US Virgin Islands Advisory Data and Products

Post-Hurricanes Irma and Maria

Prepared by:

STARR II Strategic Alliance for Risk Reduction

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1.0 Project Summary

Hurricane Irma passed to the north of St. Thomas and St. John on September 6, 2017, as a Category 5 hurricane, with high winds impacting the Islands (Presidential Disaster Declaration FEMA-4335-DR). Hurricane Maria passed just to the south of St. Croix also as a Category 5 hurricane on September 20, 2017 (Presidential Disaster Declaration FEMA-4340-DR). Both hurricanes caused extensive damage across the U.S. Virgin Islands (USVI). Hurricane Irma caused minor coastal flooding; however coastal erosion, riverine flooding, and wind damages were significant in St. Thomas and St. John. Hurricane Maria also caused minor coastal flooding; however coastal erosion and wind damages were significant in St. Croix. In addition, there were areas within the current effective 1-percent and 0.2-percent annual chance floodplains that did not receive significant storm surge, but experienced significant wind damage. In the aftermath of these disasters, updated flood risk information is vital in order to inform rebuilding efforts across the USVI.

Accordingly, this project provides advisory flood hazard and coastal erosion data and associated products for USVI in an effort to increase resilience and reduce vulnerabilities within the islands. Data and products include:

1. Riverine Advisory Data
    - Hydrologic analyses
    - Hydraulic analyses
2. Coastal Advisory Data
    - Storm induced coastal erosion
3. Mapping Products
    - 1-percent and 0.2-percent annual chance floodplain mapping
    - Water surface elevation grids and depth grids
4. Supporting Advisory Products
    - Map change products
    - Critical facility flood risk summaries

This report documents the methodologies, assumptions, and data sources used to develop the advisory flood hazard data and associated products.

2.0 Data Acquisition

Table 2-1 summarizes the data collected for development of the advisory flood information products and their origins.

Table 2-1: Data Sources and Notes

Data	Source/Notes
Topography Data	• National Oceanic and Atmospheric Administration (NOAA) 2013 Light Detection and Ranging (LiDAR) provided the base topographic data source for the project. This dataset was utilized for riverine modeling and erosion assessments. • 30 meter Digital Elevation Models (DEM) from USGS National Elevation Dataset (NED) were used only for hydrologic analyses.
Streamlines	USGS National Hydrographic Dataset (NHD) streamlines were utilized for developing hydrologic model stream network. The dataset also included Hydrologic Unit Code – 10 (HUC-10) boundaries, used for data management and work distribution.
Effective FIRM Data	Effective flood hazard data for the study area was obtained from published FIRM databases and the National Flood Hazard Layer (NFHL).
Coordinated Needs Management System	FEMA's Coordinated Needs Management System (CNMS) was utilized to identify and validate the scope for riverine advisory data development.
Pre-storm Imagery	Storm erosion analyses utilized aerial imagery from NOAA and Google Earth.
Post-storm Imagery	Storm erosion analyses utilized post-storm aerial imagery from Vexcel and NOAA.

3.0 Advisory Data

3.1 Riverine Advisory Data Development

Final riverine advisory data development deliverables include:

1. A GIS line shapefile representing the 1-percent and 0.2-percent annual chance riverine floodplain boundaries delineated with the NOAA 2013 LiDAR, as well as GIS polygons covering the 1-percent and 0.2-percent annual chance floodplain.

2. 1- and 0.2-percent annual chance water surface elevation grids.

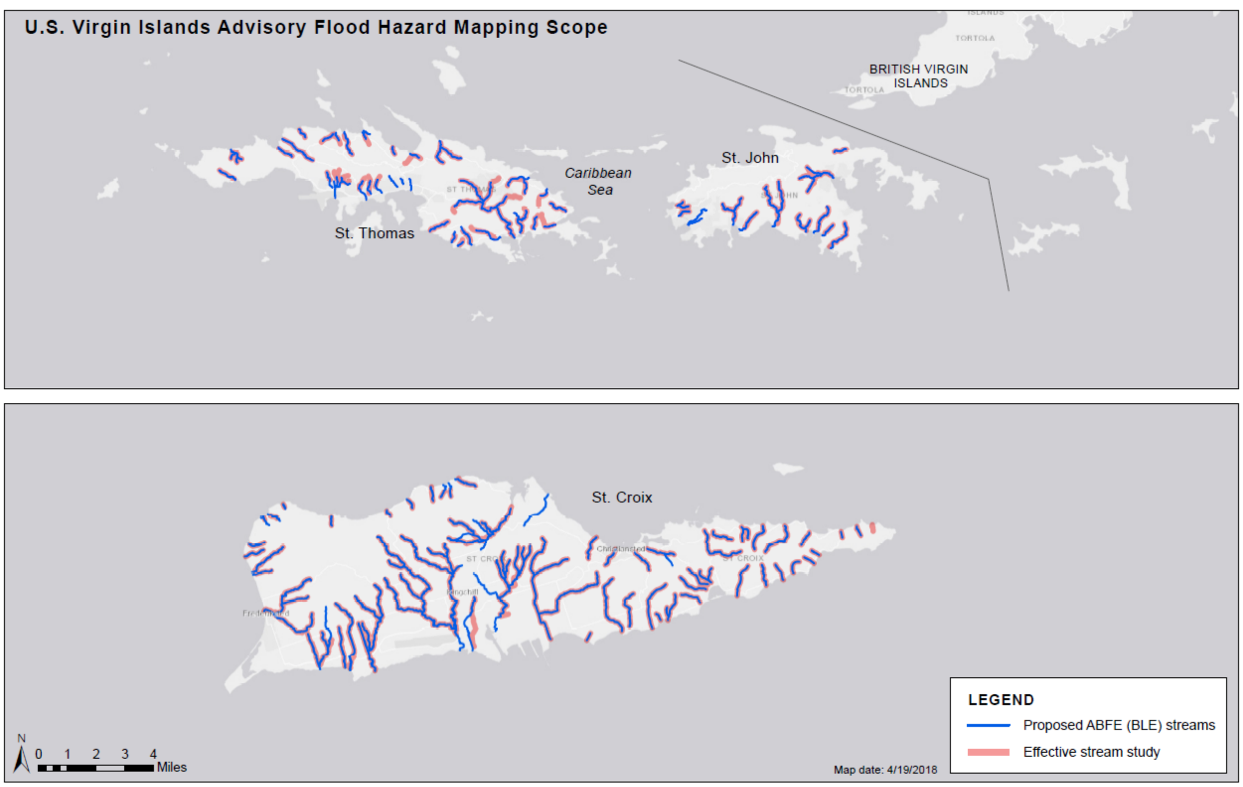
3. A GIS line-shapefile of Base Level Engineering (BLE) analysis cross sections and stream centerlines; these include water surface elevations for all recurrence intervals analyzed.

4. Advisory flood hazard information for existing CNMS stream mileage, as well as an additional 25 miles of unmapped streams.

5. All network hydrologic and hydraulic models, including BLE inputs and outputs.

Figure 1 shows the stream reaches (161 miles) where advisory data was developed.

Figure 1: HUC-10 Watersheds and Stream Reaches



These products are intended for digital delivery and dissemination for desktop GIS and/or Web-GIS platforms. The following sections provide information on data sources and limitations, productions procedures, and guidance on usability for each of the riverine advisory data deliverables.

3.1.1 Terrain Processing

STARR II developed a custom tool to mosaic the 2013 NOAA LiDAR and NED DEMs, as needed, to fill any gaps that may occur in the processing of the terrain mosaic. The tool uses bilinear resampling to determine cell value and uses the mosaic process to make sure that all gaps were properly addressed. For well registered data tiles (i.e., same cell size, as well as same x/y registration of cell corners), the application mosaics the dataset first with neighboring tiles before resampling. The data developed by this custom tool was utilized in the riverine hydrologic and hydraulic analyses only.

3.1.2 Hydrologic Analyses

There are no existing USGS regression equations readily available for the US Virgin Islands (St. Thomas, St. John, and St. Croix). The bullets below summarize the available flow data.

- Hydrologic analysis in the effective Flood Insurance Study (FIS) dated April 2007
  - The most recent hydrologic analysis was completed in 1993.
  - Rainfall/runoff methods used to compute flows for the Frenchtown Basin on St. Thomas and eight guts on St. Croix.
- USGS Stream Gages are listed in **Table 3-1**
  - Five gages have flow records greater than 10 years (three on St. Thomas, one on St. John, and one on St. Croix).
  - There are no streamflow measurements available for the 2017 hurricane events.
- Additional stream flow data for the US Virgin Islands was not available.
- Due to non-availability of regression equations for USVI, Puerto Rico regression equations were applied to test their applicability. Peak flows computed using the equations for Puerto Rico were significantly lower than the FIS and gage flows. Therefore, the Puerto Rico equations are not applicable to the US Virgin Islands and were not used.

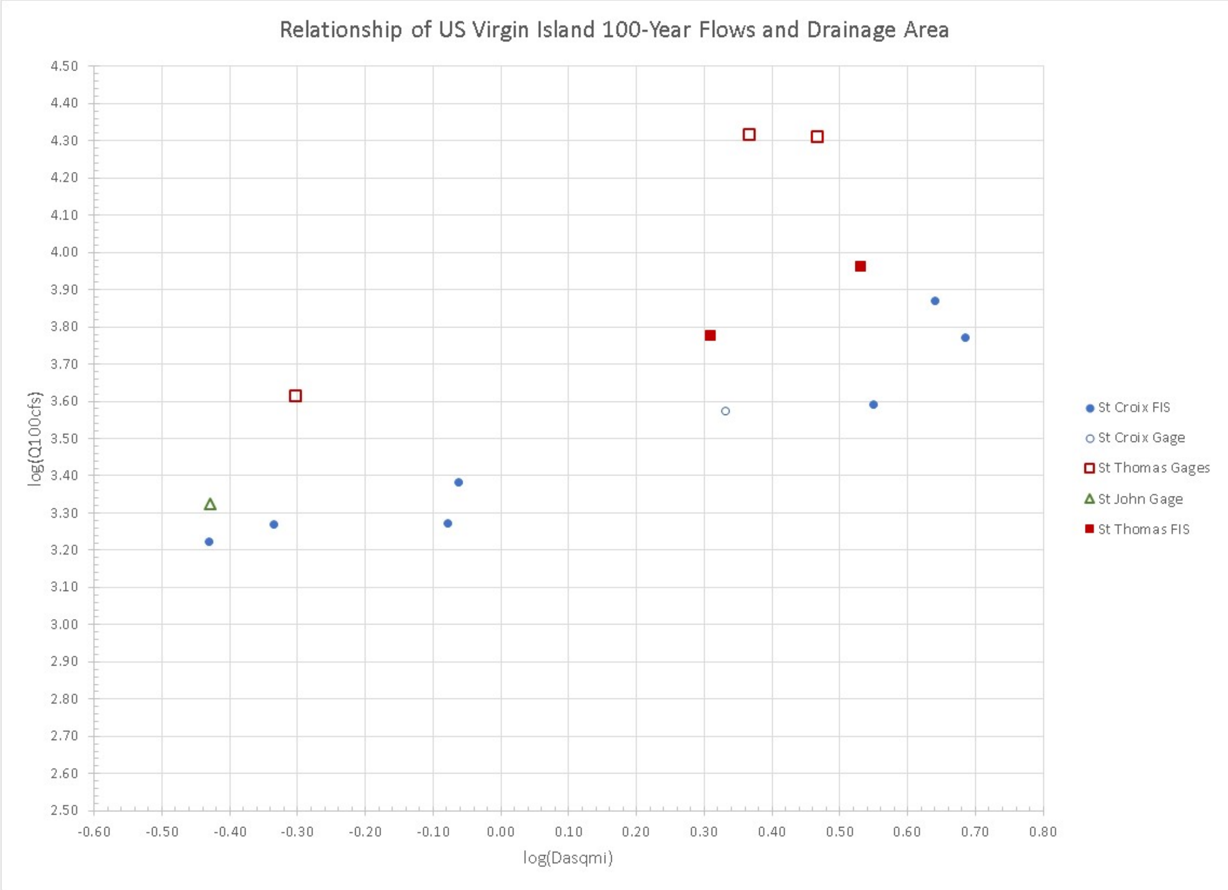
Table 3-1: USGS Gage Data Details

USGS Gage Number	USGS Gage Location	Start Date	End Date	# of Years of Record
50252000	Bonne Resolution Gut at Bonne Resolution St. Thomas USVI	8/28/1963	10/10/2005	28
50274000	Turpentine Run at Mt. Zion, St. Thomas USVI	4/28/1993	10/4/2005	14
50276000	Turpentine Run at Mariendal, St. Thomas USVI	8/28/1963	1/5/1992	17
50292600	Lameshur Bay Gut at Lameshur Bay, St. John USVI	11/27/1992	11/27/1992	1
50294000	Fish Bay Gut at Fish Bay, St. John USVI	5/24/1992	11/26/1993	3
50295000	Guinea Gut at Bethany, St. John USVI	8/27/1963	10/4/2005	27
50332000	River Gut at River, St. Croix USVI	5/24/1992	5/27/1993	2
50333500	River Gut NR Golden Grove, St. Croix USVI	10/26/1990	5/27/1993	3
50345000	Jolly Hill Gut at Jolly Hill, St. Croix USVI	1/4/1963	11/24/2005	29

