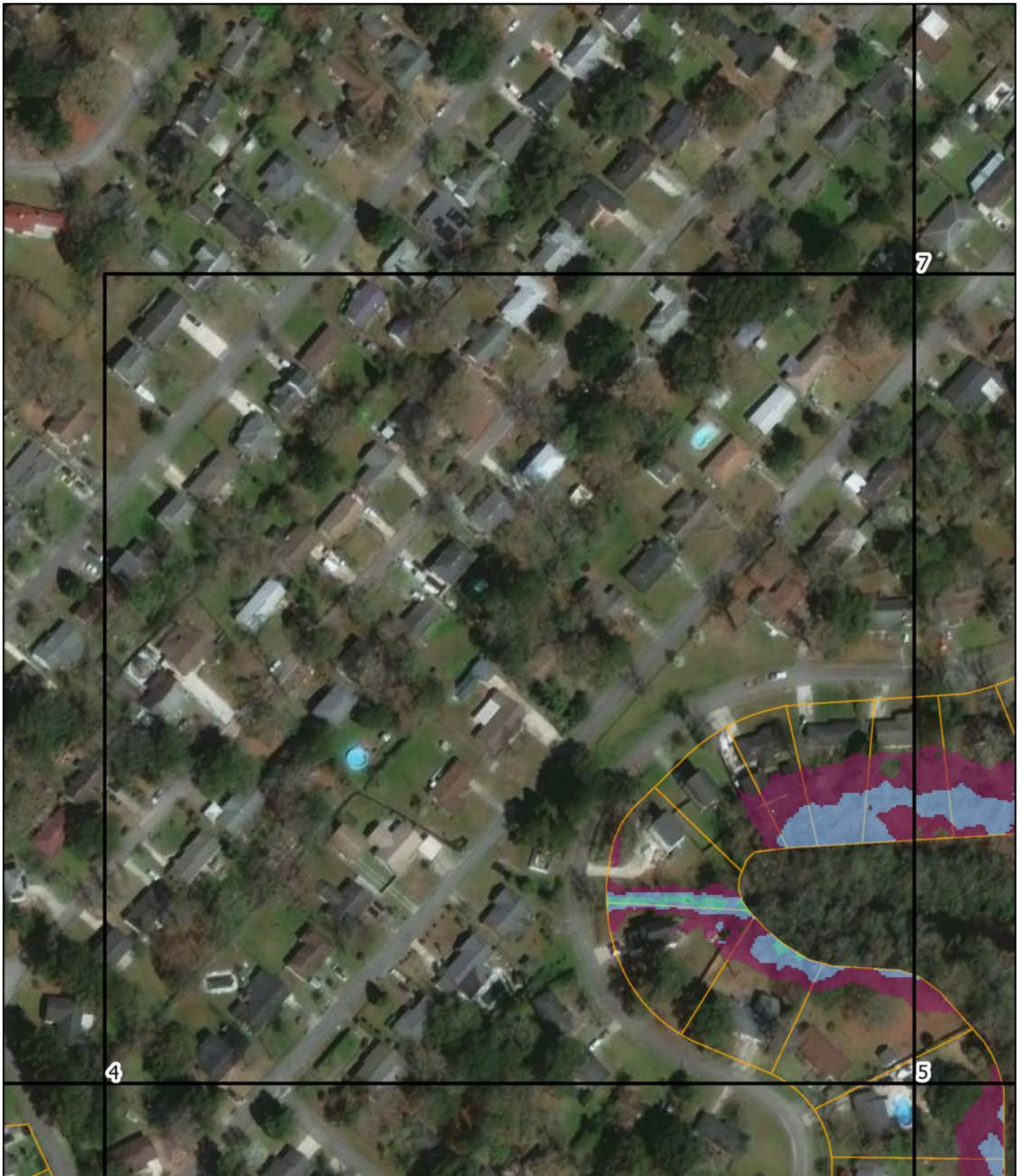

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
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US Army Corps of Engineers
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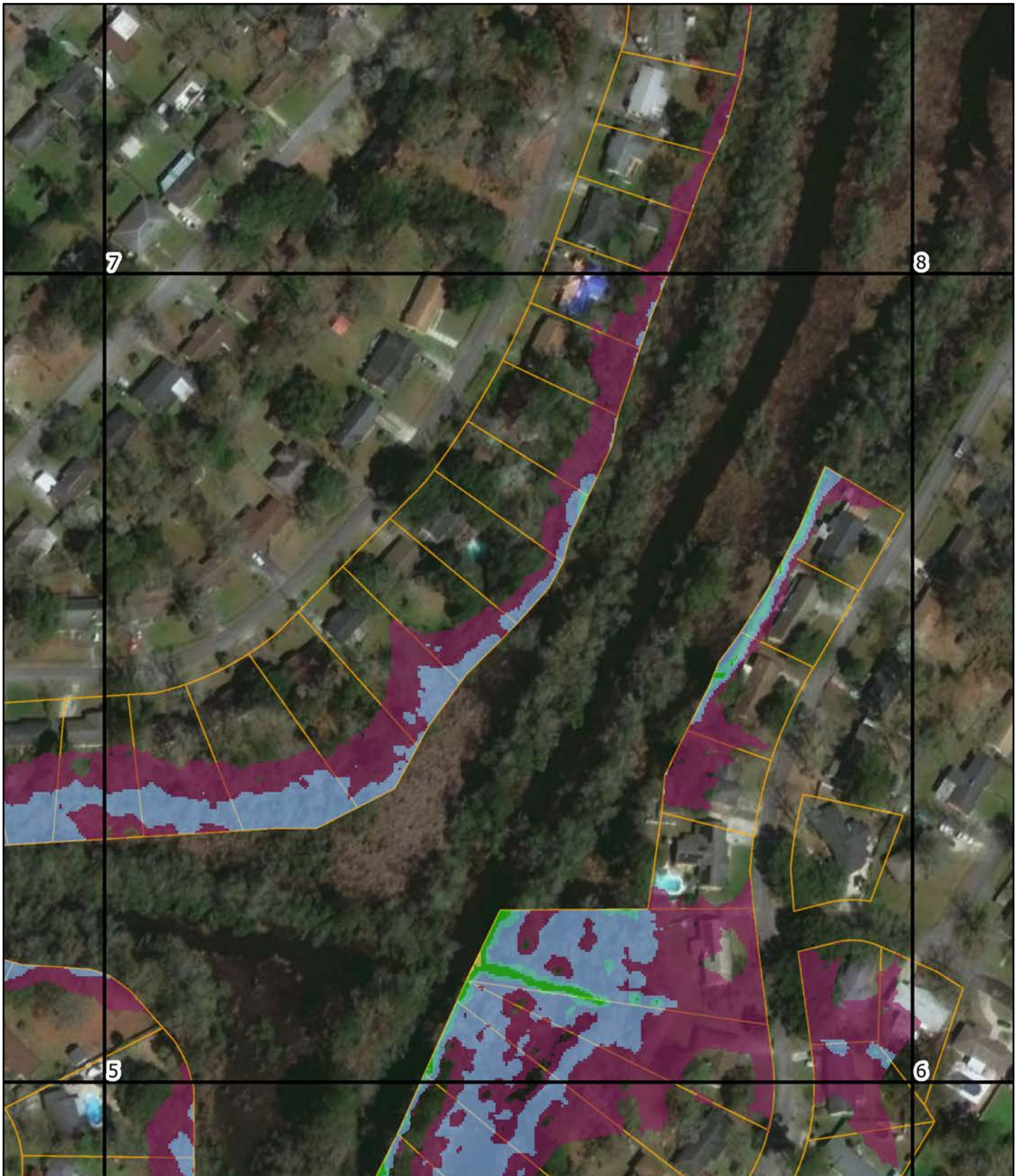

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
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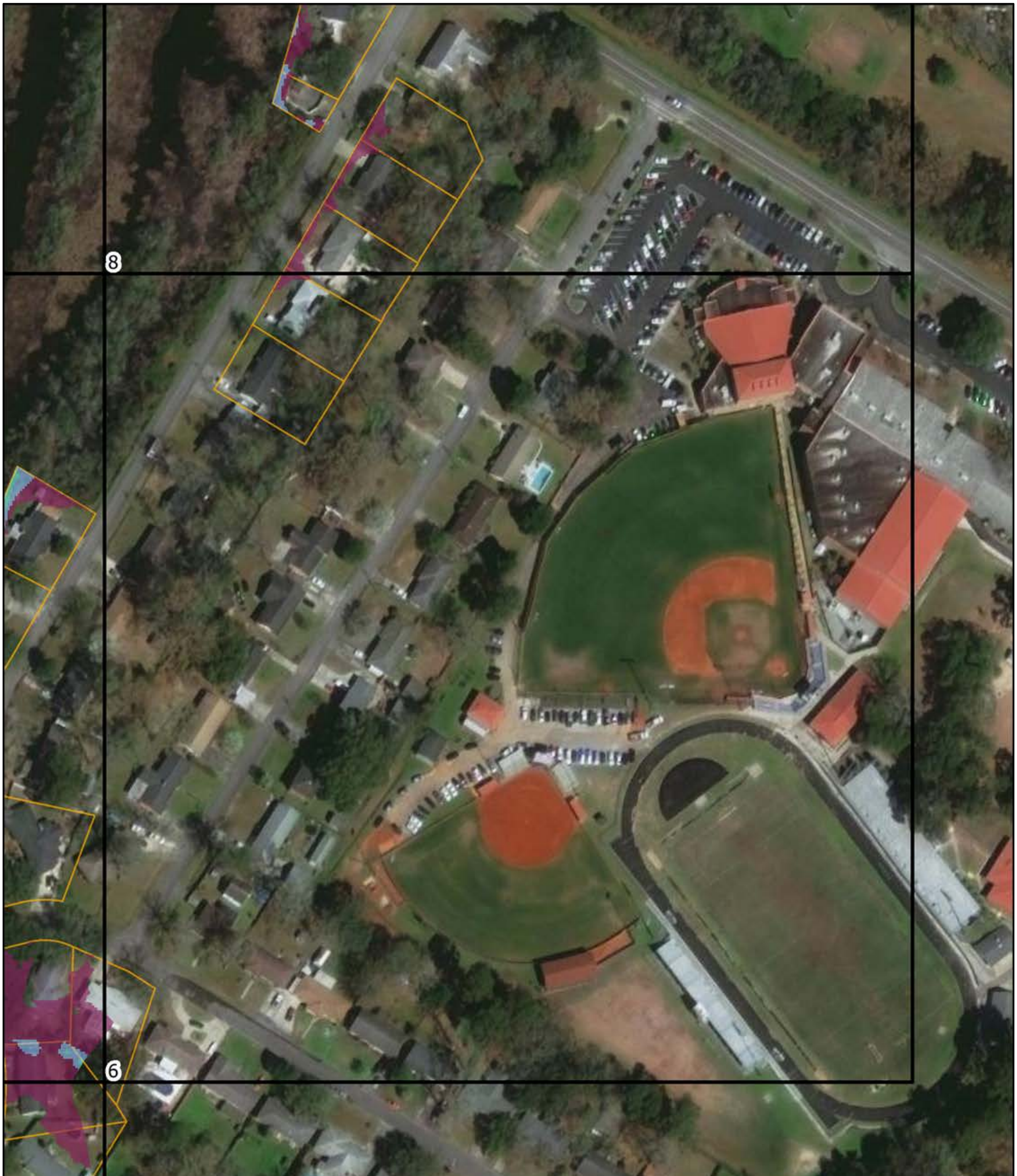

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42	≤ 4.26
≤ 2.84	≤ 5.68
	≤ 7.09
	≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
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GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
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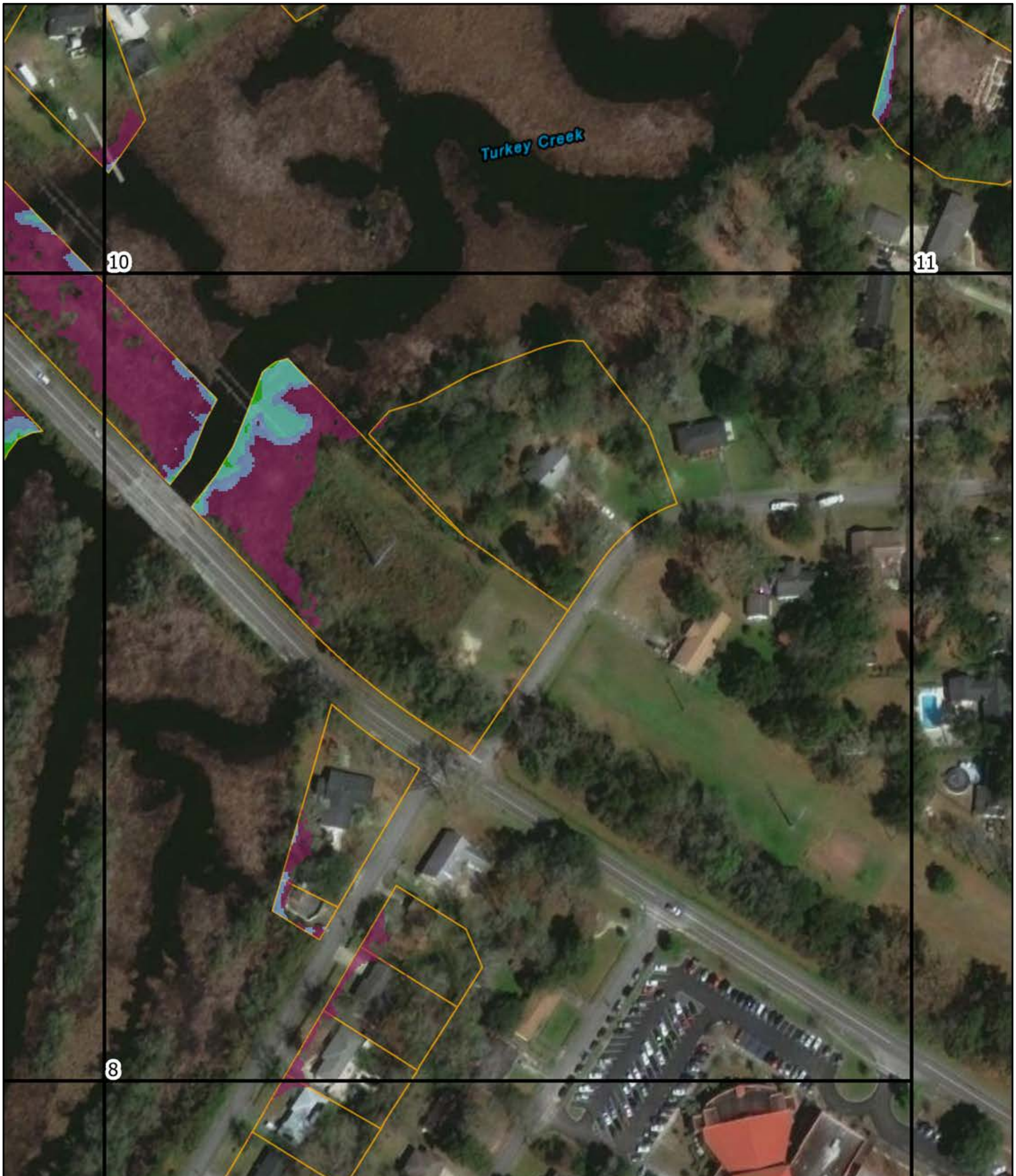
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study	Created: March, 2020
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W
E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W
E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study