PeakFQ Bulletin 17B return period analyses were computed peak flows for the 10-percent, 4-percent, 2-percent, 1-percent, and 0.2-percent annual chance events. **Figure 2** shows the relationship between the logarithms of the 1-percent annual chance flows and the drainage areas for the FIS locations and gages on all three islands. The bullets below list observations and conclusions:

- The flow and drainage area relationships are different on St. Thomas and St. Croix.
- Because St. John is closer to St. Thomas, the hydrologic analyses are combined for both islands.
- The flows listed in the effective FIS on St. Thomas are approximately half of the gage flows. The gages have a long period of record justifying the gage analysis. Furthermore, the gage flows are more conservative. Therefore, only the gage flows, and not the St. Thomas FIS flows, are used for this hydrologic analysis.
- Because the Turpentine Run gage locations are close to each other and have successive period of records, PeakFQ input reflected a combined dataset to perform the frequency analysis of the gage flows.
- The gage and FIS flows on St. Croix have the same trend, so both datasets are used in this hydrologic analysis.

Figure 2: Relationship of USVI 1-Percent Annual Chance Flows and Drainage Area



There was a weak correlation between the flows and slope as well as flows and basin average annual precipitation. Therefore, the peak flows for this study have been derived from a flow and drainage area relationship.

For St. John and St. Thomas, a linear regression between the logarithms of the gage flows in cubic feet per second and drainage area in square miles was performed. **Figure 3** shows the graphical results for the 1-percent annual chance peak flows and **Table 3-2** shows the equation used for the 10-percent, 4-percent, 2-percent, 1-percent, and 0.2-percent annual chance events.

Figure 3: 1-Percent Annual Chance Peak Flow Analysis for St. Thomas and St. John

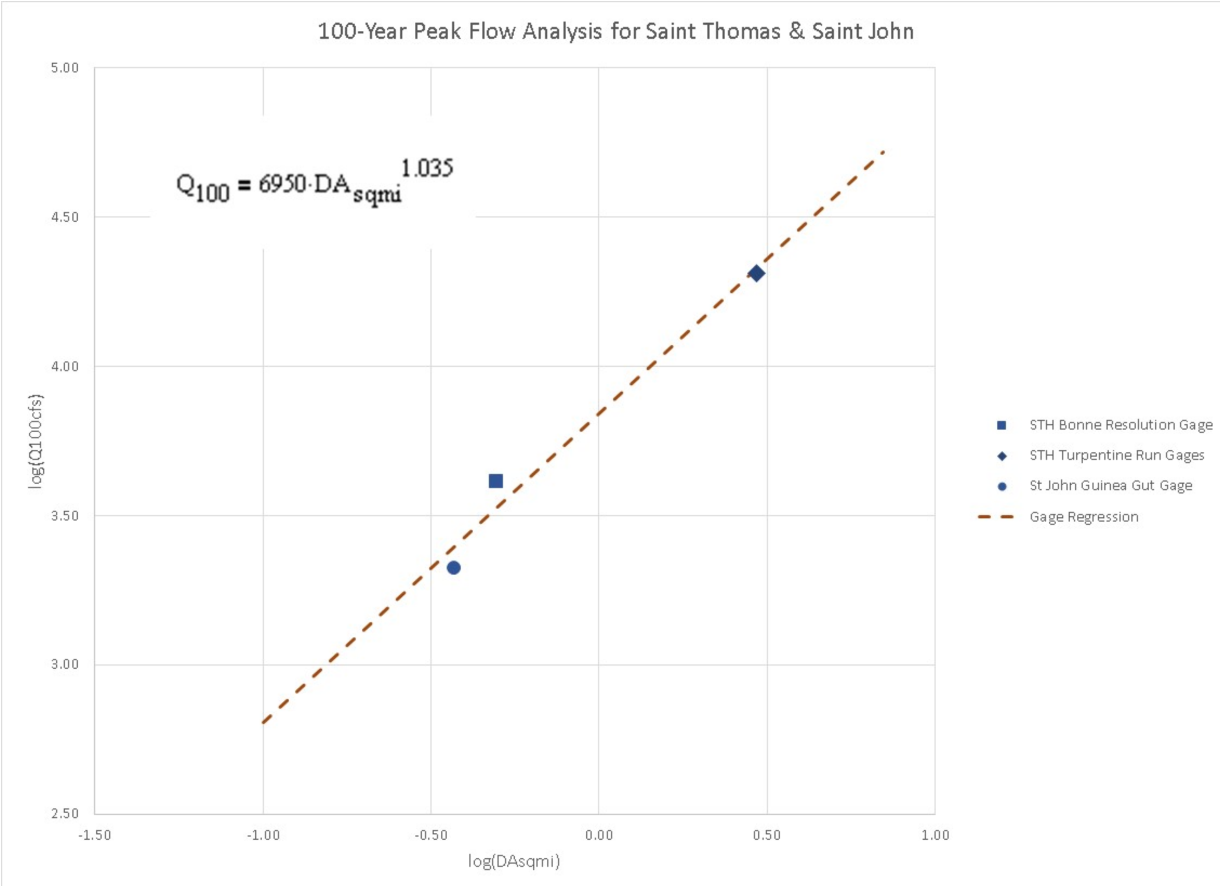


Table 3-2: Peak Flows (Q in cfs) and Drainage Area (DA in square miles) Relationships for St. Thomas and St. John.

Recurrence Interval	Equation	R^2	Standard Error (log units)
10-Percent Annual Chance	$Q = 1706 \cdot DA^{0.9713}$	0.921	0.195
4-Percent Annual Chance	$Q = 3214 \cdot DA^{0.9926}$	0.952	0.153
2-Percent Annual Chance	Q = 4831·DA1.013	0.966	0.131
1-Percent Annual Chance	$Q = 6950 \cdot DA^{1.035}$	0.975	0.114
0.2-Percent Annual Chance	$Q = 14454 \cdot DA^{1.094}$	0.985	0.092

For St. Croix, a linear regression between the logarithms of the FIS and gage flows in cubic feet per second and drainage area in square miles was performed. At each location, the 4-percent annual chance FIS flows were estimated from a frequency curve developed from the other flow events at that location. **Figure 4** shows the graphical results for the 1-percent annual chance peak flows and **Table 3-3** shows the equation used for the 10-percent, 4-percent, 2-percent, 1-percent, and 0.2-percent annual chance events.

Figure 4: 1-Percent Annual Chance Peak Flow Analysis for St. Croix

Table 3-3: Peak Flows (Q in cfs) and Drainage Area (DA in square miles) Relationships for St. Croix

Recurrence Interval	Equation	R^2	Standard Error (log units)
10-Percent Annual Chance	$Q = 1169 \cdot DA^{0.3948}$	0.495	0.192
4-Percent Annual Chance	$Q = 1641 \cdot DA^{0.4525}$	0.761	0.122
2-Percent Annual Chance	$Q = 2030 \cdot DA^{0.4656}$	0.846	0.096
1-Percent Annual Chance	$Q = 2553 \cdot DA^{0.5240}$	0.906	0.081
0.2-Percent Annual Chance	$Q = 3698 \cdot DA^{0.5989}$	0.859	0.117

Gridded hydrology was developed using the equations described above. For each island, a grid was generated for the drainage area parameter and for each of the flow events. Each grid cell has a value for the drainage area with the basin draining to that cell.

The primary steps for the development of hydrologic data are as follows:

- Prepared stream network, hydrologic network, and delineated watersheds
- Developed gridded input parameters and peak discharges from the equations summarized in **Table 3-2** and **Table 3-3**
- Where the FIS discharges were higher, the computed discharges were increased to match the FIS discharges

The details for each of these steps are included in the following sections.

3.1.2.1 Stream Network Preparation and Watershed Delineation

The stream network was derived from the CNMS study lines and the NHD high-definition flow lines for the watershed, and was used as a basis for stream centerlines and for developing hydrologic flow paths and drainage basins.

The steps used to develop the stream network, delineate watersheds, and compute drainage areas are listed below:

1. A 30-meter DEM topographic dataset for each of the islands was created. These DEMs were extracted from the NED 1/3 arcsecond (approximately 10 meter) rasters, and were then downloaded from ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/13/GridFloat.
2. The NED 1/3 arcsecond data, as it existed from mid-2016, was utilized. These were mosaicked as needed and re-projected into USGS Albers North American Datum of 1983 (NAD 83), 30-meter grids to cover the islands. The sampling method utilized during re-projection was bilinear resampling. Note that this DEM was only used to develop hydrologic parameters and was not used for hydraulic modeling.
3. All CNMS and NHD high-definition lines that intersected the contributing basins were extracted and the lines classified as coastlines were deleted.
4. The lines were joined to create the stream network. Split flow locations were reviewed and the primary flow path identified. The alternate flow paths were deleted from the network.
5. This stream network was then used as the basis for development of an adjusted DEM - the “burn” layer. In the burn process, DEM cells that crossed burn lines were modified to have lower elevations. The “burn” layer was necessary to accurately locate the flooding sources.
6. Sinks were inserted into the DEM at some stream outlets to the ocean. A sink was added by converting a DEM cell to a “null” value. When sinks were inserted, the flowlines would

terminate at the sink, therefore sinks were only inserted when it was believed with a high degree of confidence that the 1-percent annual chance event would not have sufficient volume to overflow the depression.

7. A flow direction grid was created from the filled DEM, where each cell pointed to the next downstream cell.

8. Watershed delineation was performed (i.e., flowlines and basins were created from the flow direction grids). Basins were delineated up to a threshold of 0.05 square mile, and hydrologic flowlines were also created up the 0.05 square mile of drainage area.

9. The following quality checks were performed:

   - Delineated watersheds and flow lines were examined for consistency with the expected flow paths for the basin. The flow directions and alignments between the stream network and the hydrologic network were checked and differences were highlighted with automated tools. Generally, differences occurred when two burn lines were too close together and the flow direction grid was incorrect. At these locations, only the larger stream line was burned into the DEM to correct the direction.

   - A drainage area grid was computed along the flow paths and checked against stream gage drainage areas and FIS drainage areas. If the flowlines or basins appeared to be in error, then the stream network was modified. If there was agreement, no modifications were made. Please note that StreamStats does not currently include the US Virgin Islands and could not be used for spot checks.

   - The flowlines were checked to make sure there were no cross-basin flows.

   - If modifications were made, the fill, flow direction, and watershed delineation steps were repeated and drainage areas were recalculated. The flagged locations were then checked again.

The spatial files developed are described in **Table 3-4**. All files listed below are projected in USGS Albers NAD 1983. The "*" is an abbreviation for each island: STH for St. Thomas, SJN for St. John, and SCX for St. Croix.

Table 3-4: Stream Network Preparation and Watershed Delineation Spatial Files

File Name	Type	Description
*_topo.bil	grid	Mosaicked 30-meter USGS DEM covering the contributing drainage area
*_burn_reaches.shp	polyline	Connected stream network derived from modified CNMS and NHD flow lines
*_sinks.shp	point	Sinks inserted into the DEM
*_topo_burn.bil	grid	30-meter topography with stream network (i.e., burn reaches) burned in and sinks inserted

File Name	Type	Description
*_fd.bil	grid	Flow direction grid
*_fa.bil	grid	Flow accumulation grid
*_sqmi.tif	grid	Contributing drainage area (in square miles) for all drainage areas of 0.1 square miles or greater
*_basinpolys_0.05.shp	polygon	Basins delineated up to a threshold of 0.05 square miles of drainage area
*_basinpaths_0.05_join.shp	polyline	Hydrologic flow paths up to 0.05 square miles of drainage area
*_basinpolys_0.1.shp	polygon	Basins delineated up to a threshold of 0.1 square miles of drainage area
*_basinpaths_0.1_join.shp	polyline	Hydrologic flow paths up to 0.1 square miles of drainage area
*_basinpolys_1.shp	polygon	Basins delineated up to a threshold of 1 square mile of drainage area
*_basinpaths_1_join.shp	polyline	Hydrologic flow paths up to 1 square mile of drainage area
*_basinpolys_5.shp	polygon	Basins delineated up to a threshold of 5 square miles of drainage area
*_basinpaths_5_join.shp	polyline	Hydrologic flow paths up to 5 square miles of drainage area

3.1.2.2 Peak Flows Computed from Equations Only

Peak flows for the 10-percent, 4-percent, 2-percent, 1-percent, and 0.2-percent annual chance events were computed utilizing the equations presented in the tables above. Flow grids were developed for each frequency event for drainage areas of 0.05 square mile or greater.

The spatial files developed are described in **Table 3-5**. All files listed below are projected in USGS Albers NAD 1983. The "*" is an abbreviation for each island: STH for St. Thomas and SJN for St. John.

Please note that there were no adjustments to the computed flows for St. Thomas and St. John; these regression flows were the final flows used in the modeling.

Table 3-5: Spatial Files for Computation of Peak Flows From Equations Only

File Name	Type	Description
*_sqmi.tif	grid	Contributing drainage area in square miles for all drainage areas of 0.05 square mile or greater
SCX_Q10_eqs_only.tif *_Q10_final.tif	grid	Regression equation peak stream flows with 10-percent annual chance exceedance for all drainage areas of 0.05 square mile or greater

File Name	Type	Description
SCX_Q25_eqs_only.tif *_Q25_final.tif	grid	Regression equation peak stream flows with 4-percent annual chance exceedance for all drainage areas of 0.05 square mile or greater
SCX_Q50_eqs_only.tif *_Q50_final.tif	grid	Regression equation peak stream flows with 2-percent annual chance exceedance for all drainage areas of 0.05 square mile or greater
SCX_Q100_eqs_only.tif *_Q100_final.tif	grid	Regression equation peak stream flows with 1-percent annual chance exceedance for all drainage areas of 0.05 square mile or greater
SCX_Q500_eqs_only.tif *_Q500_final.tif	grid	Regression equation peak stream flows with 0.2-percent annual chance exceedance for all drainage areas of 0.05 square mile or greater

"*" represent St. Thomas (STH) and St. John (SJN)

3.1.2.3 Adjustments to Flows on St. Croix

Two adjustments were made to the computed flows in the detailed study areas on St. Croix:

- The downstream flow was applied constantly upstream to the detailed study boundary (i.e., no variation of flow with drainage area).
- For Guts 1, 2, 3, and 6 and the Salt River, the FIS flows were higher than the computed flows. The computed flows were replaced with the more conservative FIS flows on these reaches.

The spatial files developed are described in **Table 3-6**. All files listed below are projected in USGS Albers NAD 1983.

Table 3-6: Spatial Files and Related Data for the Final Peak Flows Adjusted for High Drainage Area and Regulation by Large Dams

File Name	Type	Description
SCX_adj_streams.shp	polyline	Polylines showing where FIS flows replaced the computed flows and where constant flow rates where applied
SCX_Q10_final.tif	grid	Final peak stream flows with gage and FIS flow adjustments for the 10-percent annual chance event
SCX_Q25_final.tif	grid	Final peak stream flows with gage and FIS flow adjustments for the 4-percent annual chance event
SCX_Q50_final.tif	grid	Final peak stream flows with gage and FIS flow adjustments for the 2-percent annual chance event
SCX_Q100_final.tif	grid	Final peak stream flows with gage and FIS flow adjustments for the 1-percent annual chance event
SCX_Q500_final.tif	grid	Final peak stream flows with gage and FIS flow adjustments for the 0.2-percent annual chance event

3.1.2.4 Summary of Discharges

Table 3-7 provides a summary of discharges at two locations for each studied stream. These discharges were developed at the most upstream and downstream cross-section locations of each studied stream. In the table below streams without identified names in either the effective Flood Insurance Study or the USGS National Hydrography Dataset are identified as "Unnamed Stream" followed by the HEC-RAS model name from this study.

Table 3-7: Summary of Discharges

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
10001	Unnamed Stream (Saint Croix Model #33)	33	Downstream End above Confluence with Caribbean Sea	1,258	1,784	2,213	2,813	4,132
10070	Unnamed Stream (Saint Croix Model #33)	13,505	Upstream End at Limit of Study	369	438	521	552	643
10080	Unnamed Stream (Saint Croix Model #36)	2,637	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #33)	647	834	1,011	1,165	1,509
10093	Unnamed Stream (Saint Croix Model #36)	4,964	Upstream End at Limit of Study	421	509	609	659	786
10101	Unnamed Stream (Saint Croix Model #39)	1,867	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #33)	737	966	1,177	1,383	1,835
10132	Unnamed Stream (Saint Croix Model #39)	8,209	Upstream End below Split from Gut #6 (Saint Croix Model #157)	568	718	867	990	990
10133	Unnamed Stream (Saint Croix Model #49)	0	Downstream End at Confluence with Long Point Bay	1,354	1,941	2,413	3,101	4,619
10179	Unnamed Stream (Saint Croix Model #49)	15,497	Upstream End at Limit of Study	802	1,065	1,301	1,548	2,087
10180	Unnamed Stream (Saint Croix Model #60)	0	Downstream End at Confluence with Long Point Bay	913	1,237	1,517	1,840	2,543

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
10223	Unnamed Stream (Saint Croix Model #60)	8,209	Upstream End at Limit of Study	664	859	1,043	1,206	1,570
10224	Gut #5 (Saint Croix Model #76)	45	Downstream End above Confluence with Caribbean Sea	1,931	1,931	1,931	4,969	7,916
10303	Gut #5 (Saint Croix Model #76)	20,461	Upstream End at Limit of Study	972	972	972	1,997	2,793
10308	Unnamed Stream (Saint Croix Model #84)	5,664	Downstream End above Confluence with Gut #5 (Saint Croix Model #76)	1,177	1,177	1,177	2,576	3,737
10345	Unnamed Stream (Saint Croix Model #84)	13,240	Upstream End at Limit of Study	893	893	893	1,785	2,457
10356	Unnamed Stream (Saint Croix Model #93)	2,745	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #95)	568	718	867	980	1,238
10380	Unnamed Stream (Saint Croix Model #93)	7,300	Upstream End at Limit of Study	362	428	510	539	625
10389	Unnamed Stream (Saint Croix Model #95)	2,576	Downstream End above Confluence with Gut #5 (Saint Croix Model #76)	771	1,019	1,243	1,470	1,968
10411	Unnamed Stream (Saint Croix Model #95)	6,841	Upstream End at Limit of Study	691	898	1,091	1,270	1,665
10420	Jolly Hill Gut (Saint Croix Model #128)	2,781	Downstream End above Confluence with Gut #6 (Saint Croix Model #157)	1,917	2,892	3,637	4,921	7,829
10465	Jolly Hill Gut (Saint Croix Model #128)	14,020	Upstream End at Limit of Study	1,429	2,067	2,574	3,334	5,018
10471	Unnamed Stream (Saint Croix Model #148)	2,533	Downstream End above Confluence with Jolly Hill Gut (Saint Croix Model #128)	830	1,108	1,356	1,621	2,200

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
10514	Unnamed Stream (Saint Croix Model #148)	7,631	Upstream End at Limit of Study	458	561	672	736	892
10515	Gut #6 (Saint Croix Model #157)	103	Downstream End above Confluence with Caribbean Sea	2,790	3,778	4,320	5,890	9,517
10590	Gut #6 (Saint Croix Model #157)	13,321	Upstream End at Limit of Study	401	481	574	616	729
10591	River Gut (Saint Croix Model #211)	28	Downstream End above Confluence with Caribbean Sea	2,936	4,715	6,013	8,666	14,949
10721	River Gut (Saint Croix Model #211)	37,940	Upstream End at Limit of Study	769	1,015	1,239	1,464	1,959
10728	Unnamed Stream (Saint Croix Model #222)	1,009	Downstream End above Confluence with River Gut (Saint Croix Model #211)	575	728	879	996	1,260
10760	Unnamed Stream (Saint Croix Model #222)	4,321	Upstream End at Limit of Study	364	431	513	543	630
10768	Unnamed Stream (Saint Croix Model #229)	1,752	Downstream End above Confluence with River Gut (Saint Croix Model #211)	886	1,194	1,463	1,766	2,427
10800	Unnamed Stream (Saint Croix Model #229)	7,386	Upstream End at Limit of Study	376	448	533	567	663
10806	Unnamed Stream (Saint Croix Model #241)	1,857	Downstream End above Confluence with River Gut (Saint Croix Model #211)	1,483	2,156	2,688	3,502	5,307
10860	Unnamed Stream (Saint Croix Model #241)	15,126	Upstream End at Limit of Study	844	1,130	1,383	1,658	2,257
10870	Unnamed Stream (Saint Croix Model #264)	3,347	Downstream End above Confluence with River Gut (Saint Croix Model #211)	2,048	2,048	2,048	5,373	8,657

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second 10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
10937	Unnamed Stream (Saint Croix Model #264)	24,284	Upstream End at Limit of Study	503	503	503	834	1,029
10942	Unnamed Stream (Saint Croix Model #266)	918	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #264)	448	546	654	714	862
10964	Unnamed Stream (Saint Croix Model #266)	3,348	Upstream End at Limit of Study	363	430	511	541	628
10972	Unnamed Stream (Saint Croix Model #272)	2,207	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #264)	856	1,147	1,405	1,687	2,303
10976	Unnamed Stream (Saint Croix Model #272)	2,981	Upstream End at Limit of Study	802	1,065	1,301	1,548	2,087
10993	Unnamed Stream (Saint Croix Model #275)	3,190	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #264)	410	494	591	636	636
10999	Unnamed Stream (Saint Croix Model #275)	4,351	Upstream End below Split from Unnamed Stream (Saint Croix Model #266)	410	494	591	636	636
11001	Bethlehem Gut (Saint Croix Model #285)	1,920	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #264)	1,259	1,786	2,215	2,816	4,137
11056	Bethlehem Gut (Saint Croix Model #285)	15,472	Upstream End at Limit of Study	421	508	608	657	784
11057	Unnamed Stream (Saint Croix Model #301)	0	Downstream End at Confluence with Caribbean Sea	1,280	1,280	1,280	2,878	4,241
11113	Unnamed Stream (Saint Croix Model #301)	11,399	Upstream End at Limit of Study	422	422	422	660	789
11119	Unnamed Stream (Saint Croix Model #312)	1,149	Downstream End above Confluence with Creque Gut (Saint Croix Model #318)	756	996	1,215	1,432	1,910

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
11133	Unnamed Stream (Saint Croix Model #312)	3,941	Upstream End at Limit of Study	672	869	1,056	1,223	1,595
11134	Creque Gut (Saint Croix Model #318)	15	Downstream End above Confluence with Caribbean Sea	1,222	1,727	2,140	2,709	3,958
11206	Creque Gut (Saint Croix Model #318)	8,347	Upstream End at Limit of Study	897	1,212	1,486	1,797	2,476
11215	Unnamed Stream (Saint Croix Model #335)	6,487	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #337)	785	1,039	1,269	1,505	2,021
11246	Unnamed Stream (Saint Croix Model #335)	11,848	Upstream End at Limit of Study	371	440	524	556	648
11257	Unnamed Stream (Saint Croix Model #336)	5,911	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #335)	529	661	797	891	1,110
11271	Unnamed Stream (Saint Croix Model #336)	8,026	Upstream End at Limit of Study	420	507	607	656	782
11276	Unnamed Stream (Saint Croix Model #337)	6,108	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #341)	1,094	1,521	1,877	2,337	3,343
11314	Unnamed Stream (Saint Croix Model #337)	14,139	Upstream End at Limit of Study	523	653	787	879	1,093
11326	Unnamed Stream (Saint Croix Model #340)	5,926	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #341)	677	878	1,066	1,237	1,616
11341	Unnamed Stream (Saint Croix Model #340)	8,578	Upstream End at Limit of Study	518	645	777	867	1,075
11342	Unnamed Stream (Saint Croix Model #341)	0	Downstream End at Confluence at Limetree Bay	2,368	3,685	4,666	6,514	10,788