Created: March, 2020

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 10YR NGC

Turkey Creek Hanahan PAS Study	Created: March, 2020
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
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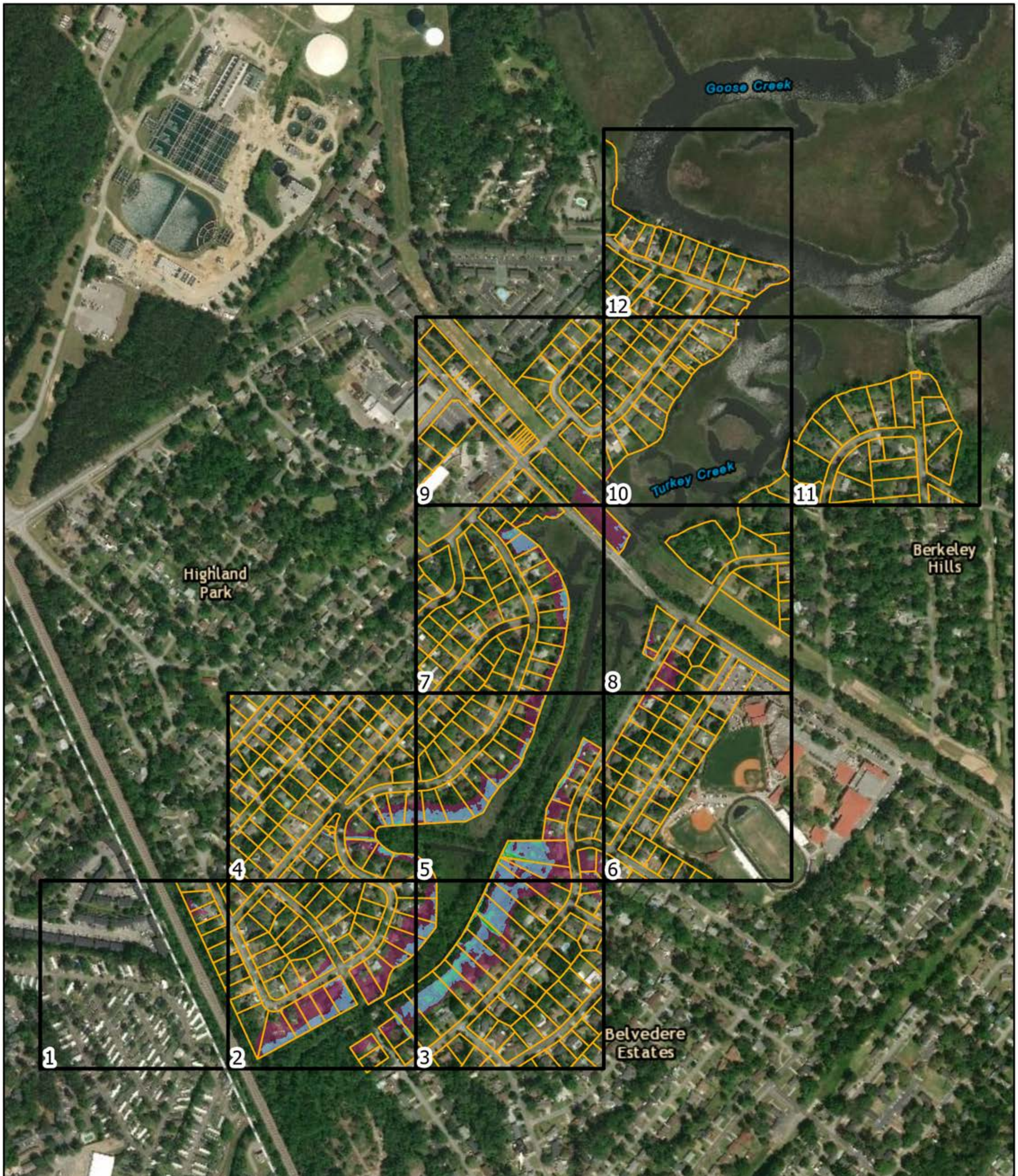
Modeled Scenario:
RAINY DSNT 25YR NGC



Legend

Grid

Parcels

N
W
E
S

0 250 500 1,000 US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
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Datum: NAD 1983 NSRS2007

Scale: 1:8,605

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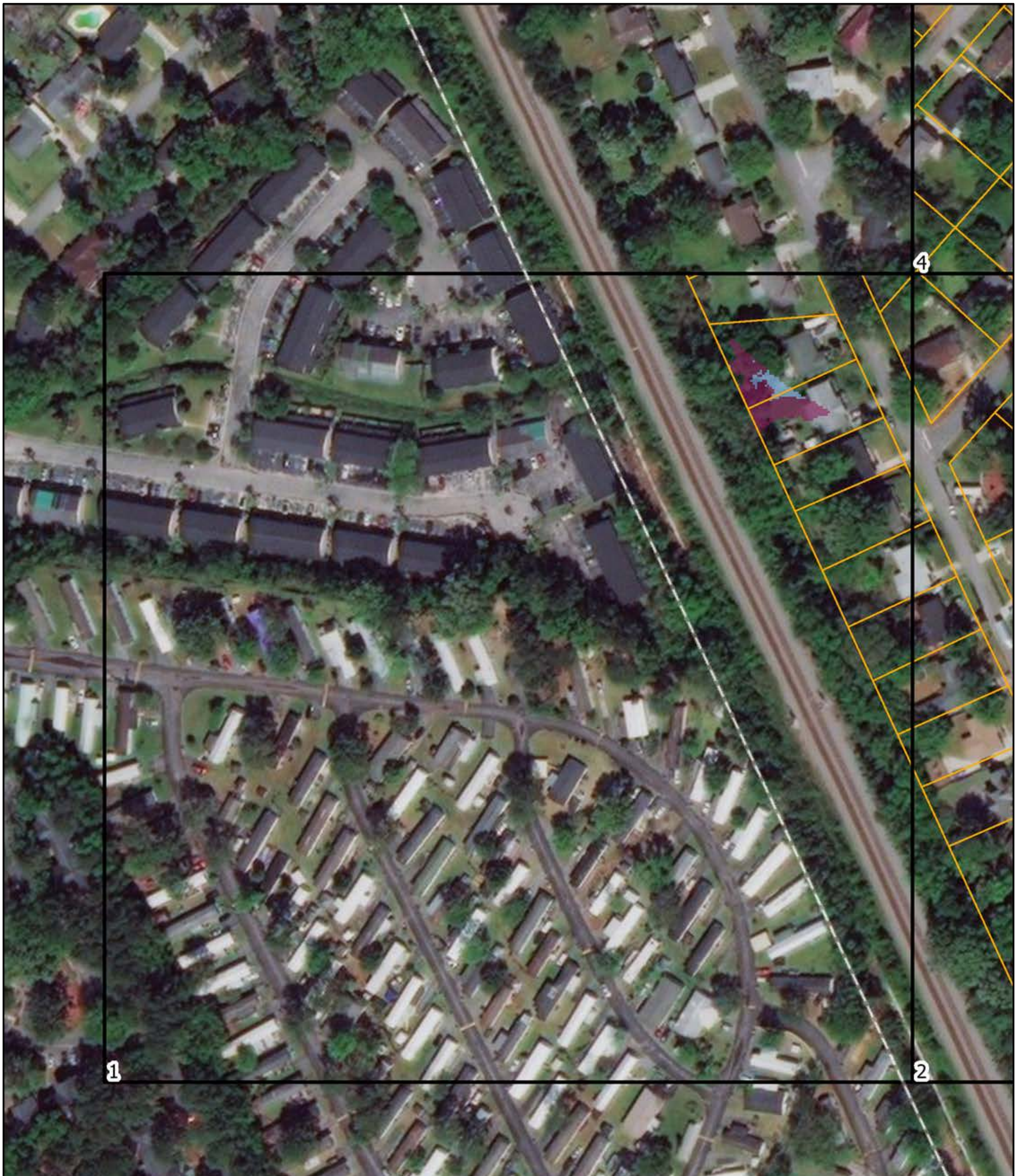

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
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US Army Corps of Engineers
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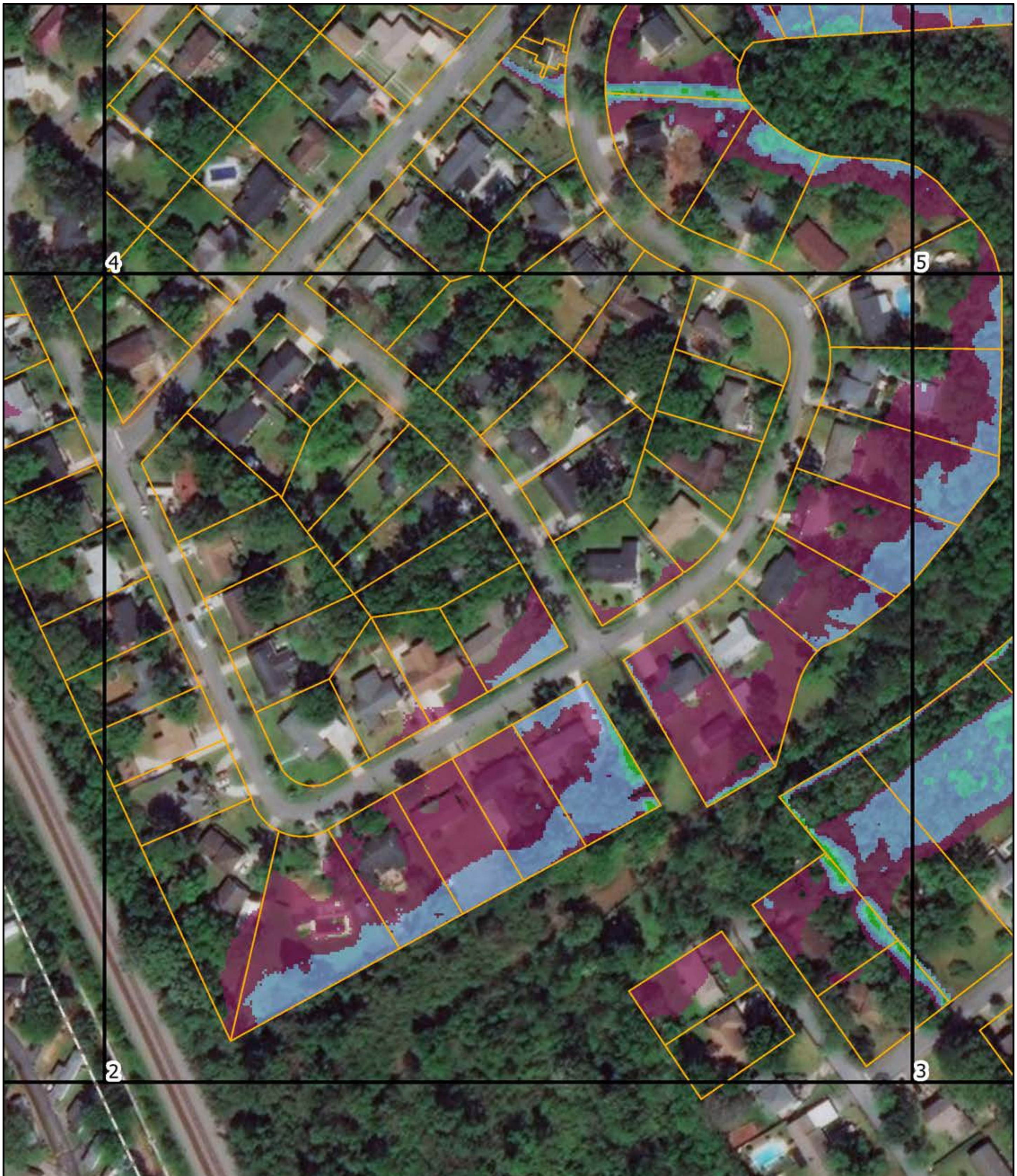

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
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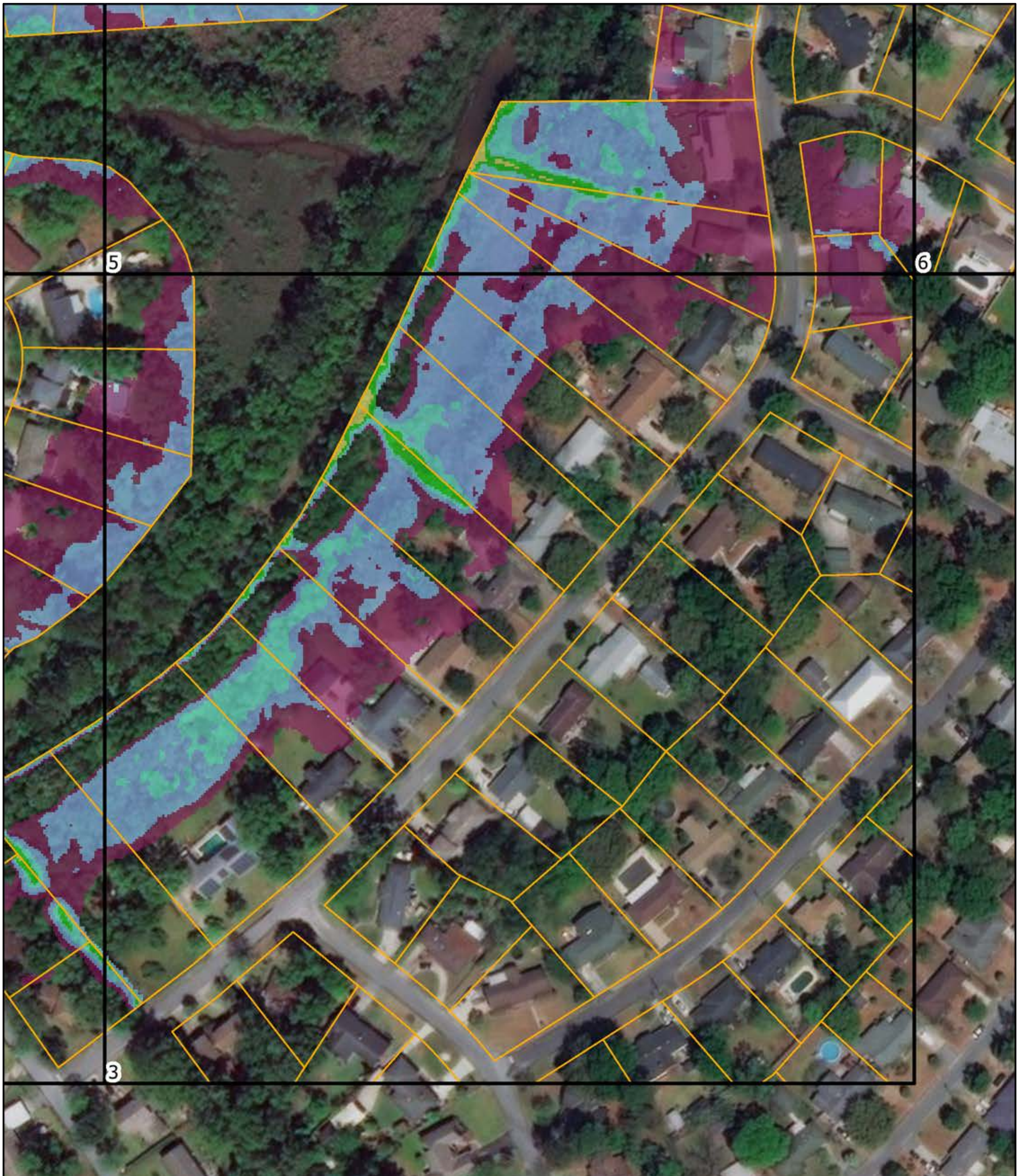

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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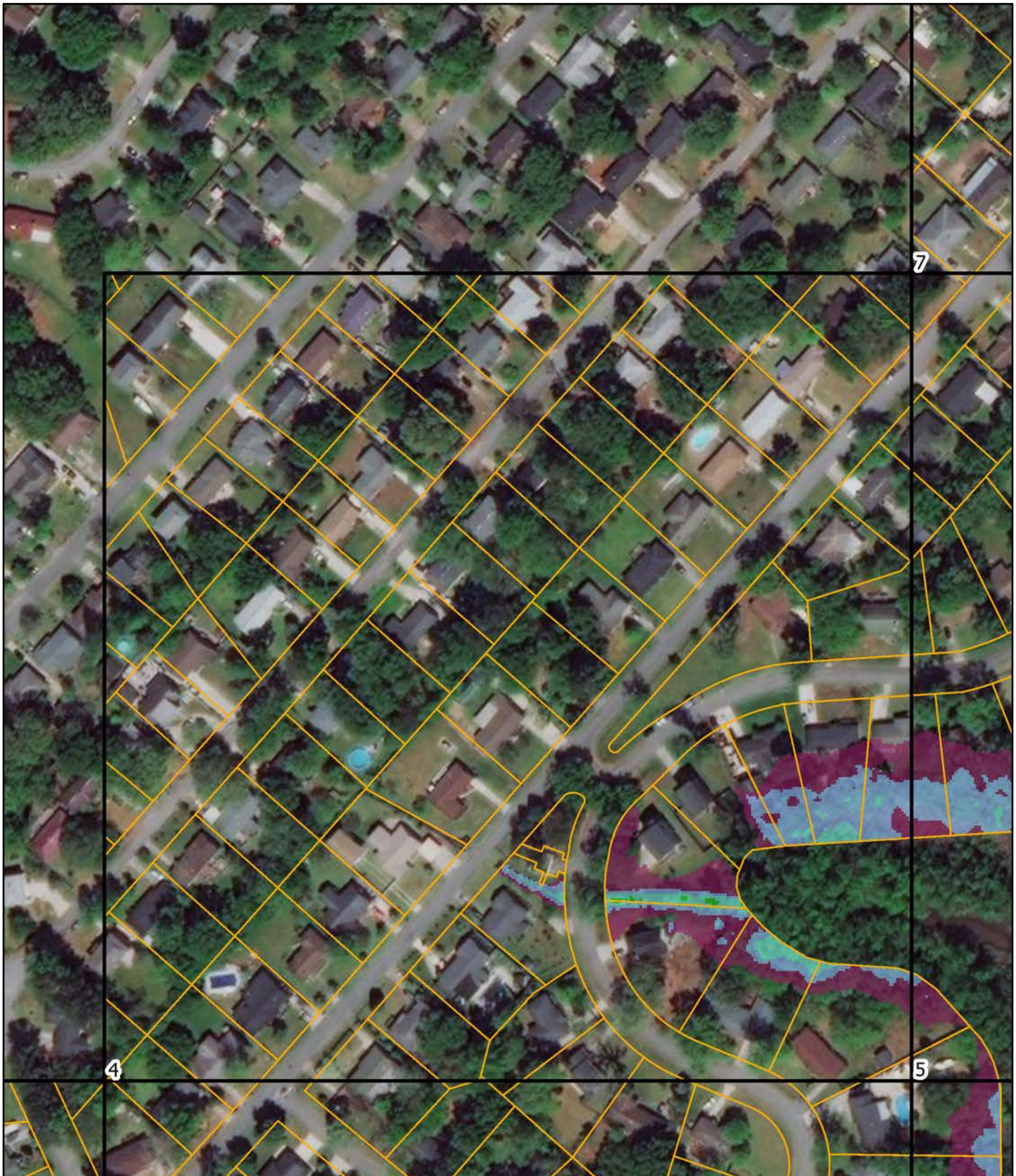
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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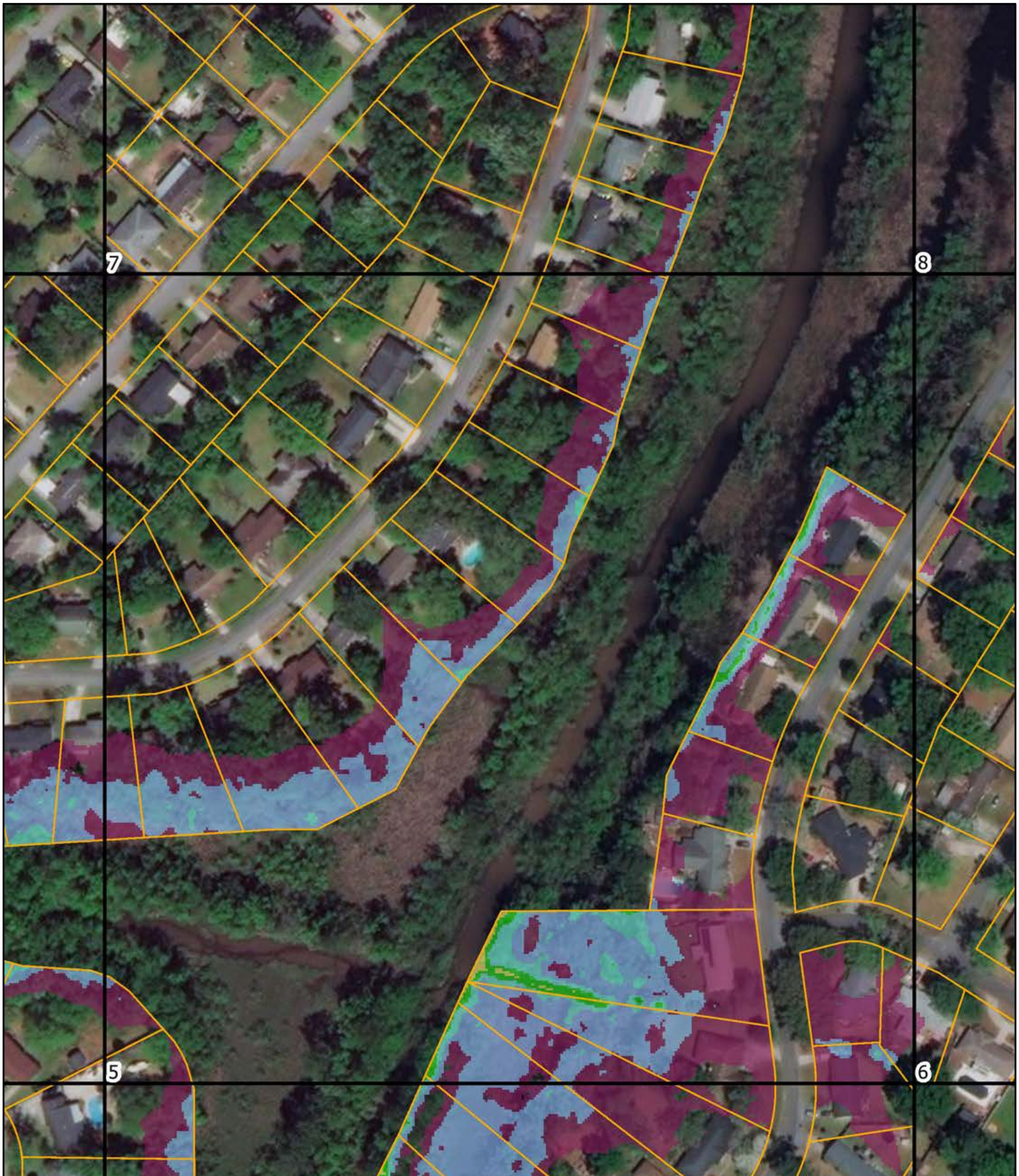


Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

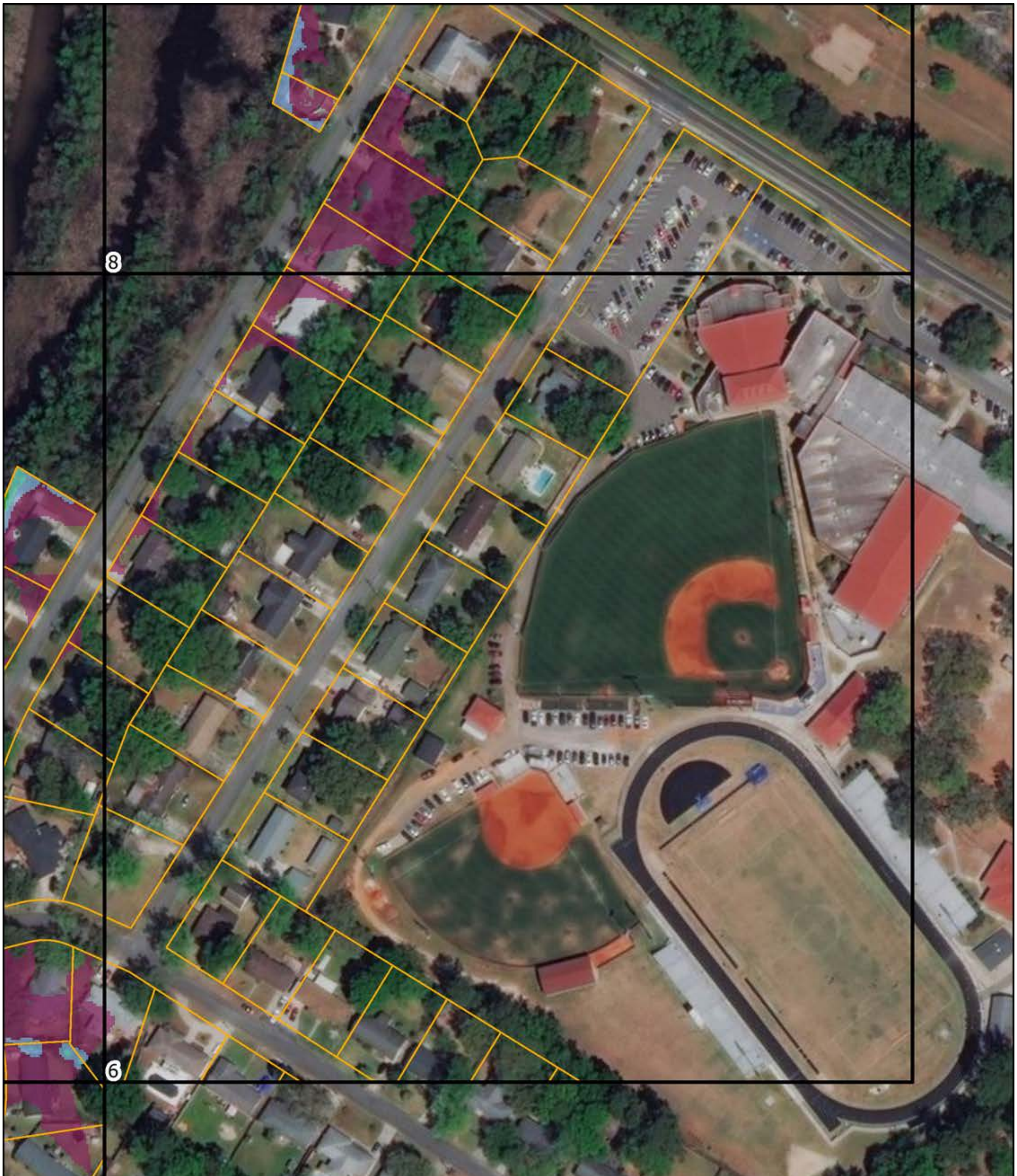
N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.83

≤ 4.26

≤ 5.67

≤ 7.09

≤ 8.51

N S E W

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 25YR NGC

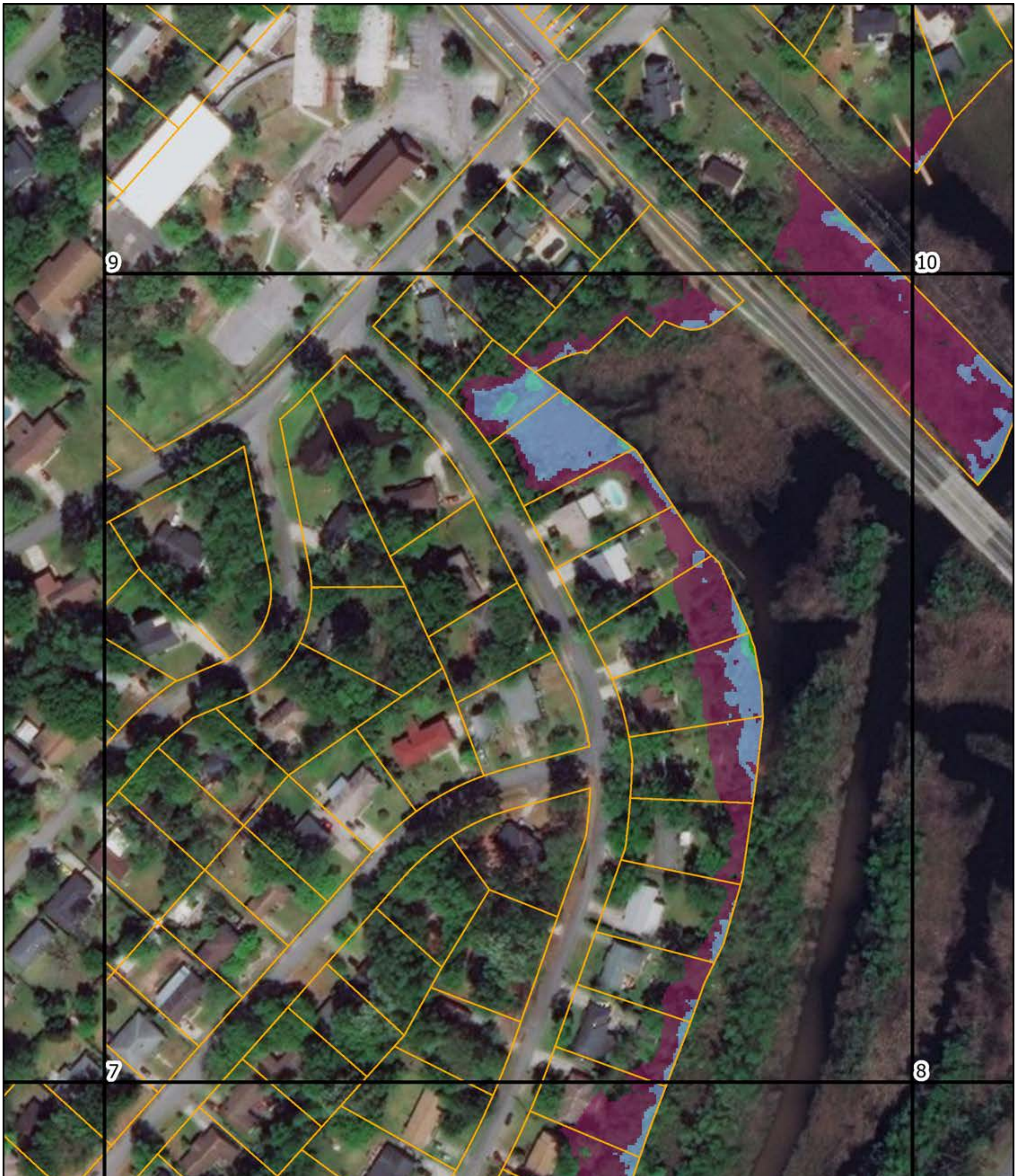
Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