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
11400	Unnamed Stream (Saint Croix Model #341)	21,823	Upstream End at Limit of Study	362	428	510	539	625
11410	Unnamed Stream (Saint Croix Model #342)	5,861	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #341)	632	811	983	1,129	1,455
11432	Unnamed Stream (Saint Croix Model #342)	9,494	Upstream End at Limit of Study	416	502	600	648	771
11440	Unnamed Stream (Saint Croix Model #348)	5,524	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #341)	1,156	1,621	2,004	2,516	3,637
11460	Unnamed Stream (Saint Croix Model #348)	12,878	Upstream End at Limit of Study	366	434	516	547	635
11461	Unnamed Stream (Saint Croix Model #383)	10	Downstream End above Confluence with Caribbean Sea	620	794	961	1,101	1,414
11544	Unnamed Stream (Saint Croix Model #383)	3,916	Upstream End at Limit of Study	421	509	609	659	786
11545	Unnamed Stream (Saint Croix Model #386)	5	Downstream End above Confluence with Caribbean Sea	737	967	1,178	1,384	1,836
11578	Unnamed Stream (Saint Croix Model #386)	3,310	Upstream End at Limit of Study	611	781	945	1,080	1,383
11584	Drainage Canal (Saint Croix Model #400)	1,297	Downstream End above Confluence with Drainage Canal (Saint Croix Model #403)	696	906	1,101	1,283	1,684
11624	Drainage Canal (Saint Croix Model #400)	8,376	Upstream End at Limit of Study	381	454	541	576	675
11625	Drainage Canal (Saint Croix Model #403)	0	Downstream End at Confluence at Canegarden Bay	2,319	3,598	4,553	6,337	10,453

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
11722	Drainage Canal (Saint Croix Model #403)	22,049	Upstream End at Limit of Study	408	491	587	631	749
11730	Unnamed Stream (Saint Croix Model #426)	2,174	Downstream End above Confluence with Drainage Canal (Saint Croix Model #403)	1,474	2,141	2,669	3,474	5,259
11809	Unnamed Stream (Saint Croix Model #426)	18,080	Upstream End at Limit of Study	393	471	561	601	708
11810	Unnamed Stream (Saint Croix Model #448)	79	Downstream End above Confluence with Manchenil Bay	854	1,145	1,402	1,683	2,297
11824	Unnamed Stream (Saint Croix Model #448)	3,393	Upstream End at Limit of Study	717	937	1,141	1,335	1,763
11825	Unnamed Stream (Saint Croix Model #455)	18	Downstream End above Confluence with Caribbean Sea	755	994	1,212	1,429	1,905
11849	Unnamed Stream (Saint Croix Model #455)	2,569	Upstream End at Limit of Study	509	633	762	848	1,049
11850	Caledonia Gut (Saint Croix Model #460)	11	Downstream End above Confluence with Hams Bay	1,236	1,750	2,169	2,750	4,026
11879	Caledonia Gut (Saint Croix Model #460)	3,015	Upstream End at Limit of Study	1,164	1,633	2,020	2,539	3,674
11880	Unnamed Stream (Saint Croix Model #471)	21	Downstream End above Confluence with Manchenil Bay	1,373	1,973	2,454	3,161	4,720
11944	Unnamed Stream (Saint Croix Model #471)	14,367	Upstream End at Limit of Study	389	465	554	592	696
11945	Unnamed Stream (Saint Croix Model #481)	64	Downstream End above Confluence with Halfpenny Bay	1,022	1,407	1,733	2,136	3,016

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
11997	Unnamed Stream (Saint Croix Model #481)	8,924	Upstream End at Limit of Study	364	431	513	543	630
11998	Unnamed Stream (Saint Croix Model #500)	2,675	Downstream End above Confluence with Caribbean Sea	968	1,322	1,625	1,988	2,778
12042	Unnamed Stream (Saint Croix Model #500)	10,202	Upstream End at Limit of Study	372	441	526	558	650
12043	Unnamed Stream (Saint Croix Model #502)	0	Downstream End at Confluence with Caribbean Sea	547	688	830	932	1,170
12060	Unnamed Stream (Saint Croix Model #502)	1,005	Upstream End at Limit of Study	486	600	720	796	976
12061	Unnamed Stream (Saint Croix Model #506)	7	Downstream End above Confluence with Annaly Bay	706	921	1,120	1,308	1,722
12084	Unnamed Stream (Saint Croix Model #506)	2,025	Upstream End at Limit of Study	632	811	984	1,130	1,456
12085	Unnamed Stream (Saint Croix Model #510)	62	Downstream End above Confluence with Caribbean Sea	750	986	1,202	1,416	1,885
12136	Unnamed Stream (Saint Croix Model #510)	5,607	Upstream End at Limit of Study	365	432	515	545	633
12164	Unnamed Stream (Saint Croix Model #512)	29	Downstream End above Confluence with Spring Bay	664	858	1,041	1,204	1,567
12183	Unnamed Stream (Saint Croix Model #512)	1,683	Upstream End at Limit of Study	559	705	851	960	1,209
12184	Unnamed Stream (Saint Croix Model #524)	8	Downstream End above Confluence with Caribbean Sea	713	931	1,133	1,325	1,747

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
12198	Unnamed Stream (Saint Croix Model #524)	1,380	Upstream End at Limit of Study	675	874	1,062	1,231	1,606
12199	Unnamed Stream (Saint Croix Model #527)	92	Downstream End above Confluence with Great Pond Bay	709	925	1,126	1,315	1,732
12227	Unnamed Stream (Saint Croix Model #527)	5,008	Upstream End at Limit of Study	382	455	542	578	677
12228	Unnamed Stream (Saint Croix Model #530)	10	Downstream End above Confluence with Caribbean Sea	731	958	1,167	1,369	1,814
12245	Unnamed Stream (Saint Croix Model #530)	2,159	Upstream End at Limit of Study	484	597	717	792	970
12246	Unnamed Stream (Saint Croix Model #540)	206	Downstream End above Confluence with Great Pond at Great Pond Bay	1,187	1,671	2,068	2,607	3,787
12268	Unnamed Stream (Saint Croix Model #540)	4,251	Upstream End at Limit of Study	427	517	618	670	802
12278	Unnamed Stream (Saint Croix Model #542)	1,923	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #540)	564	712	860	971	1,225
12292	Unnamed Stream (Saint Croix Model #542)	4,576	Upstream End at Limit of Study	412	497	593	640	760
12293	Unnamed Stream (Saint Croix Model #544)	206	Downstream End above Confluence with Great Pond at Great Pond Bay	818	1,090	1,332	1,590	2,152
12329	Unnamed Stream (Saint Croix Model #544)	6,393	Upstream End at Limit of Study	399	479	571	613	724
12330	Unnamed Stream (Saint Croix Model #551)	2,696	Downstream End above Confluence with Great Pond at Great Pond Bay	671	868	1,055	1,222	1,593

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
12359	Unnamed Stream (Saint Croix Model #551)	6,319	Upstream End at Limit of Study	384	459	547	583	684
12360	Unnamed Stream (Saint Croix Model #555)	156	Downstream End above Confluence with Caribbean Sea	870	1,170	1,433	1,726	2,364
12411	Unnamed Stream (Saint Croix Model #555)	6,599	Upstream End at Limit of Study	416	502	600	648	771
12412	Unnamed Stream (Saint Croix Model #560)	22	Downstream End above Confluence with Caribbean Sea	583	739	894	1,014	1,287
12428	Unnamed Stream (Saint Croix Model #560)	2,845	Upstream End at Limit of Study	362	428	510	539	625
12429	Gut #2 (Saint Croix Model #569)	0	Downstream End at Confluence with Christiansted Harbor	1,030	1,257	1,430	1,850	2,330
12448	Gut #2 (Saint Croix Model #569)	4,038	Upstream End at Limit of Study	518	645	777	867	1,075
12453	Unnamed Stream (Saint Croix Model #579)	777	Downstream End above Confluence with Caribbean Sea	565	713	861	972	1,227
12470	Unnamed Stream (Saint Croix Model #579)	2,593	Upstream End at Limit of Study	441	537	643	701	844
12471	Unnamed Stream (Saint Croix Model #584)	63	Downstream End above Confluence with Robin Bay	700	911	1,108	1,292	1,697
12494	Unnamed Stream (Saint Croix Model #584)	4,357	Upstream End at Limit of Study	397	476	569	609	719
12495	Gut #1 (Saint Croix Model #595)	0	Downstream End at Confluence with Caribbean Sea	920	1,202	1,420	1,670	2,400

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
12524	Gut #1 (Saint Croix Model #595)	5,132	Upstream End at Limit of Study	438	533	639	695	835
12525	Unnamed Stream (Saint Croix Model #601)	25	Downstream End above Confluence with Caribbean Sea	1,087	1,510	1,864	2,319	3,314
12564	Unnamed Stream (Saint Croix Model #601)	3,765	Upstream End at Limit of Study	682	885	1,076	1,250	1,634
12565	Gut #3 (Saint Croix Model #609)	21	Downstream End above Confluence with Gallows Bay	1,240	1,684	2,090	2,400	3,450
12593	Gut #3 (Saint Croix Model #609)	5,198	Upstream End at Limit of Study	746	980	1,194	1,405	1,869
12596	Unnamed Stream (Saint Croix Model #626)	3,578	Downstream End above Confluence with Gut #4 (Saint Croix Model #628)	743	976	1,189	1,398	1,858
12619	Unnamed Stream (Saint Croix Model #626)	6,584	Upstream End at Limit of Study	482	594	714	788	964
12620	Gut #4 (Saint Croix Model #628)	126	Downstream End above Confluence with Altona Lagoon	1,090	1,514	1,869	2,326	3,324
12643	Gut #4 (Saint Croix Model #628)	6,033	Upstream End at Limit of Study	504	626	753	836	1,033
12644	Unnamed Stream (Saint Croix Model #634)	22	Downstream End above Confluence with Caribbean Sea	713	932	1,134	1,326	1,749
12690	Unnamed Stream (Saint Croix Model #634)	4,393	Upstream End at Limit of Study	376	448	533	567	663
12693	Unnamed Stream (Saint Croix Model #635)	401	Downstream End above Confluence with Unnamed Stream (Saint Croix Model #634)	407	490	585	630	747

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
12717	Unnamed Stream (Saint Croix Model #635)	2,025	Upstream End at Limit of Study	363	430	511	541	628
12718	Unnamed Stream (Saint Croix Model #650)	37	Downstream End above Confluence with Caribbean Sea	561	707	854	963	1,214
12752	Unnamed Stream (Saint Croix Model #650)	3,422	Upstream End at Limit of Study	367	435	518	549	638
12753	Salt River (Saint Croix Model #675)	0	Downstream End at Confluence with Salt River Bay	3,300	4,713	5,880	7,400	11,000
12817	Salt River (Saint Croix Model #675)	17,027	Upstream End at Limit of Study	983	1,345	1,655	2,028	2,843
12823	Salt River Diversion Channel (Saint Croix Model #677)	2,682	Downstream End above Confluence with Salt River (Saint Croix Model #675)	3,300	4,713	5,880	7,400	11,000
12840	Salt River Diversion Channel (Saint Croix Model #677)	6,777	Upstream End below Split from Salt River (Saint Croix Model #675)	3,300	4,713	5,880	7,400	11,000
12853	Unnamed Stream (Saint Croix Model #681)	1,554	Downstream End above Confluence with Salt River Diversion Channel (Saint Croix Model #677)	879	1,183	1,450	1,748	2,398
12914	Unnamed Stream (Saint Croix Model #681)	7,290	Upstream End at Limit of Study	366	434	516	547	635
12923	Unnamed Stream (Saint Croix Model #686)	2,135	Downstream End above Confluence with Salt River (Saint Croix Model #675)	901	1,218	1,494	1,808	2,493
12933	Unnamed Stream (Saint Croix Model #686)	3,907	Upstream End at Limit of Study	798	1,059	1,294	1,538	2,072