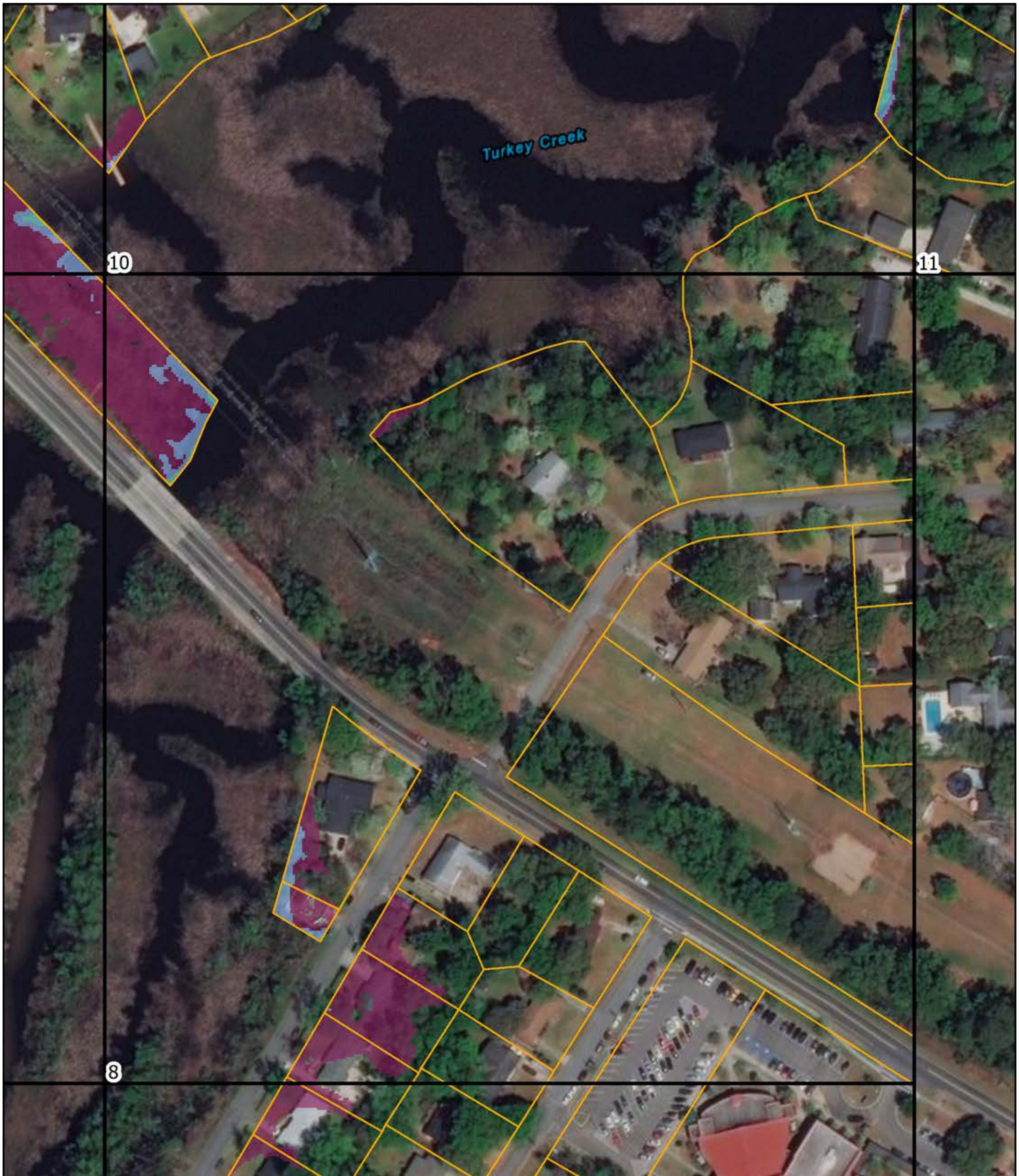
N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.83
- ≤ 4.26
- ≤ 5.67
- ≤ 7.09
- ≤ 8.51

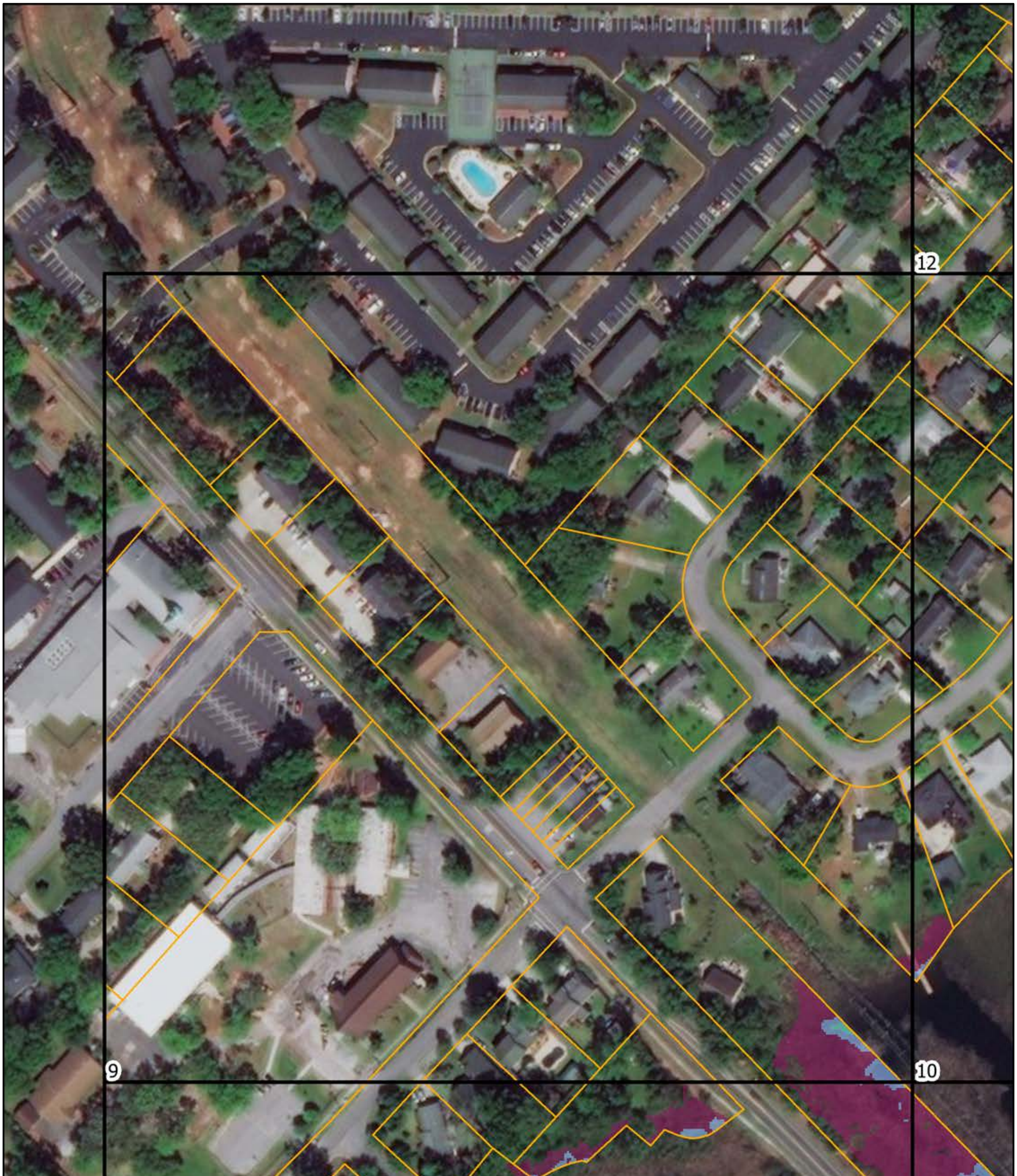
N S E W

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.83

≤ 4.26

≤ 5.67

≤ 7.09

≤ 8.51

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.83

≤ 4.26

≤ 5.67

≤ 7.09

≤ 8.51

N S W E

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.83

≤ 4.26

≤ 5.67

≤ 7.09

≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.83

≤ 4.26

≤ 5.67

≤ 7.09

≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSNT 25YR NGC

Turkey Creek Hanahan PAS Study

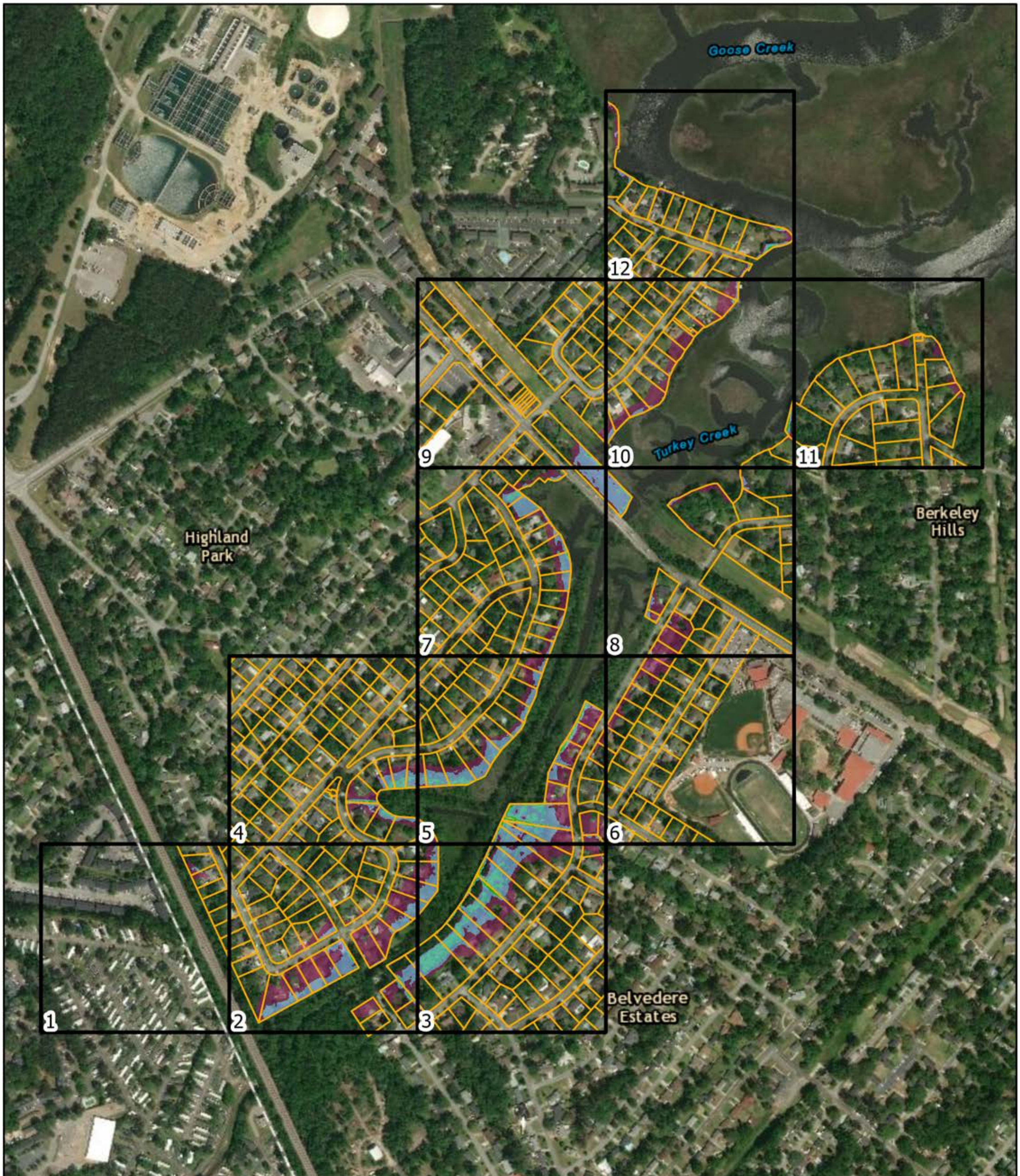
Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Modeled Scenario:
RAINY DSKT 25YR NGC



Legend

- Grid
- Parcels

N
W E
S

0 250 500 1,000
US Feet

Model Scenario: RAINY DSKT 25YR NGC

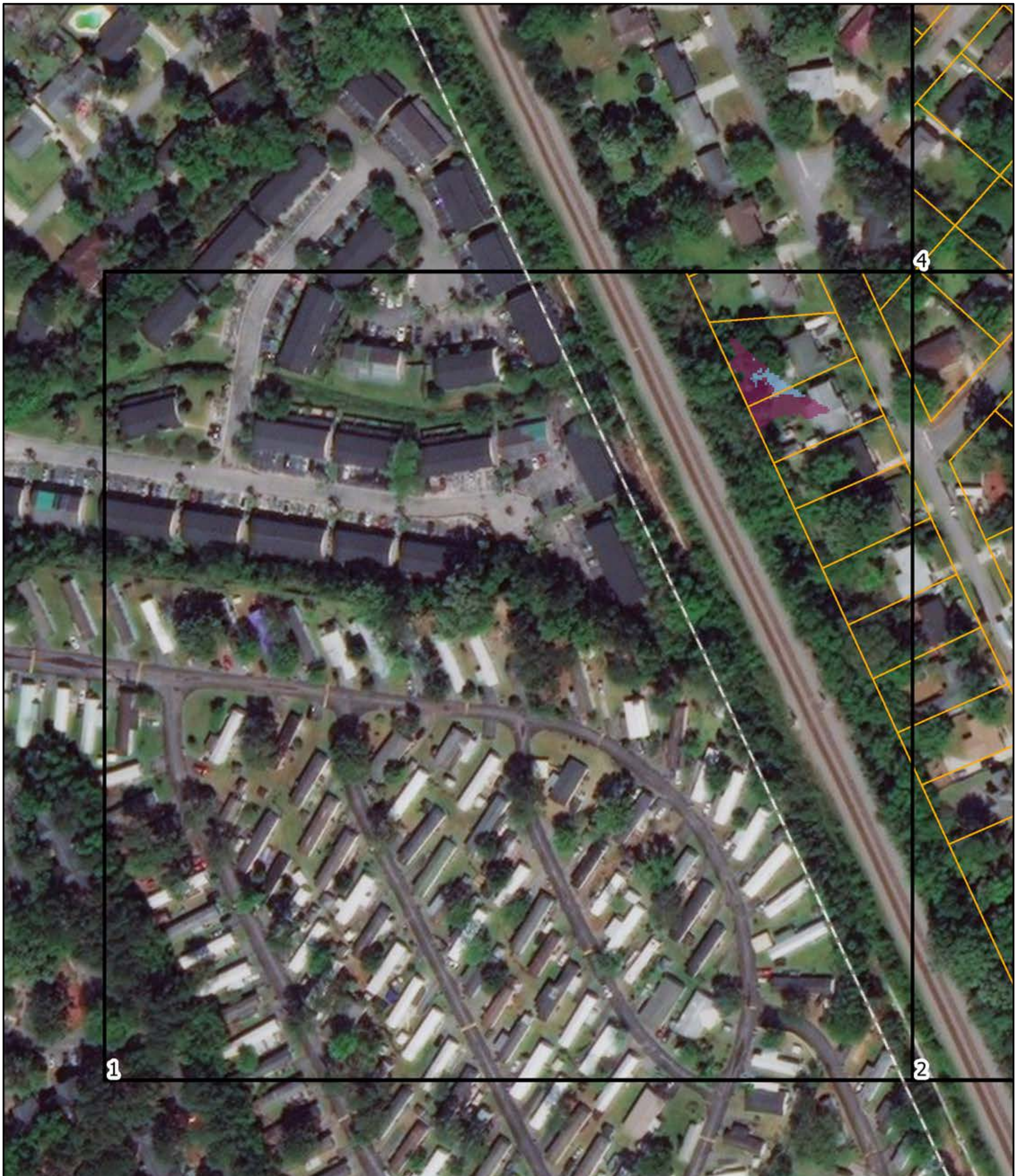
Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:8,605