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
12941	Unnamed Stream (Saint Croix Model #689)	2,491	Downstream End above Confluence with Salt River (Saint Croix Model #675)	702	915	1,113	1,298	1,706
12978	Unnamed Stream (Saint Croix Model #689)	6,732	Upstream End at Limit of Study	576	730	882	999	1,265
12984	Unnamed Stream (Saint Croix Model #692)	1,716	Downstream End above Confluence with Salt River (Saint Croix Model #675)	703	916	1,114	1,299	1,709
13011	Unnamed Stream (Saint Croix Model #692)	5,051	Upstream End at Limit of Study	494	611	734	813	1,000
13012	Unnamed Stream (Saint Croix Model #707)	44	Downstream End above Confluence with Rod Bay	766	1,012	1,234	1,458	1,949
13030	Unnamed Stream (Saint Croix Model #707)	3,197	Upstream End at Limit of Study	399	479	571	613	724
13031	Unnamed Stream (Saint Croix Model #712)	31	Downstream End above Confluence with Caribbean Sea	993	1,362	1,675	2,057	2,888
13073	Unnamed Stream (Saint Croix Model #712)	8,077	Upstream End at Limit of Study	476	585	703	774	945
13074	Unnamed Stream (Saint Croix Model #719)	51	Downstream End above Confluence with Caribbean Sea	493	610	733	812	998
13099	Unnamed Stream (Saint Croix Model #719)	2,494	Upstream End at Limit of Study	372	441	526	558	650
13101	Unnamed Stream (Saint Croix Model #729)	1,811	Downstream End above Confluence with Chenay Bay	1,224	1,730	2,144	2,715	3,967
13149	Unnamed Stream (Saint Croix Model #729)	13,640	Upstream End at Limit of Study	365	432	515	545	633

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
13150	Unnamed Stream (Saint Croix Model #740)	47	Downstream End above Confluence with Chenay Bay	981	1,342	1,651	2,023	2,835
13184	Unnamed Stream (Saint Croix Model #740)	6,298	Upstream End at Limit of Study	396	475	567	608	717
13185	Unnamed Stream (Saint Croix Model #748)	57	Downstream End above Confluence with Caribbean Sea	481	593	713	786	962
13206	Unnamed Stream (Saint Croix Model #748)	2,189	Upstream End at Limit of Study	367	435	518	549	638
13207	Unnamed Stream (Saint Croix Model #756)	3,236	Downstream End above Confluence with Coakley Bay	542	679	819	920	1,151
13218	Unnamed Stream (Saint Croix Model #756)	5,255	Upstream End at Limit of Study	400	480	573	615	726
13219	Unnamed Stream (Saint Croix Model #757)	14	Downstream End above Confluence with Coakley Bay	541	679	818	918	1,149
13234	Unnamed Stream (Saint Croix Model #757)	2,893	Upstream End at Limit of Study	359	425	505	533	618
13235	Unnamed Stream (Saint Croix Model #763)	30	Downstream End above Confluence with Caribbean Sea	833	1,113	1,362	1,629	2,213
13263	Unnamed Stream (Saint Croix Model #763)	5,605	Upstream End at Limit of Study	427	517	618	670	802
13264	Unnamed Stream (Saint Croix Model #770)	86	Downstream End above Confluence with Yellowcliff Bay	1,152	1,614	1,996	2,504	3,618
13307	Unnamed Stream (Saint Croix Model #770)	8,289	Upstream End at Limit of Study	438	532	637	693	833

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
13308	Unnamed Stream (Saint Croix Model #782)	50	Downstream End above Confluence with Tague Bay	814	1,084	1,325	1,579	2,136
13332	Unnamed Stream (Saint Croix Model #782)	3,437	Upstream End at Limit of Study	362	428	510	539	625
13333	Unnamed Stream (Saint Croix Model #793)	26	Downstream End above Confluence with Knight Bay	528	660	795	889	1,107
13341	Unnamed Stream (Saint Croix Model #793)	1,660	Upstream End at Limit of Study	366	434	516	547	635
13342	Unnamed Stream (Saint Croix Model #795)	50	Downstream End above Confluence with Caribbean Sea	714	933	1,135	1,327	1,751
13357	Unnamed Stream (Saint Croix Model #795)	2,146	Upstream End at Limit of Study	411	495	592	638	758
20001	Guinea Gut (Saint John Model #5)	143	Downstream End above Confluence with Great Cruz Bay	889	1,651	2,448	3,470	6,937
20044	Guinea Gut (Saint John Model #5)	5,258	Upstream End at Limit of Study	454	831	1,216	1,697	3,257
20050	Unnamed Stream (Saint John Model #7)	1,697	Downstream End above Confluence with Great Cruz Bay	269	487	704	972	1,806
20067	Unnamed Stream (Saint John Model #7)	2,974	Upstream End at Limit of Study	200	360	517	709	1,294
20068	Battery Gut (Saint John Model #16)	9	Downstream End above Confluence with Fish Bay	2,890	5,508	8,372	12,189	26,174
20114	Battery Gut (Saint John Model #16)	6,161	Upstream End at Limit of Study	1,047	1,951	2,902	4,129	8,336

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
20118	Fish Bay Gut (Saint John Model #21)	2,979	Downstream End above Confluence with Battery Gut (Saint John Model #16)	644	1,187	1,748	2,460	4,822
20162	Fish Bay Gut (Saint John Model #21)	6,047	Upstream End at Limit of Study	577	1,061	1,559	2,188	4,260
20163	Unnamed Stream (Saint John Model #29)	21	Downstream End above Confluence with Fish Bay	883	1,640	2,431	3,446	6,885
20192	Unnamed Stream (Saint John Model #29)	5,299	Upstream End at Limit of Study	232	418	603	829	1,528
20193	Unnamed Stream (Saint John Model #36)	212	Downstream End above Confluence with Turner Bay	327	595	864	1,197	2,252
20213	Unnamed Stream (Saint John Model #36)	2,646	Upstream End at Limit of Study	96	169	239	322	562
20214	Unnamed Stream (Saint John Model #38)	0	Downstream End at Confluence with Cruz Bay	573	1,054	1,549	2,173	4,230
20240	Unnamed Stream (Saint John Model #38)	2,348	Upstream End at Limit of Study	299	542	786	1,086	2,033
20246	Unnamed Stream (Saint John Model #39)	649	Downstream End above Confluence with Unnamed Stream (Saint John Model #38)	144	256	365	497	889
20254	Unnamed Stream (Saint John Model #39)	1,380	Upstream End at Limit of Study	112	198	282	381	671
20255	Cob Gut (Saint John Model #46)	78	Downstream End above Confluence with Grootpan Bay	992	1,846	2,743	3,898	7,844
20322	Cob Gut (Saint John Model #46)	6,923	Upstream End at Limit of Study	229	413	595	818	1,505

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
20323	Unnamed Stream (Saint John Model #58)	51	Downstream End above Confluence with Reef Bay	2,966	5,656	8,601	12,530	26,950
20378	Unnamed Stream (Saint John Model #58)	10,343	Upstream End at Limit of Study	118	210	298	404	714
20384	Unnamed Stream (Saint John Model #61)	4,756	Downstream End above Confluence with Unnamed Stream (Saint John Model #58)	476	873	1,277	1,785	3,436
20398	Unnamed Stream (Saint John Model #61)	6,074	Upstream End at Limit of Study	332	603	875	1,213	2,285
20403	Reef Bay Gut (Saint John Model #64)	3,878	Downstream End above Confluence with Unnamed Stream (Saint John Model #58)	931	1,731	2,569	3,646	7,309
20530	Reef Bay Gut (Saint John Model #64)	10,319	Upstream End at Limit of Study	179	320	459	628	1,139
20531	Unnamed Stream (Saint John Model #72)	34	Downstream End above Confluence with Great Lameshur Bay	421	769	1,122	1,564	2,987
20578	Unnamed Stream (Saint John Model #72)	3,023	Upstream End at Limit of Study	132	235	334	454	808
20579	Unnamed Stream (Saint John Model #77)	0	Downstream End at Confluence with Great Lameshur Bay	976	1,816	2,698	3,832	7,704
20681	Unnamed Stream (Saint John Model #77)	6,744	Upstream End at Limit of Study	99	176	249	336	587
20682	Unnamed Stream (Saint John Model #84)	0	Downstream End at Confluence with Little Lameshur Bay	863	1,602	2,374	3,363	6,710
20735	Unnamed Stream (Saint John Model #84)	4,652	Upstream End at Limit of Study	155	276	395	538	967

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
20740	Unnamed Stream (Saint John Model #86)	954	Downstream End above Confluence with Unnamed Stream (Saint John Model #84)	248	448	646	890	1,646
20767	Unnamed Stream (Saint John Model #86)	2,928	Upstream End at Limit of Study	136	243	346	470	838
20768	Unnamed Stream (Saint John Model #116)	17	Downstream End above Confluence with Coral Harbor	2,775	5,284	8,024	11,672	25,002
20796	Unnamed Stream (Saint John Model #116)	7,773	Upstream End at Limit of Study	399	728	1,062	1,478	2,815
20802	Unnamed Stream (Saint John Model #123)	4,950	Downstream End above Confluence with Unnamed Stream (Saint John Model #116)	797	1,476	2,183	3,088	6,131
20836	Unnamed Stream (Saint John Model #123)	7,912	Upstream End at Limit of Study	96	169	239	322	562
20843	Coral Bay Gut (Saint John Model #127)	3,978	Downstream End above Confluence with Unnamed Stream (Saint John Model #116)	405	738	1,077	1,500	2,858
20857	Coral Bay Gut (Saint John Model #127)	6,011	Upstream End at Limit of Study	107	190	270	365	642
20858	Unnamed Stream (Saint John Model #190)	0	Downstream End at Confluence with Earle Pond at Brown Bay	555	1,019	1,497	2,099	4,077
20875	Unnamed Stream (Saint John Model #190)	2,623	Upstream End at Limit of Study	194	349	501	686	1,249
30001	Unnamed Stream (Saint Thomas Model #8)	0	Downstream End at Confluence with Fortuna Bay	762	1,410	2,084	2,944	5,830
30051	Unnamed Stream (Saint Thomas Model #8)	4,076	Upstream End at Limit of Study	140	250	357	486	868

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
30057	Unnamed Stream (Saint Thomas Model #9)	562	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #8)	150	267	382	520	933
30088	Unnamed Stream (Saint Thomas Model #9)	1,849	Upstream End at Limit of Study	97	172	244	329	575
30089	Unnamed Stream (Saint Thomas Model #14)	7	Downstream End above Confluence with Little Coculus Bay	109	193	273	370	650
30108	Unnamed Stream (Saint Thomas Model #14)	1,295	Upstream End at Limit of Study	94	167	236	318	554
30109	Unnamed Stream (Saint Thomas Model #16)	10	Downstream End above Confluence with Frenchman Bay	396	722	1,052	1,464	2,786
30143	Unnamed Stream (Saint Thomas Model #16)	2,394	Upstream End at Limit of Study	233	420	605	832	1,532
30144	Unnamed Stream (Saint Thomas Model #23)	8	Downstream End above Confluence with Morningstar Bay	634	1,169	1,721	2,421	4,742
30215	Unnamed Stream (Saint Thomas Model #23)	4,255	Upstream End at Limit of Study	96	170	241	324	567
30216	Unnamed Stream (Saint Thomas Model #25)	0	Downstream End at Confluence with Bolongo Bay	547	1,006	1,476	2,070	4,018
30264	Unnamed Stream (Saint Thomas Model #25)	4,192	Upstream End at Limit of Study	97	172	244	329	575
30265	Unnamed Stream (Saint Thomas Model #32)	325	Downstream End above Limit of Study	577	1,061	1,559	2,188	4,260
30314	Unnamed Stream (Saint Thomas Model #32)	3,242	Upstream End at Limit of Study	131	233	333	451	803