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

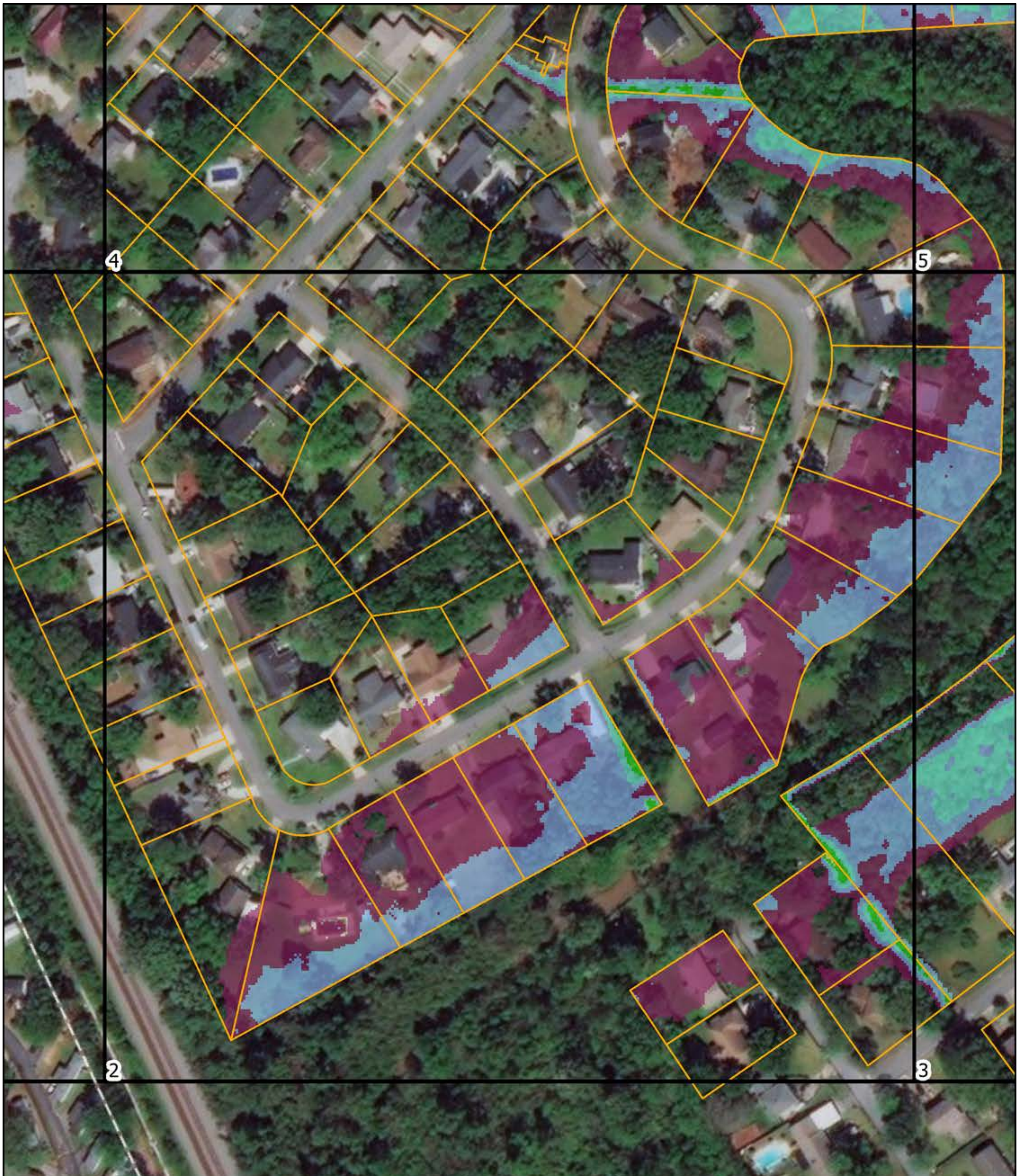
N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl GCS: GCS North American 1983 Datum: North American 1983	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

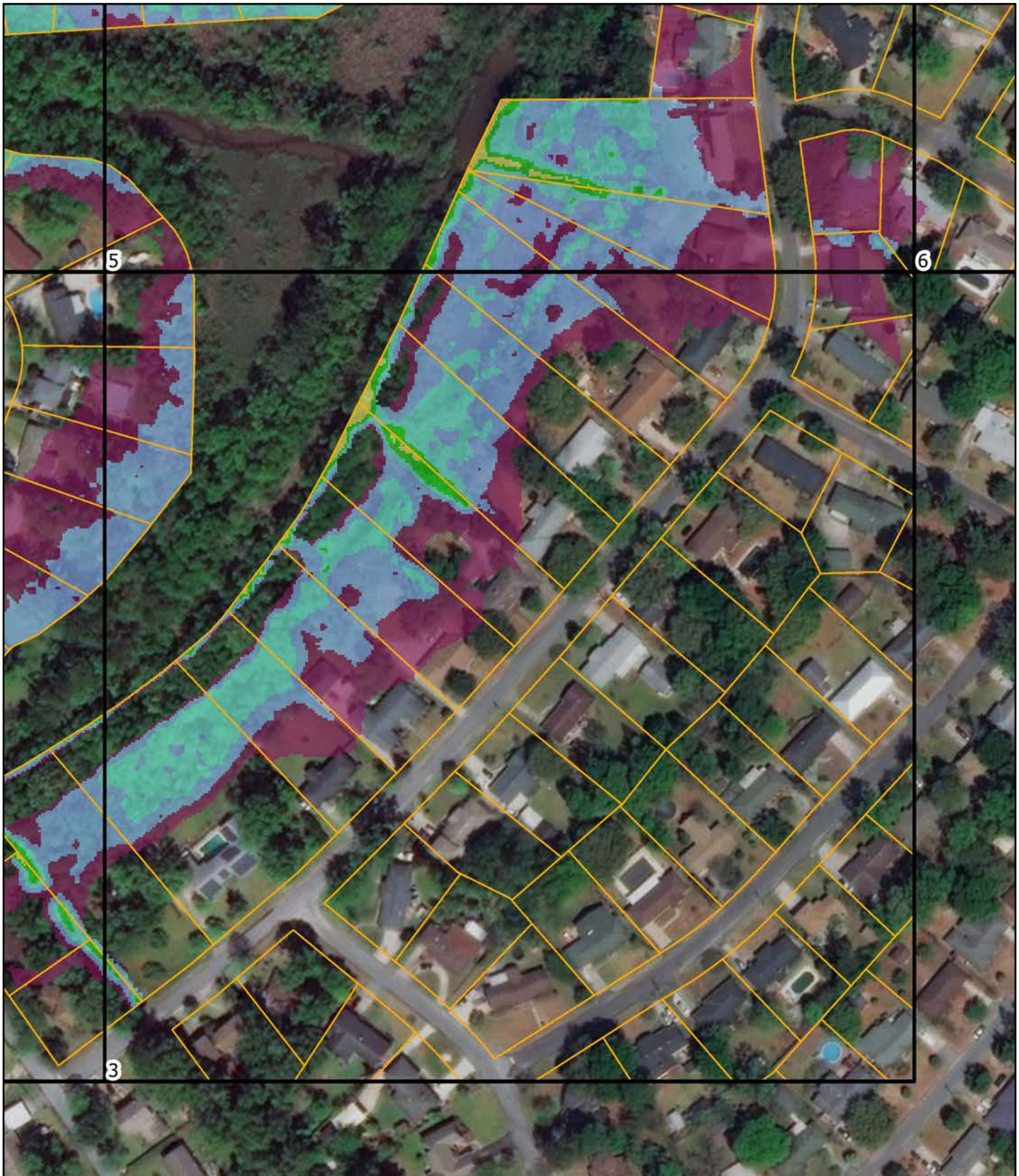
N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl GCS: GCS North American 1983 Datum: North American 1983	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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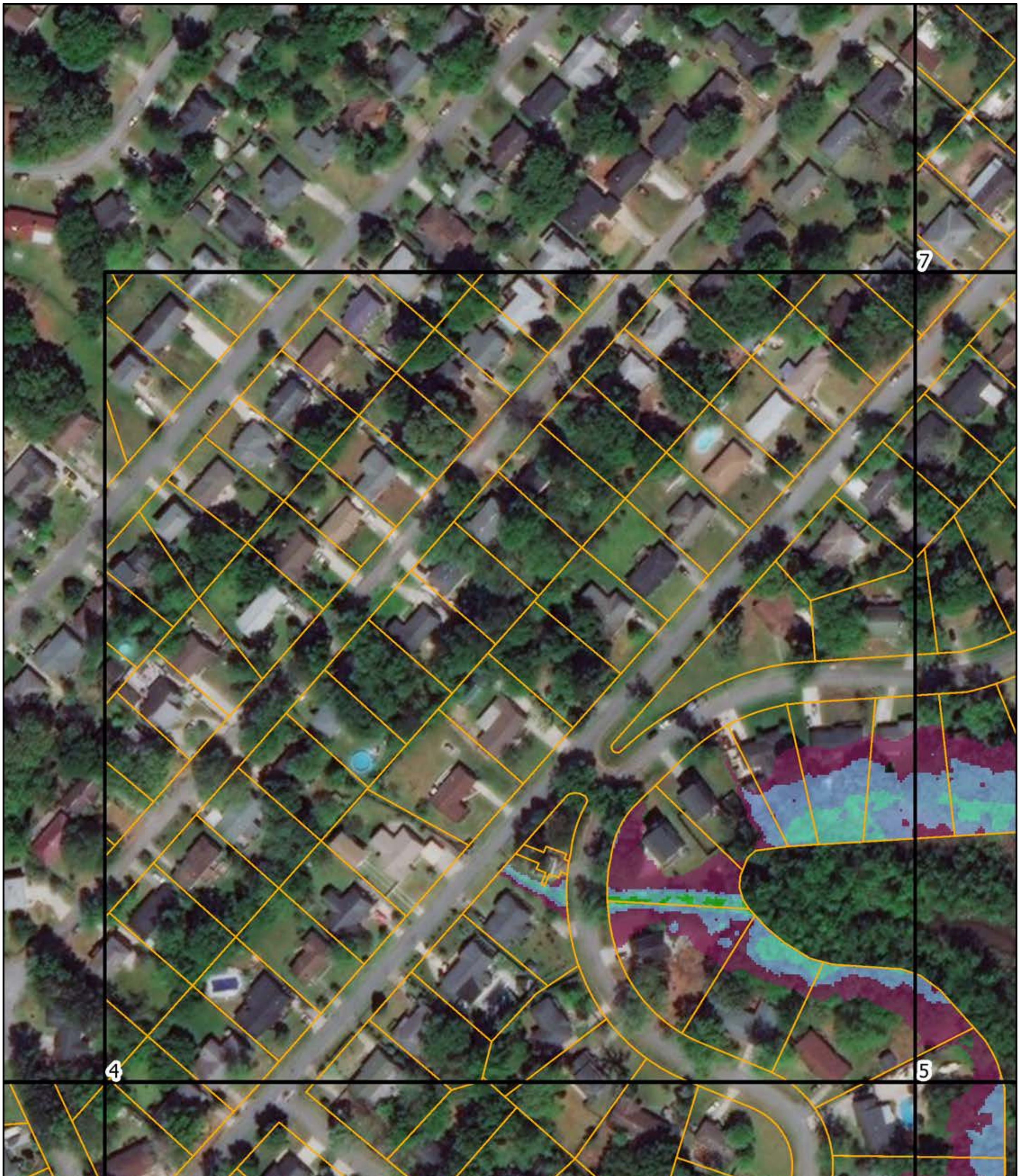
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200 US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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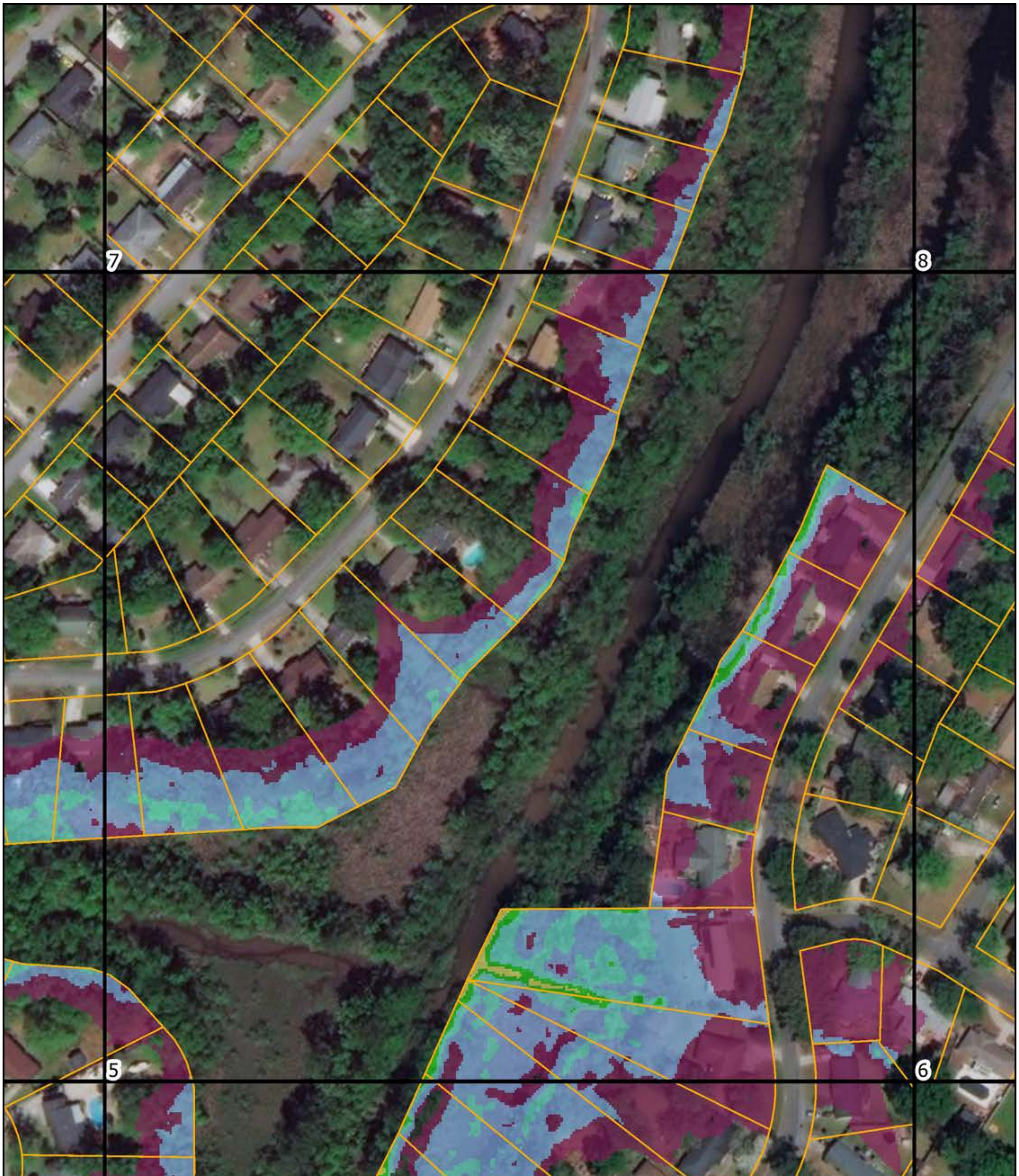
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

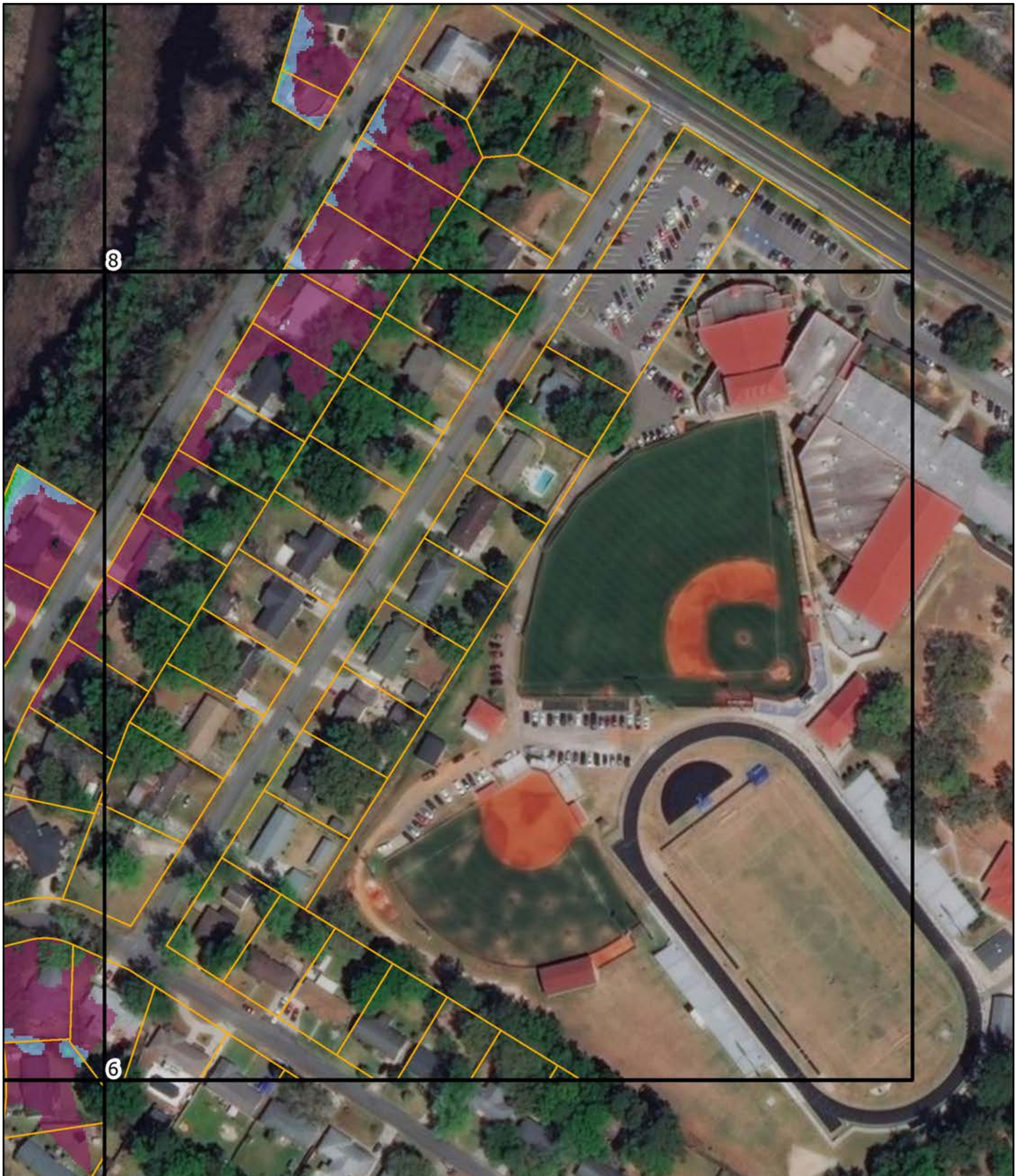
N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl GCS: GCS North American 1983 Datum: North American 1983	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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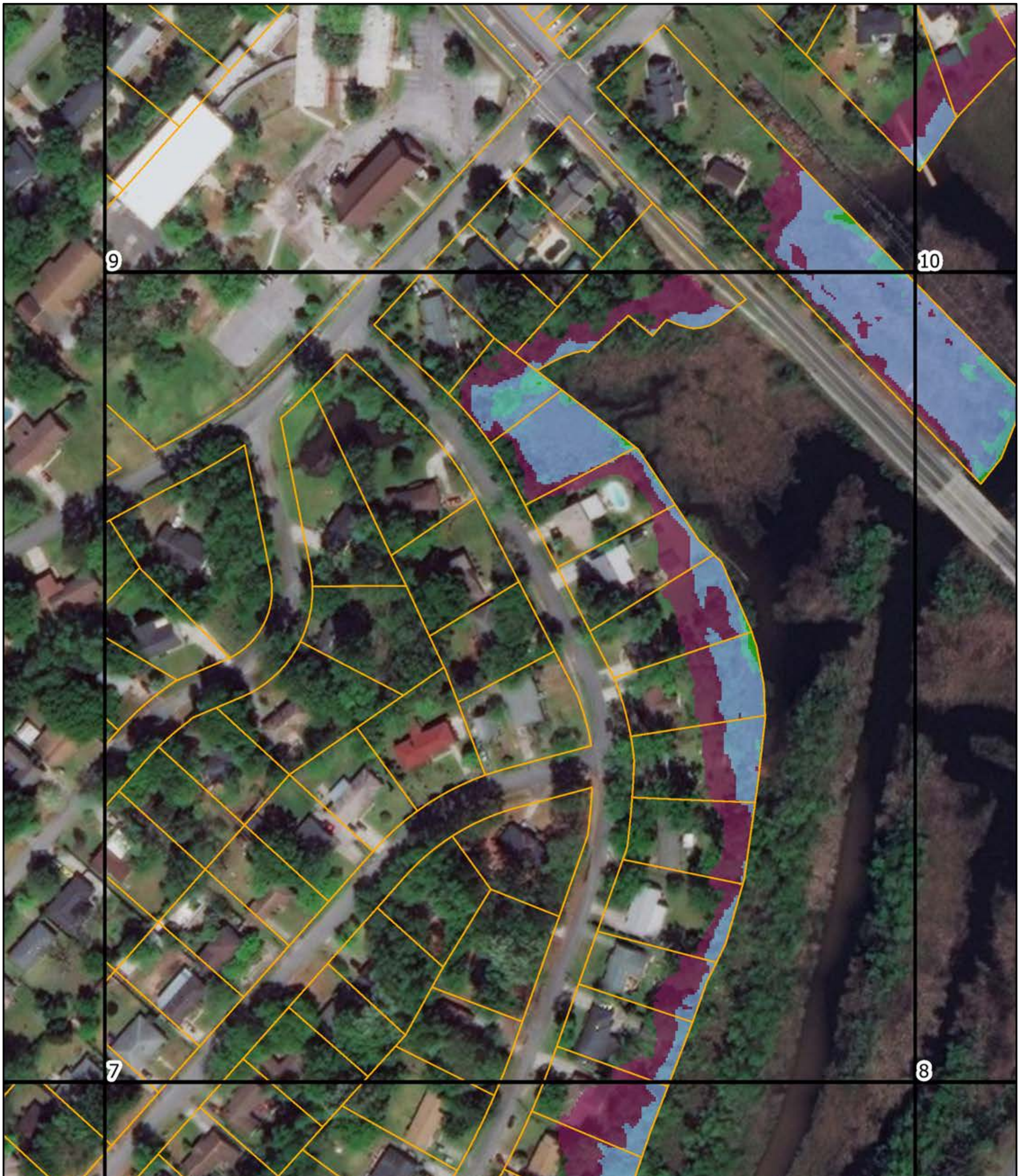
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

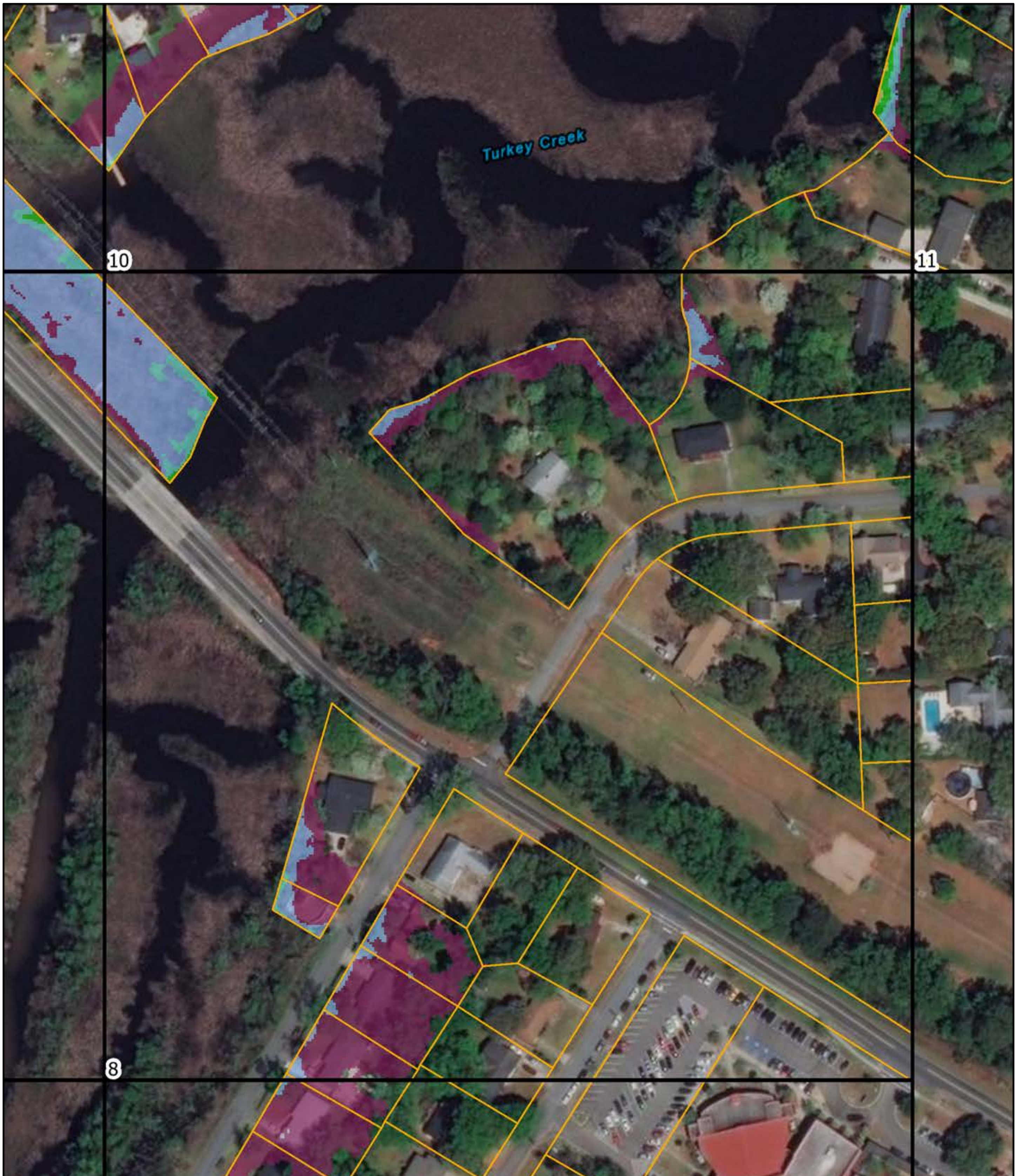
N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl GCS: GCS North American 1983 Datum: North American 1983	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51

N
W
E
S

0 50 100 200

US Feet

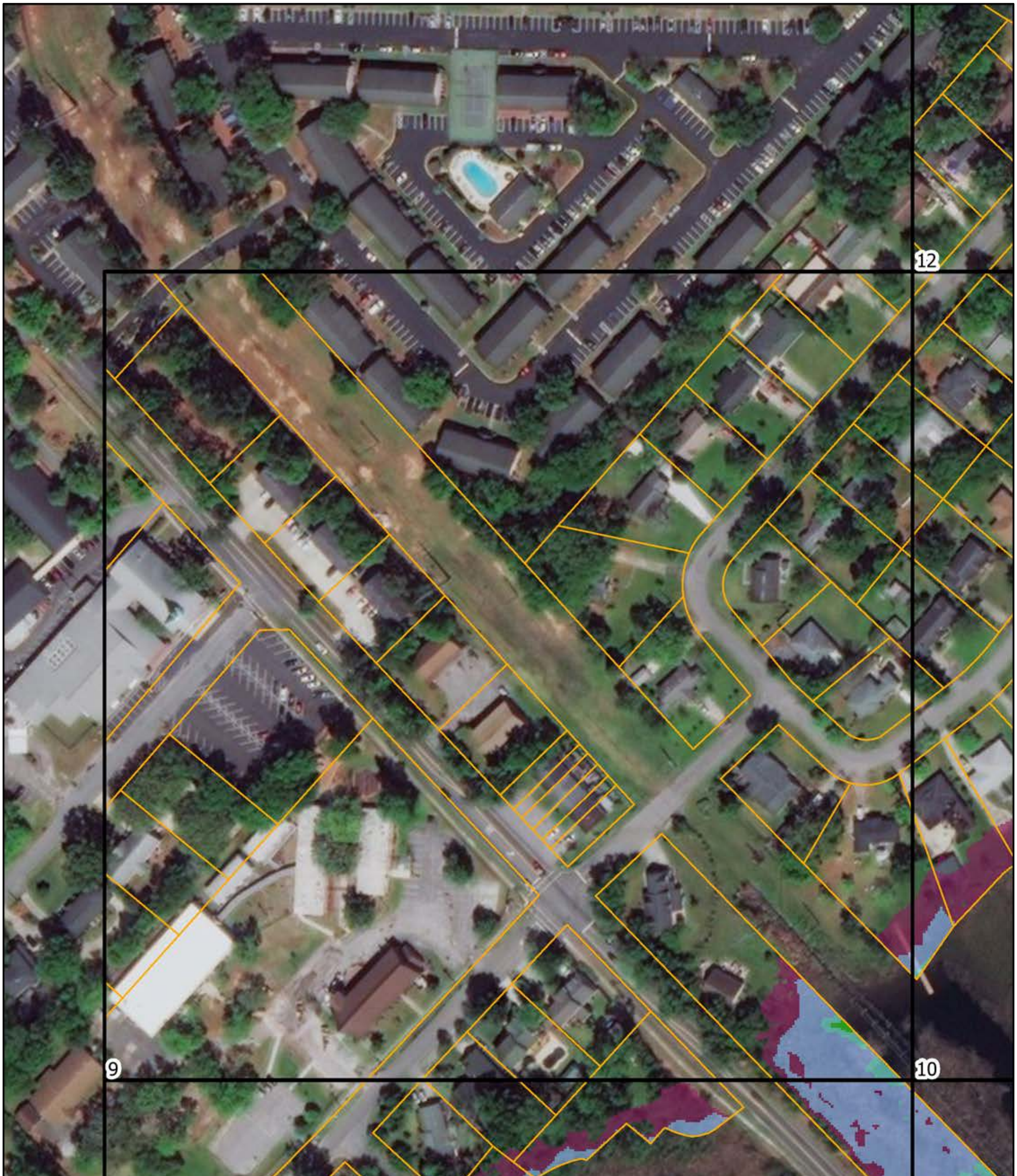
Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

- Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl GCS: GCS North American 1983 Datum: North American 1983	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤ 1.42

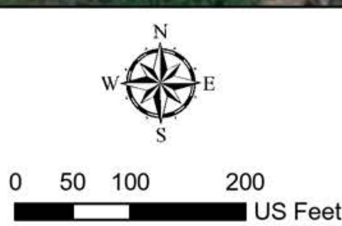
≤ 2.84

≤ 4.26

≤ 5.68

≤ 7.09

≤ 8.51



Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤ 1.42
- ≤ 2.84
- ≤ 4.26
- ≤ 5.68
- ≤ 7.09
- ≤ 8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DSKT 25YR NGC