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
30321	Unnamed Stream (Saint Thomas Model #33)	365	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #32)	259	468	676	932	1,728
30336	Unnamed Stream (Saint Thomas Model #33)	1,160	Upstream End at Limit of Study	183	328	471	644	1,170
30337	Unnamed Stream (Saint Thomas Model #35)	231	Downstream End above Limit of Study	343	623	905	1,256	2,369
30368	Unnamed Stream (Saint Thomas Model #35)	2,102	Upstream End at Limit of Study	135	240	342	465	829
30369	Unnamed Stream (Saint Thomas Model #39)	0	Downstream End at Limit of Study	493	904	1,324	1,852	3,572
30407	Unnamed Stream (Saint Thomas Model #39)	2,249	Upstream End at Limit of Study	281	508	736	1,016	1,894
30408	Unnamed Stream (Saint Thomas Model #49)	913	Downstream End above Limit of Study	686	1,267	1,869	2,634	5,183
30452	Unnamed Stream (Saint Thomas Model #49)	4,320	Upstream End at Limit of Study	336	611	887	1,230	2,317
30453	Unnamed Stream (Saint Thomas Model #60)	889	Downstream End above Limit of Study	473	867	1,269	1,773	3,412
30522	Unnamed Stream (Saint Thomas Model #60)	4,845	Upstream End at Limit of Study	94	167	236	318	554
30523	Unnamed Stream (Saint Thomas Model #69)	7	Downstream End above Confluence with Bordeaux Bay	979	1,821	2,706	3,844	7,730
30560	Unnamed Stream (Saint Thomas Model #69)	3,459	Upstream End at Limit of Study	205	368	529	725	1,325

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
30566	Unnamed Stream (Saint Thomas Model #70)	787	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #69)	191	343	492	674	1,227
30597	Unnamed Stream (Saint Thomas Model #70)	1,602	Upstream End at Limit of Study	134	238	339	460	820
30604	Unnamed Stream (Saint Thomas Model #71)	868	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #69)	287	520	752	1,040	1,940
30628	Unnamed Stream (Saint Thomas Model #71)	2,103	Upstream End at Limit of Study	220	397	572	785	1,442
30638	Unnamed Stream (Saint Thomas Model #72)	1,486	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #69)	149	266	380	518	928
30661	Unnamed Stream (Saint Thomas Model #72)	2,836	Upstream End at Limit of Study	101	178	252	340	596
30662	Unnamed Stream (Saint Thomas Model #79)	267	Downstream End above Confluence with Mangrove Lagoon	1,147	2,142	3,193	4,552	9,241
30756	Unnamed Stream (Saint Thomas Model #79)	6,909	Upstream End at Limit of Study	93	164	233	313	546
30757	Unnamed Stream (Saint Thomas Model #87)	1,168	Downstream End above Limit of Study	606	1,116	1,641	2,306	4,503
30797	Unnamed Stream (Saint Thomas Model #87)	3,776	Upstream End at Limit of Study	171	306	438	598	1,081
30803	Unnamed Stream (Saint Thomas Model #103)	5,626	Downstream End above Confluence with Turpentine Run (Saint Thomas Model #109)	1,062	1,981	2,948	4,195	8,477
30844	Unnamed Stream (Saint Thomas Model #103)	11,059	Upstream End at Limit of Study	153	273	390	531	954

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
30845	Turpentine Run (Saint Thomas Model #109)	470	Downstream End above Confluence with Mangrove Lagoon	5,559	10,747	16,560	24,470	54,676
30909	Turpentine Run (Saint Thomas Model #109)	16,653	Upstream End at Limit of Study	358	651	947	1,315	2,487
30914	Unnamed Stream (Saint Thomas Model #119)	5,500	Downstream End above Confluence with Turpentine Run (Saint Thomas Model #109)	1,568	2,948	4,423	6,352	13,142
30971	Unnamed Stream (Saint Thomas Model #119)	11,416	Upstream End at Limit of Study	146	261	372	506	907
30980	Unnamed Stream (Saint Thomas Model #132)	5,597	Downstream End above Confluence with Turpentine Run (Saint Thomas Model #109)	534	981	1,440	2,017	3,910
31007	Unnamed Stream (Saint Thomas Model #132)	8,151	Upstream End at Limit of Study	260	470	679	937	1,738
31008	Unnamed Stream (Saint Thomas Model #138)	131	Downstream End above Limit of Study	647	1,193	1,757	2,472	4,847
31043	Unnamed Stream (Saint Thomas Model #138)	2,760	Upstream End at Limit of Study	242	436	630	867	1,601
31044	Unnamed Stream (Saint Thomas Model #140)	98	Downstream End above Limit of Study	433	792	1,157	1,614	3,088
31066	Unnamed Stream (Saint Thomas Model #140)	2,136	Upstream End at Limit of Study	209	377	542	743	1,361
31067	Unnamed Stream (Saint Thomas Model #143)	55	Downstream End above Confluence with Benner Bay	379	690	1,005	1,398	2,653
31111	Unnamed Stream (Saint Thomas Model #143)	3,171	Upstream End at Limit of Study	94	166	234	315	550

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
31112	Unnamed Stream (Saint Thomas Model #160)	0	Downstream End at Confluence with Long Bay	750	1,388	2,051	2,896	5,729
31131	Unnamed Stream (Saint Thomas Model #160)	2,361	Upstream End at Limit of Study	117	207	295	399	705
31132	Unnamed Stream (Saint Thomas Model #164)	0	Downstream End at Confluence with Benner Bay	995	1,853	2,753	3,913	7,876
31210	Unnamed Stream (Saint Thomas Model #164)	6,899	Upstream End at Limit of Study	96	169	239	322	562
31216	Unnamed Stream (Saint Thomas Model #166)	3,254	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #164)	334	607	882	1,223	2,303
31249	Unnamed Stream (Saint Thomas Model #166)	4,933	Upstream End at Limit of Study	227	408	588	808	1,487
31250	Unnamed Stream (Saint Thomas Model #167)	0	Downstream End at Confluence with Santa Maria Bay	457	837	1,224	1,709	3,281
31344	Unnamed Stream (Saint Thomas Model #167)	3,238	Upstream End at Limit of Study	116	205	291	395	697
31345	Unnamed Stream (Saint Thomas Model #177)	0	Downstream End at Confluence with Santa Maria Bay	1,108	2,067	3,079	4,387	8,888
31482	Unnamed Stream (Saint Thomas Model #177)	7,378	Upstream End at Limit of Study	94	166	234	315	550
31483	Unnamed Stream (Saint Thomas Model #184)	6	Downstream End above Confluence with Atlantic Ocean	506	928	1,359	1,902	3,675
31523	Unnamed Stream (Saint Thomas Model #184)	2,296	Upstream End at Limit of Study	278	504	729	1,007	1,875

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
31524	Unnamed Stream (Saint Thomas Model #190)	0	Downstream End at Confluence with Vessup Bay	469	859	1,257	1,757	3,378
31601	Unnamed Stream (Saint Thomas Model #190)	4,296	Upstream End at Limit of Study	98	173	246	331	579
31602	Unnamed Stream (Saint Thomas Model #202)	97	Downstream End above Confluence with Vessup Bay	466	854	1,249	1,745	3,354
31650	Unnamed Stream (Saint Thomas Model #202)	4,491	Upstream End at Limit of Study	93	164	233	313	546
31651	Unnamed Stream (Saint Thomas Model #204)	28	Downstream End above Confluence with Atlantic Ocean	618	1,139	1,676	2,356	4,607
31698	Unnamed Stream (Saint Thomas Model #204)	3,200	Upstream End at Limit of Study	238	429	618	850	1,569
31699	Unnamed Stream (Saint Thomas Model #211)	0	Downstream End at Confluence with Dorothea Bay	1,202	2,246	3,352	4,784	9,739
31790	Unnamed Stream (Saint Thomas Model #211)	5,344	Upstream End at Limit of Study	405	740	1,079	1,502	2,863
31791	Unnamed Stream (Saint Thomas Model #215)	75	Downstream End above Confluence with Magens Bay	719	1,330	1,963	2,769	5,465
31806	Unnamed Stream (Saint Thomas Model #215)	1,905	Upstream End at Limit of Study	276	499	722	997	1,857
31807	Unnamed Stream (Saint Thomas Model #219)	45	Downstream End above Confluence with Hull Bay	698	1,290	1,903	2,682	5,284
31827	Unnamed Stream (Saint Thomas Model #219)	1,430	Upstream End at Limit of Study	144	257	367	499	894

Cross Section ID	Flooding Source Name	Stream Station (feet above mouth)	Location Description	Discharge in Cubic Feet Per Second				
				10 Yr. (10%)	25 Yr. (4%)	50 Yr. (2%)	100 Yr. (1%)	500 Yr. (0.2%)
31828	Unnamed Stream (Saint Thomas Model #222)	11	Downstream End above Confluence with Magens Bay	521	956	1,401	1,962	3,797
31857	Unnamed Stream (Saint Thomas Model #222)	1,589	Upstream End at Limit of Study	163	292	418	570	1,029
31858	Unnamed Stream (Saint Thomas Model #233)	99	Downstream End above Confluence with Smith Bay	231	416	600	825	1,519
31887	Unnamed Stream (Saint Thomas Model #233)	2,574	Upstream End at Limit of Study	102	181	257	347	608
31888	Unnamed Stream (Saint Thomas Model #242)	53	Downstream End above Confluence with Water Bay	1,133	2,116	3,154	4,495	9,120
31940	Unnamed Stream (Saint Thomas Model #242)	5,519	Upstream End at Limit of Study	175	314	449	614	1,112
31946	Unnamed Stream (Saint Thomas Model #246)	1,524	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #242)	227	408	588	808	1,487
31979	Unnamed Stream (Saint Thomas Model #246)	4,152	Upstream End at Limit of Study	114	202	287	388	684
31980	Unnamed Stream (Saint Thomas Model #264)	6	Downstream End above Confluence with Leeward Passage	2,308	4,377	6,621	9,590	20,314
32049	Unnamed Stream (Saint Thomas Model #264)	7,174	Upstream End at Limit of Study	185	333	477	653	1,187
32056	Unnamed Stream (Saint Thomas Model #270)	1,662	Downstream End above Confluence with Unnamed Stream (Saint Thomas Model #264)	698	1,289	1,901	2,680	5,279
32105	Unnamed Stream (Saint Thomas Model #270)	5,136	Upstream End at Limit of Study	189	340	487	667	1,214

3.1.3 Hydraulic Analyses

The scope for the hydraulic analyses was to develop non-regulatory BLE flood hazard information for approximately 130 miles of existing CNMS stream mileage, as well as an additional 25 miles of unmapped areas determined after project initiation. A stream network was developed by leveraging FEMA's CNMS centerlines and NHD high-resolution data for unmapped areas. **Figure 1** provides spatial location of the BLE analysis of 161 miles. **Appendix A** provides the list of streams where the hydraulic analysis was conducted, along with HEC-RAS model naming convention. Stream centerlines were adjusted to better fit the LiDAR data from the original source of CNMS database or NHD stream centerlines.

Steady flow HEC-RAS hydraulic models were developed for the 10-percent, 4-percent, 2-percent, 1-percent, and 0.2-percent annual chance flood events. Model geometry and mapping were developed automatically using GIS tools and scripts and then refined as needed. A common modeling practice that was not considered in this analysis was the inclusion of field survey data for bridges, culverts, levees, and split flow analysis. The models were developed for the 1-percent and 0.2-percent annual chance flood events. They were not refined for the more frequent, lower flow events. These are included for informational purposes only.

A single conveyance area was used for each cross-section, e.g. bank stations were set at the outer limits of the cross-section. This method has been found to give good results, especially when Manning's n-values were set based on land-use coverage and wetted area.

No supercritical flows were permitted in the models, so the lowest possible water surface elevation for any cross-section was critical depth.

After automated hydraulic models were developed, the floodplains and cross-sections were visually reviewed. Cross sections with unusual changes in hydraulic parameters (water surface and energy grade slopes, water surface elevations, and velocity) were examined. In numerous cases, cross-sections were deleted or modified, to improve the quality of the hydraulic model. Ineffective flow areas were added where appropriate.

3.1.3.1 Discharges

Discharges for all events were imported into HEC-RAS using the final flow grids described in Section 3.1.2 and automated tools. A flow rate was assigned for each cross-section location.

3.1.3.2 Boundary Conditions

The downstream boundary condition for almost all models was set at critical depth. At confluences, the tributary models were extended downstream to follow the main channel that they join. Generally, five cross sections, identical to the main stem sections, were modeled in the extended area. The tributary discharge was applied to these sections. This process allowed for a smooth transition in water surface elevation and thus floodplains between tributaries and main channels. In the confluence area and the downstream portion of the tributary, the higher water surface of the main stem is used to develop the water surface grids and floodplains, negating any inaccuracies associated with the critical depth boundary condition on the tributary stream.