Turkey Creek Hanahan PAS Study

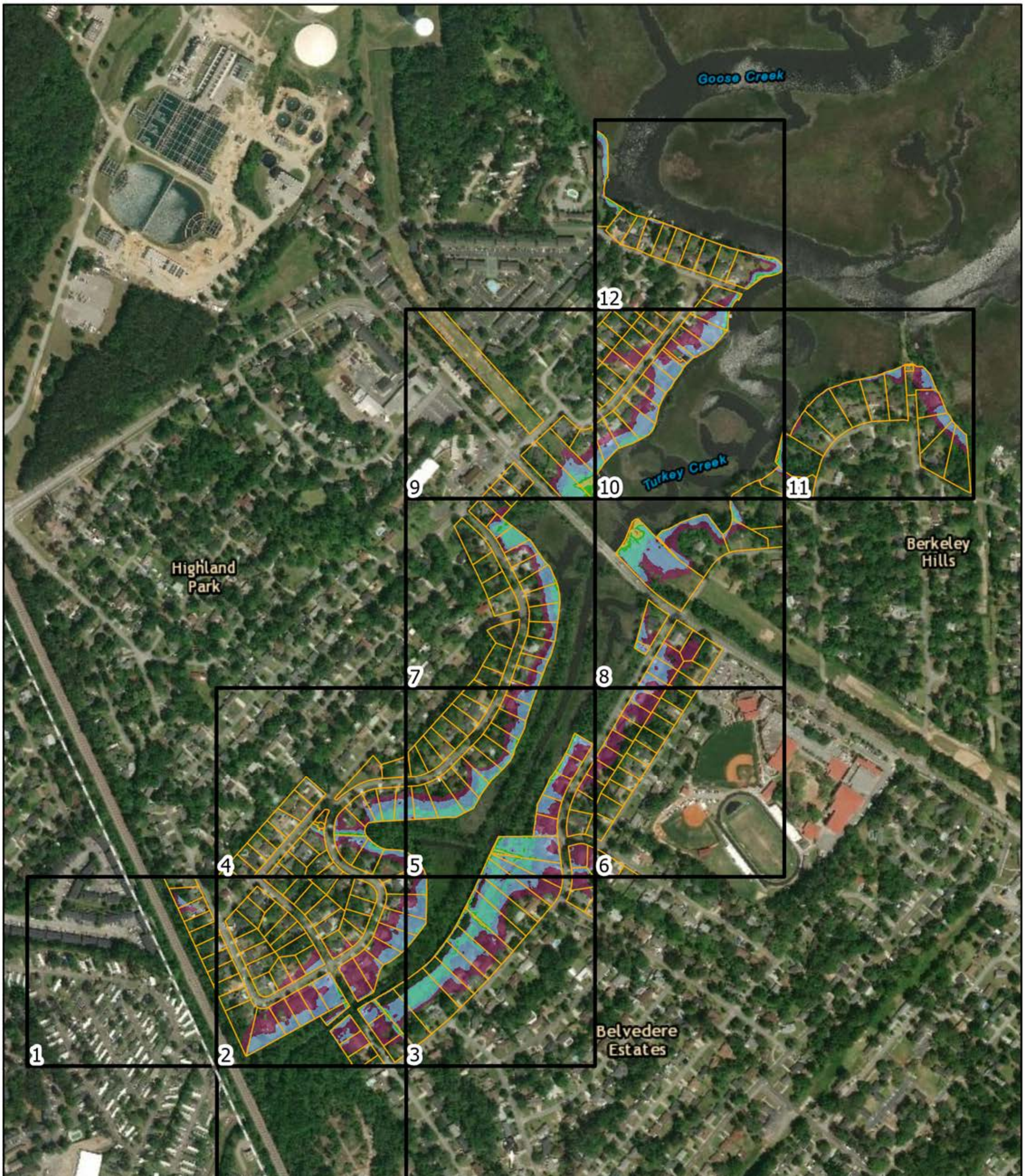
Created: December, 2019

Spatial Reference
Name: NAD 1983 StatePlane South Carolina FIPS 3900 Feet Intl
GCS: GCS North American 1983
Datum: North American 1983

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Modeled Scenario:
RAINY DS SURGE 50YR NGC



Legend

- Grid
- Parcels

N
W E
S

0 250 500 1,000 US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

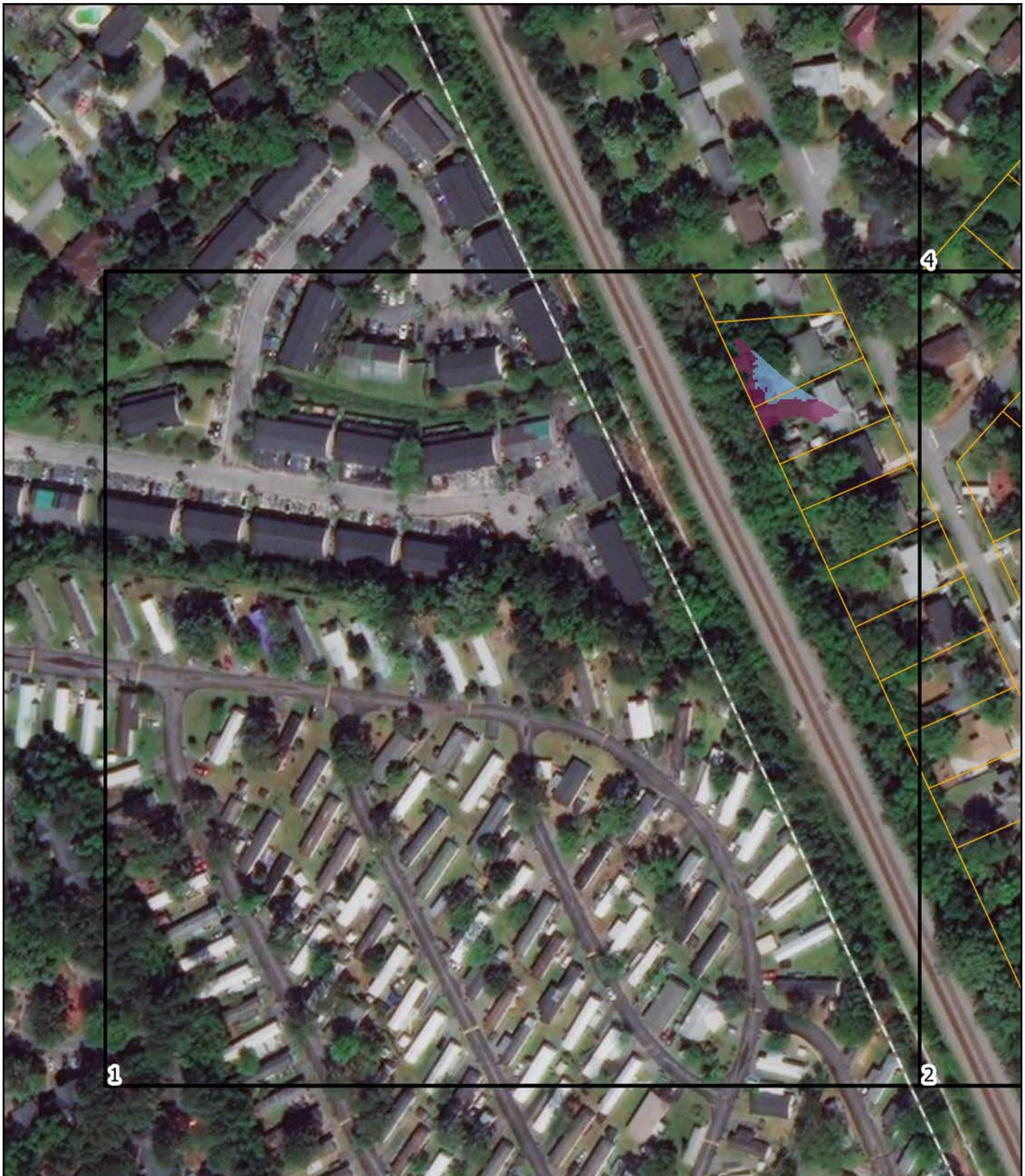
Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:8,605

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤1.42
≤2.84
≤4.26
≤5.68
≤7.09
≤8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤1.42
- ≤2.84
- ≤4.26
- ≤5.68
- ≤7.09
- ≤8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
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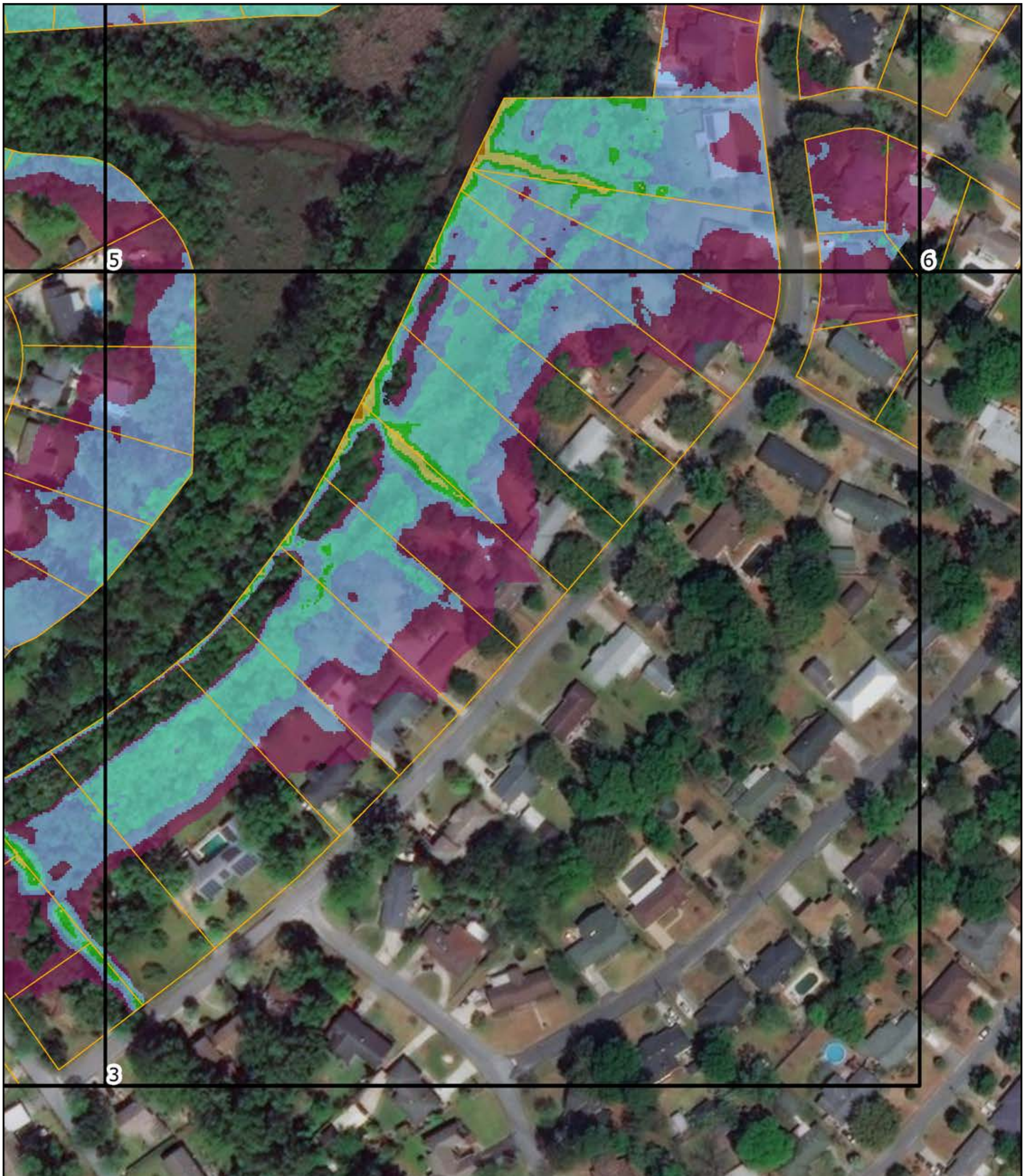

Legend

Parcels

Water Depth (ft) Above Ground

- ≤1.42
- ≤2.84
- ≤4.26
- ≤5.68
- ≤7.09
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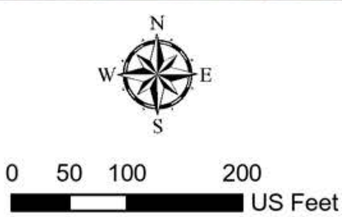
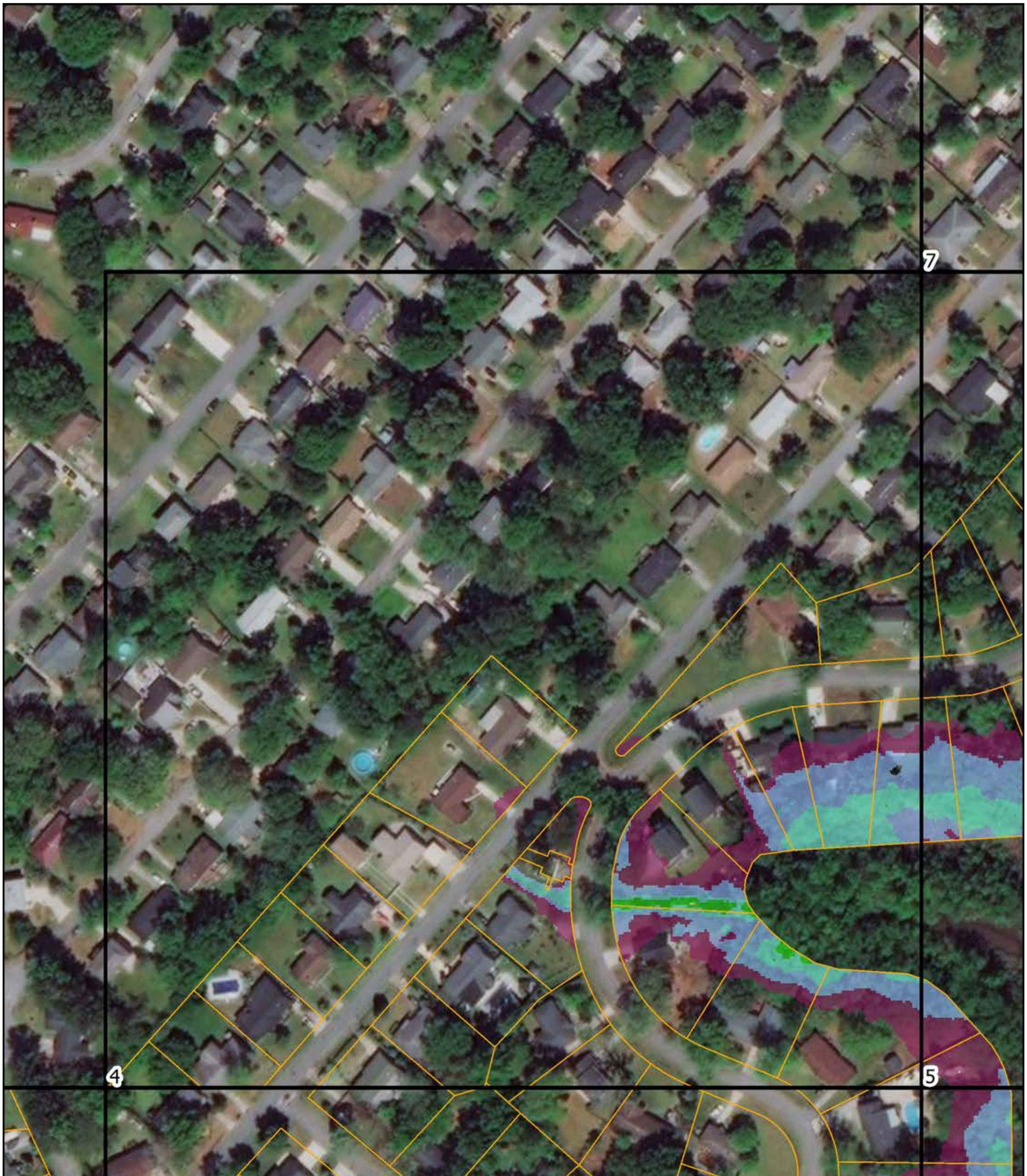


Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
Spatial Reference Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl GCS: GCS NAD 1983 NSRS2007 Datum: NAD 1983 NSRS2007	Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤1.42

≤2.84

≤4.26

≤5.68

≤7.09

≤8.51

N
W
E
S

0 50 100 200
US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤1.42
- ≤2.84
- ≤4.26
- ≤5.68
- ≤7.09
- ≤8.51