"Normal" depth is typically used in hydraulic models as the downstream boundary condition. However, the use of normal depth requires an estimate of the "normal slope," which depends on the method used to estimate it. Fully automated methods to estimate the normal slope for large numbers of reaches are not completely reliable. In particular, there is a risk that the slope may be estimated too low, which can cause a significant and unrealistic backwater conditions at the start of the model, which may perpetuate for a long distance upstream. When critical depth is used, the models will typically stabilize to a “normal” depth within just a few cross-sections.

3.1.3.3 Cross Sections

Although some cross sections were edited manually, cross section placement was primarily automated. Cross sections were placed perpendicular to the direction of flow. Cross section spacing was typically at 200 feet or less. Cross section geometries were obtained by overlaying the cross-section on the DEM topography.

After automated placement, a series of checks was performed to look for unusual changes in water surface elevation, slope, or velocity between cross-sections for the water surface profile of the 1-percent plus annual chance exceedance event. Places flagged as exhibiting unusual behavior were examined, and cross-sections were sometimes modified (or deleted) in these areas. This process resulted in the final cross-sections location and orientation.

There is a single HEC-RAS geometry that is used for all flow events (i.e., the same cross sections are used to model all events).

3.1.3.4 Ineffective Areas

Ineffective flow limits were added to account for non-conveyance areas and flow contraction (1:1 ratio) and expansion (2-3: 1 ratio). The ineffective flow locations were identified based on the 1-percent and 0.2-percent annual chance events. The same ineffective flow limits were applied to all events.

3.1.3.5 Channel Roughness Values

Manning’s n values were assigned to each class in the International Institute of Tropical Forestry land cover for the US Virgin Islands (Kennaway et al., 2008). The correlation between land use codes and the Manning’s n-values are provided in **Appendix B**. For each model cross-section, a single n-value was computed by compositing the land cover Manning’s n values, using the Lotter method (Chow, 1959, p. 136-137), along the portion of the cross section that was wetted by the 1-percent annual chance flow. These composite n-values were then used for all other event simulations. If the Manning’s n value varied significantly at adjacent cross section, aerial imagery was used to check the reasonableness and adjustments were made where appropriate.

3.1.3.6 Structures

Detailed bridge and culvert data were not available for the islands. To be conservative, elevated roadways were modeled as weir flow cross sections.

3.1.3.7 Expansion and Contraction

Default contraction and expansion coefficients (0.1 and 0.3) were used.

3.1.3.8 Special Issues

Flows were not decreased due to model breakouts, nor were models modified to take them into account.

Where possible, the streamlines were extended to the coast. However, if the stream was not defined in the LiDAR near the coast, the streamline was terminated based on the topography. One-dimension modeling was deemed inappropriate downstream of these locations.

Some streams turned into perched drainage ditches that could not convey or contain the 1-percent annual chance discharge. The streamlines were modified as appropriate to follow the main flow path rather than the drainage ditch.

A polygon shapefile identifying hydraulic model issues and comments was provided with the model deliverables.

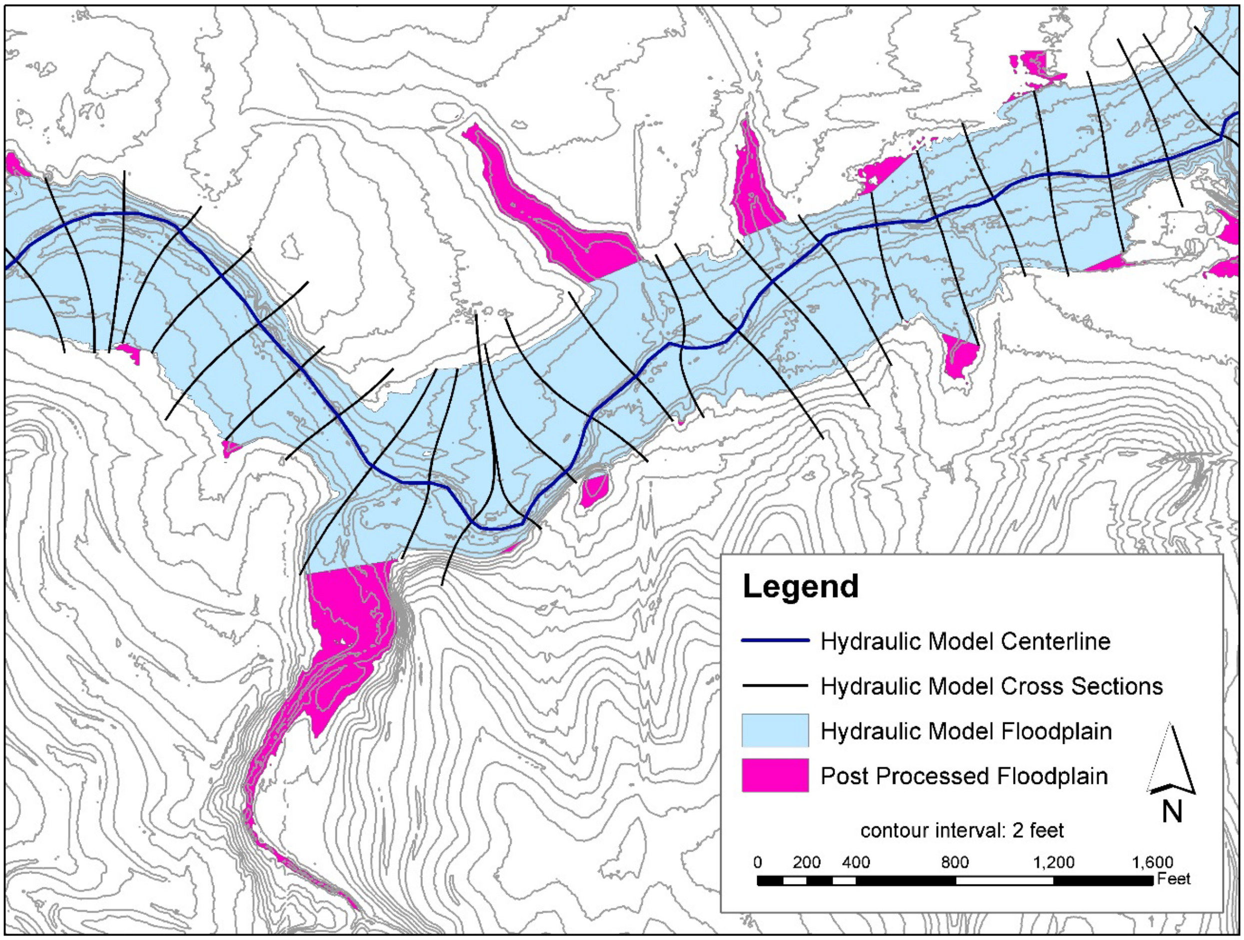
3.1.4 Floodplain Mapping

Floodplains were generated for the 1-percent and 0.2-percent annual chance exceedance events for the hydraulic model reaches. **Appendix A** provides the list of the streams where the floodplains were developed. These floodplains were utilized to determine if the hydraulic model results looked reasonable, and if the models needed adjustment.

The floodplains were based on water surfaces interpolated from the hydraulic model cross-sections. In most locations where flow containment was lost at the limits of the models, backwater conditions were considered and the floodplains adjusted with an automated post-processing step to include additional backwater areas.

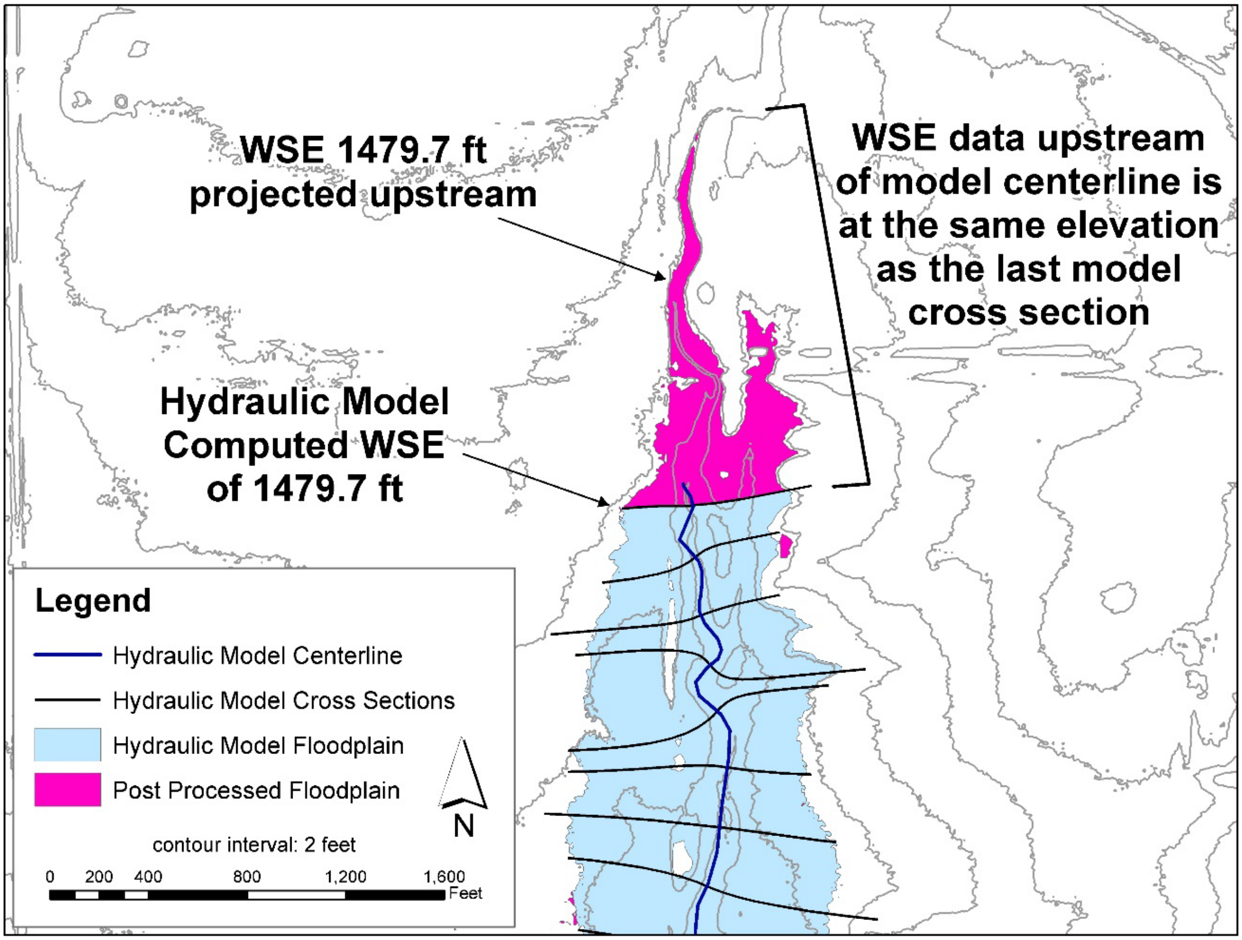
Figure 5 shows backwater that was added beyond the limits of the hydraulic model. **Figure 6** shows an example of backwater that required additional area because the water surface elevations extend upstream beyond the upstream limits of most models.

Figure 5: Post Processed Floodplain



The post processing of floodplains adds backwater areas along a modeled reach that would be flooded but were not reflected in the hydraulic model; typically; these occur as small tributaries join a larger reach

Figure 6: Post Processed Floodplain



The post processing of floodplains also adds backwater areas upstream of the hydraulic model, these areas have the projected water surface from the most upstream cross section.

For locations where the models overlap (e.g. at confluences), the highest water surface elevation across all models dominated and resulted in the largest delineated floodplain by definition.

3.1.5 1-Percent Riverine Floodplain Product Limitations / Assumptions

The 1-percent flood hazard data produced by this effort should provide a useful resource in support of residential areas subject to riverine hazards within the 1-percent floodplain. The data were subject to internal team and independent review to identify and correct issues and ensure overall product quality. The product is subject to the following limitations/assumptions due to inherent errors in the data resources and the production approach:

1. Hydrologic Analyses

   - The recording of the peak discharges at stream gages was interrupted by gage failures during Hurricanes Irma and Maria. USGS is currently working to develop estimates using all available data. Once the USGS estimates are published, the stream gage analyses may produce different results than those estimated by this study.