N
W E
S

0 50 100 200 US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

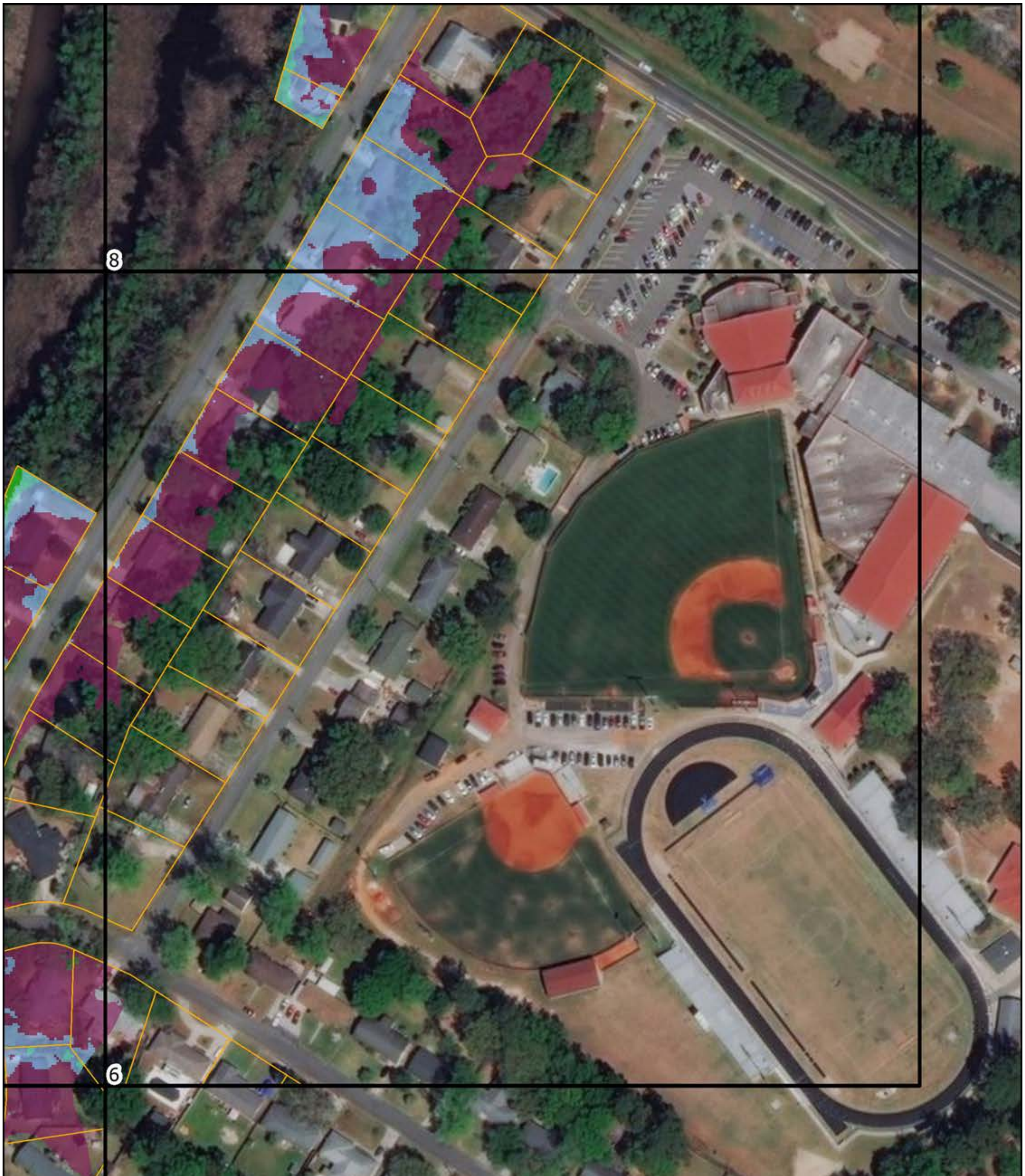
Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

≤1.42

≤2.84

≤4.26

≤5.68

≤7.09

≤8.51

N
W
E
S

0 50 100 200

US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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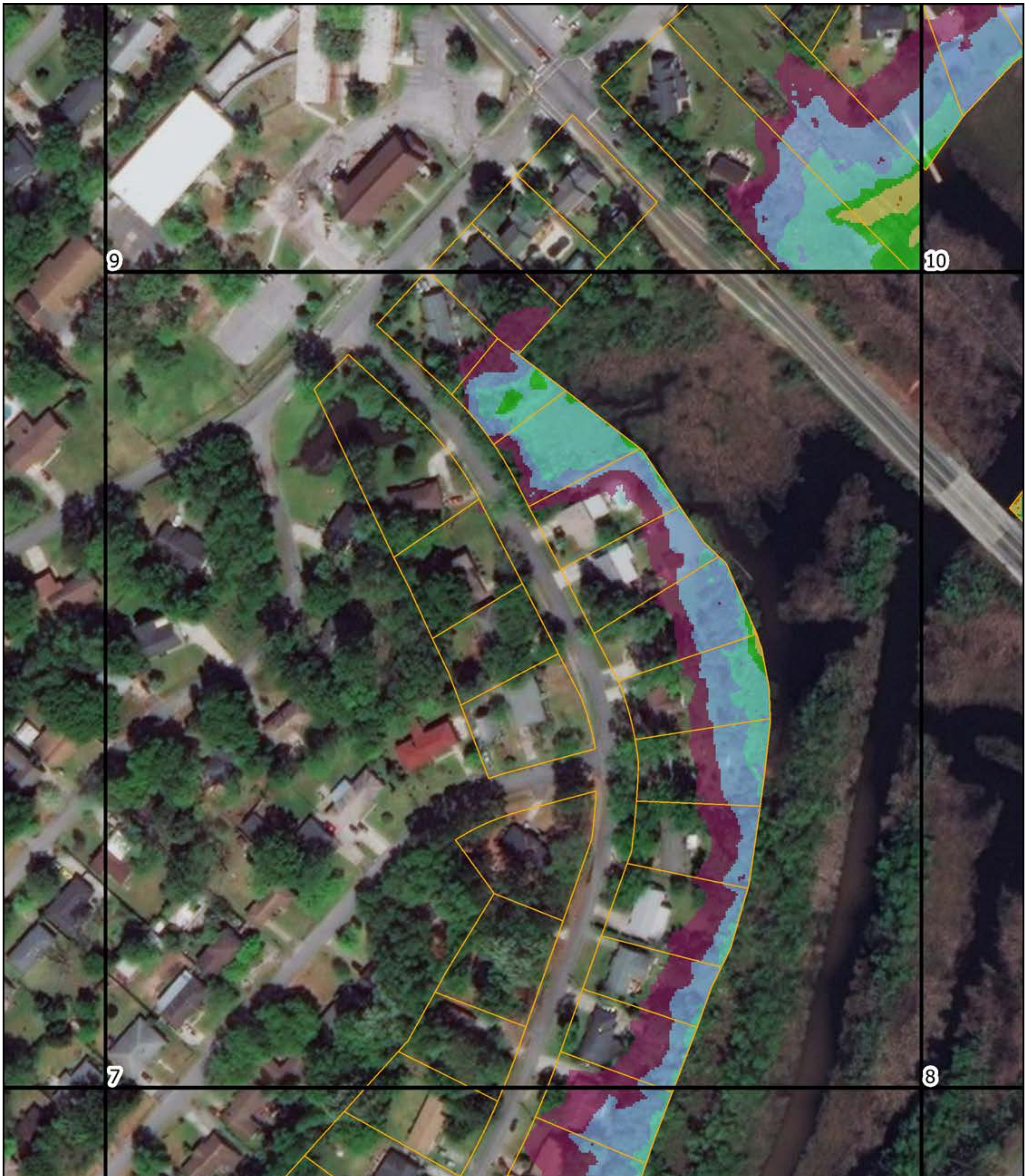
Charleston, SC 29403



Legend

Parcels

Water Depth (ft) Above Ground

- ≤1.42
- ≤2.84
- ≤4.26
- ≤5.68
- ≤7.09
- ≤8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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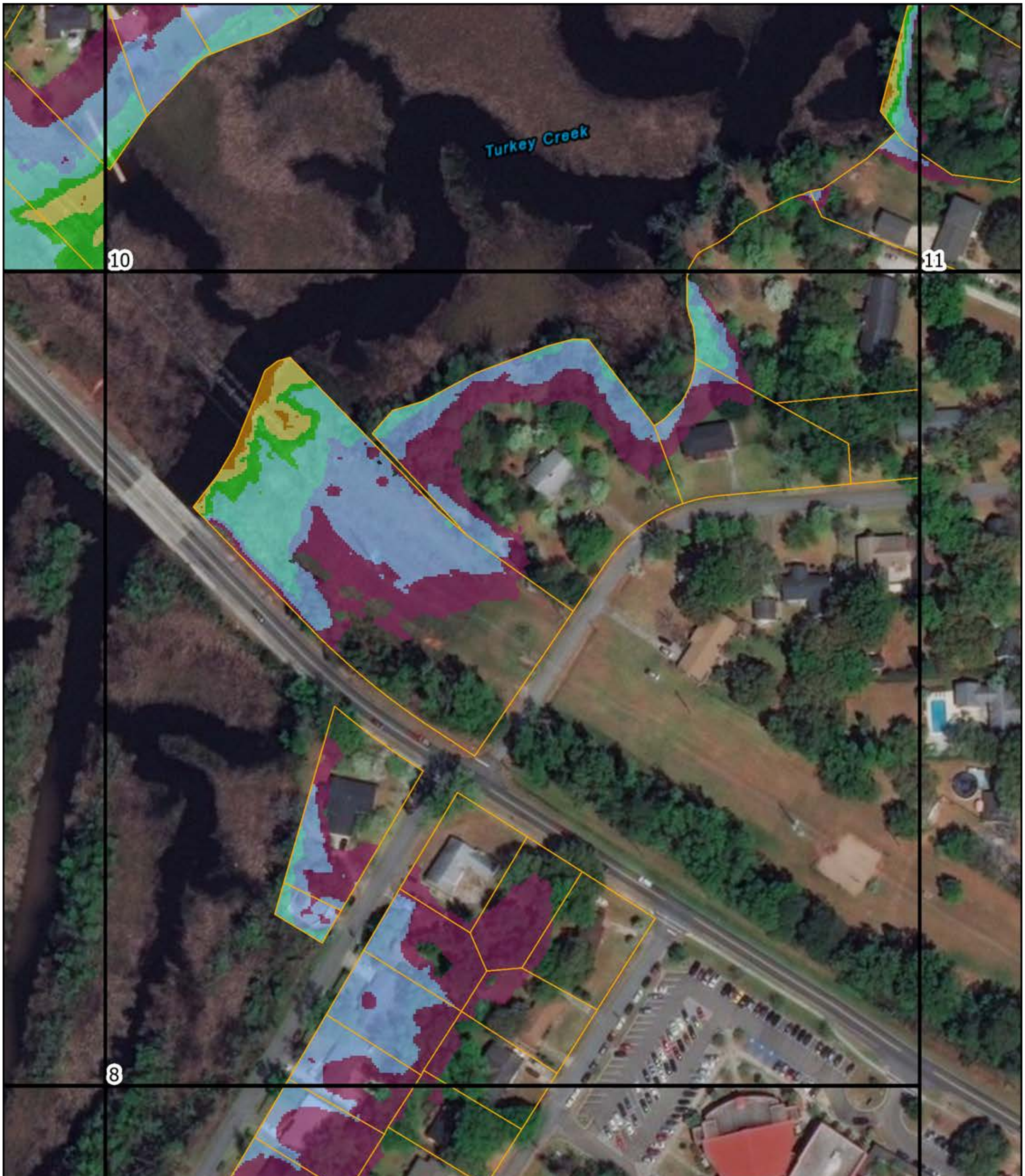

Legend

Parcels

Water Depth (ft) Above Ground

≤1.42

≤2.84

≤4.26

≤5.68

≤7.09

≤8.51

0 50 100 200

US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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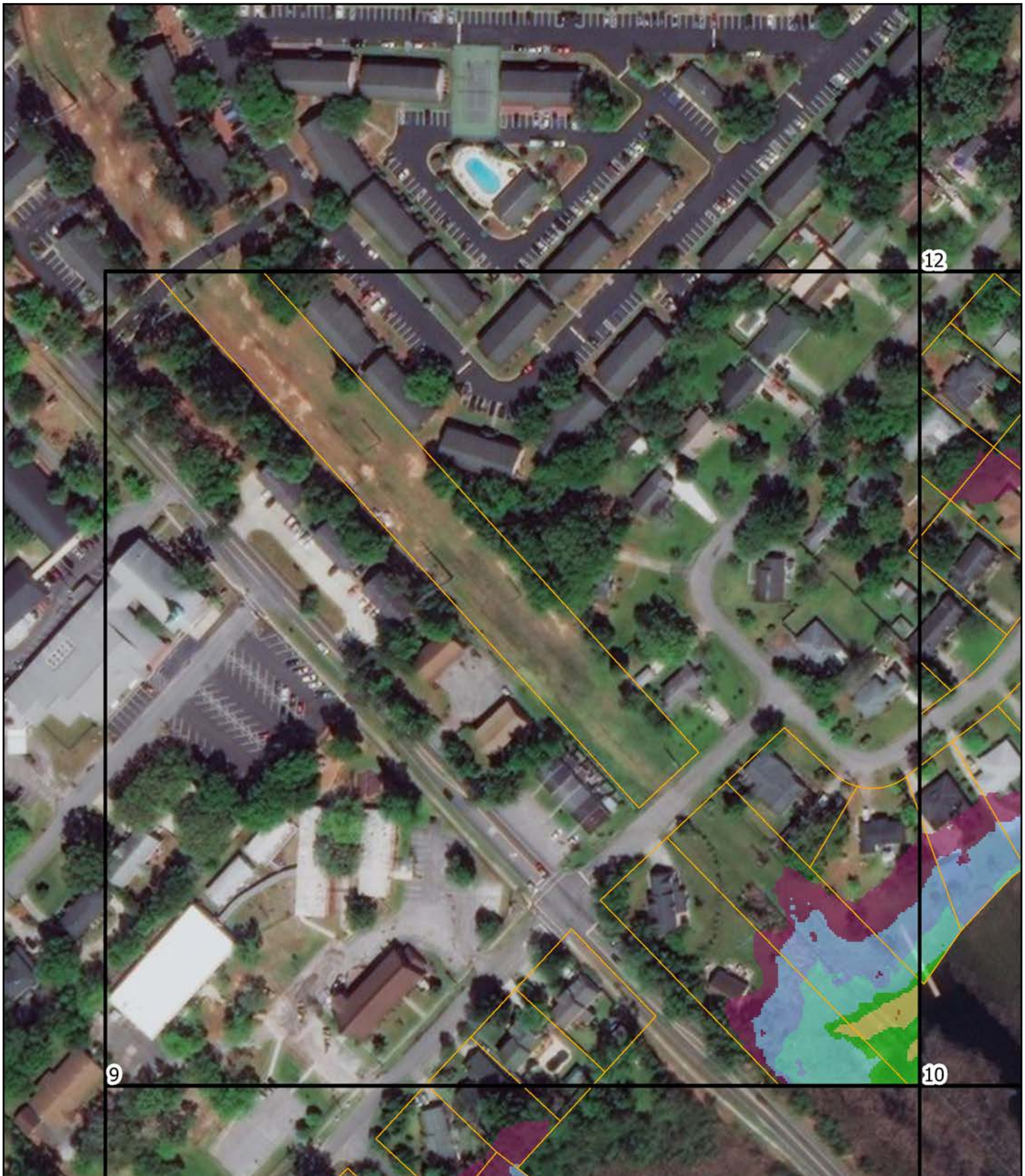

Legend

Parcels

Water Depth (ft) Above Ground

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≤2.84

≤4.26

≤5.68

≤7.09

≤8.51

N W E S

0 50 100 200 US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
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Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

≤1.42

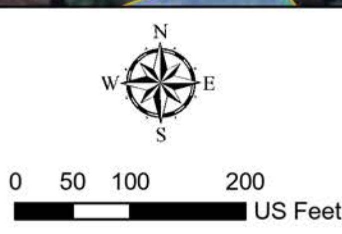
≤2.84

≤4.26

≤5.68

≤7.09

≤8.51



Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study

Created: December, 2019

Spatial Reference
Name: NAD 1983 NSRS2007 StatePlane South Carolina FIPS 3900 Ft Intl
GCS: GCS NAD 1983 NSRS2007
Datum: NAD 1983 NSRS2007

Scale: 1:2,000

US Army Corps of Engineers
Charleston District
69-A Hagood Ave
Charleston, SC 29403

Legend

Parcels

Water Depth (ft) Above Ground

- ≤1.42
- ≤2.84
- ≤4.26
- ≤5.68
- ≤7.09
- ≤8.51

N
W E
S

0 50 100 200
US Feet

Model Scenario: RAINY DS SURGE 50YR NGC

Turkey Creek Hanahan PAS Study	Created: December, 2019
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