2. Hydraulic Analyses

   - Underwater cross sections are not based on a ground survey, which may result in higher channel invert elevations.
   - Channel bank stations were set at the outer limit of cross sections. The high flow channel is not identified in the cross section geometry used by the hydraulic model. However, the significant adverse effects of this assumption are mitigated to some extent by the use of single composite Manning's roughness coefficient.
   - Split flows were not modeled separately.
   - Detailed bridge and culvert data were not available for the islands. To be conservative, elevated roadways were modeled as weir flow cross sections.

3. Floodplain Delineation, Flood Elevation Labeling, and Tie-in with Coastal Floodplain

   - FIRM-type Base Flood Elevations (BFEs) were not developed. Modeled cross sections were clipped to the floodplain boundary extents wherever possible, and used as proxies to represent the water surface elevations.
   - Minimal cleanup of floodplain mapping was performed based on visual inspection.
   - An additional deliverable termed "BFE proxy cross sections" was created to provide computed water surface information from the 1-percent annual chance flood profile in a user-friendly format. From the hydraulic model cross sections, a processed version of cross sections was created that removed overlapping cross sections. In areas with overlapping cross sections from multiple models the cross sections with the most representative extents and water surface elevation (most commonly the higher water surface elevations) were left in place. Occasionally water surface elevations were computed to decrease in the upstream direction; in these cases cross sections with decreasing upstream flood elevations were always removed.

3.2 Coastal Advisory Data Development

Final coastal advisory data development deliverables include GIS polygon shapefiles representing the storm-induced erosion, including areas identified from the erosion analysis supporting the 1-percent wave hazard modeling as well as the visual analysis of the post-storm imagery.

These products are intended for digital delivery and dissemination for desktop GIS and/or Web-GIS platforms. The following sections provide information on data sources and limitations, production procedures, and guidance on usability for each of the coastal advisory data deliverables.

3.2.1 Terrain Processing

Newly acquired high resolution topographic LiDAR data was obtained from NOAA in the Virgin Islands Vertical Datum of 2009 (VIVD09) vertical datum. The newly updated topographic DEM surface was used as the basis of all subsequent analyses.

3.2.1.1 Coordinate Systems and Unit Conversions

The data source used for the updated topographic DEM was the new 2013 NOAA topographic LIDAR dataset for the U.S. Virgin Islands. This data was provided via the NOAA Digital Coast Data Portal in a different coordinate system and units than those used in this project. Therefore, the source data was re-projected, re-sampled, and converted into the target coordinate system and units. Coordinate system re-projections were carried out using the ESRI Project Raster tool, while conversions from meters to feet were performed using the standard definition of 1 meter being equal to exactly 3.28084 feet. The specifics of the source data and target coordinate systems and units can be seen in **Table 3-8**.

Table 3-8: Resolution, Vertical Datum, and Coordinate Systems Associated with the Existing Study Data, New Data Source, and Final Topographic DEM

Raster Data	Resolution	Vertical Datum	Coordinate System
Existing Study	25 feet	feet, Local Mean Sea Level	NAD_1983_StatePlane_Puerto_Rico_Virgin_Islands_FIP_5200_feet
2013 NOAA LiDAR	1 meter	meters, VIVD09	NAD_1983_NSRS2007_StatePlane_Puerto_Rico_Virgin_Isls_FIPS_5200
Updated Project DEM	10 feet	feet, VIVD09	NAD_1983_StatePlane_Puerto_Rico_Virgin_Islands_FIP_5200_feet

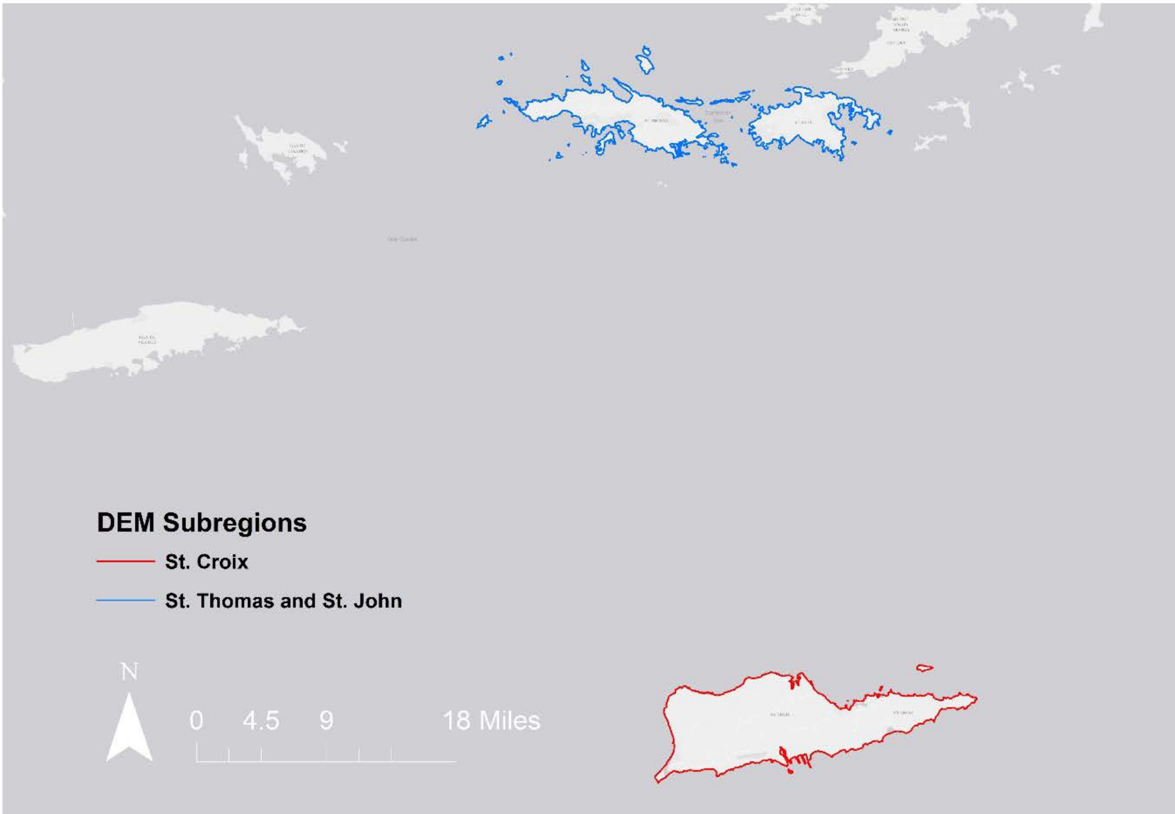
3.2.1.2 Mosaicked Topobathy DEM

Once all of the source data raster files had been converted to the specified project coordinate system and units, the final step in the new DEM creation process was to combine the topographic data rasters so that each island is represented by no more than one individual raster file. This was accomplished using the ESRI Mosaic to New Raster tool. The combined topographic raster files were then reviewed through an internal QC process. If any discontinuities or quality issues were found in the data, the source of each issue was addressed and the updated surface was created and reviewed once more. The final topographic DEM for each island was saved in raster GeoTIFF format.

3.2.1.3 Data Subregions

The advisory study topographic DEM is broken up into two subregions (shown in **Figure 7**), including one region covering both the Islands of St. John and St. Thomas, and the other including the Island of St. Croix and its associated archipelago.

Figure 7. Subregions Used to Create Topographic DEM Data



3.2.1.4 Shoreline Delineation

In order to derive a 0 foot VIVD09 shoreline, a raster layer was created by performing a focal mean over a 3x3 cell window using the ArcGIS Focal Statistics tool with the new project DEM as the input. The ArcGIS Contour List tool was then used to extract a 0 foot VIVD09 shoreline from the smoothed DEM. This shoreline was visually inspected, disconnected contours were removed, and overly complex sections of shoreline were manually redrawn. This shoreline then went through internal QC and any revisions, if needed, were made.

3.2.2 Long Term Erosion

It was initially intended to complete long-term shoreline change analysis for the US Virgin Islands to be used to inform recovery efforts of potential long-term coastal hazards. A review of existing studies did not identify any modern island wide studies of shoreline change for the US Virgin Islands. Efforts were made to locate long term shoreline change data for the three major islands of the USVI through a detailed internet search and contacting sources that could potentially provide the necessary data. The results from this research established that there is currently no long term shoreline change data available. A summary of sources found through the internet search and contacts made is provided below.

Potential sources of shoreline change data that were found from the detailed internet search included:

- Study conducted by the USGS on the “Coastal Vulnerability Assessment of Virgin Islands National Park (VIIS) to Sea – Level Rise” (Pendleton et al., 2005) in which shoreline erosion and accretion rates were only included for the Virgin Islands National Park.

- Study presented by Georgia Southern University at GSA in 2013 on the “Assessment of Shoreline Change for Small Associated Islands of Puerto Rico and the United States Virgin Islands” (Runyan et al., 2013). The authors were contacted but had no shoreline change data for the USVI that they could provide.

- The USGS Coastal Change Hazard Portal was accessed and confirmed that no data was available for the USVI.

- The “Development of National Scale inventory of Shoreline Change Data for Identification of Erosion and Accretions” (Stauble, 2004) from USACE reported that no historic shoreline change programs were found for the USVI at that time.

- NOAA historical surveys were located but only provided partial coverage for St. Thomas and St. John and no coverage for St. Croix was available.

- The Coastal Vulnerability Index database was accessed; no information for the USVI was found to be available.

The list of contacts made to inquire whether there was any available data that they could provide in regards to shoreline change rates on the USVI included:

- Chester Jackson, of Georgia Southern University involved in the study conducted in 2013, assessing shoreline change for small islands of Puerto Rico and the USVI, established that they did not have any long term shoreline data currently available.

- Greg Guannel of UVI established that there was currently no data for shoreline change in the Virgin Islands other than the study done in the Virgin Islands National Park by the USGS covering only a portion of St. Thomas. The Department of Natural Resources may be planning on conducting a survey but a timeline has not been established. UVI is submitting a proposal with NSF in July to establish a long term shoreline monitoring program.

- Pedro Nieves from the DPNR CZM indicated that there were currently no active monitoring programs looking at shoreline change in the USVI. They are looking to develop a high resolution one using drone technology but are still working on the scope.

- Emily Himmelstoss and Rob Thieler of the USGS responded that they were not currently working on any shoreline change assessments for the USVI as part of the national shoreline change project but provided direction to a shoreline vectorization effort that NOAA worked on and that converted all historic T-sheets to shapefiles. The T sheets were downloaded and it was found that coverage of the islands was limited.

3.2.3 Storm Induced Coastal Erosion Prone Areas

The USVI coastline experienced significant erosion from Hurricanes Maria and Irma. Although some areas may not have had significant flooding, many structures experienced foundation damage due to storm-induced erosion. The areas impacted by storm-induced erosion during Hurricanes Maria and Irma were identified and mapped to highlight areas of significant change based on pre- and post-storm imagery and to help identify areas where mitigation projects might be desirable. The following components comprised this task:

3.2.3.1 Areas of Significant Storm Induced Erosion from Hurricane Maria and Irma

Areas of significant storm-induced erosion from Hurricane Maria and Irma were identified from a visual review of post-disaster vertical aerial photographs in comparison with the shoreline delineated from the pre-storm 2013 NOAA LiDAR surveys, used in the mapping tasks, and available pre-storm imagery. Each area of significant storm-induced erosion was delineated and a count of structures impacted by erosion was recorded.

The erosion areas were delineated based on a visual assessment of all data sources. Post-event imagery was sourced from Vexcel and NOAA. Vexcel imagery covers St. Thomas and St. John and NOAA imagery covers St. Croix. Pre-event imagery was sourced from NOAA Digital Coast and Google Earth. Naturally dynamic areas were disregarded based on indicators of vegetation and soil disturbance, as well as historical imagery from Google Earth Pro. Through this process, care was taken to distinguish between deceptive variations in the brightness and saturation of aerial imagery. Areas where the tree and shrub canopies were stripped, exposing the substrate beneath, were evaluated on a location by location basis. Oftentimes, these areas appeared to have been eroded when in fact the removal of vegetation exposed the existing underlying non-eroded natural materials.

Three types of coastal erosion processes were determined: erosion, deposition, and overwash. Coastal erosion occurs where sand is removed from the beach system; deposition occurs where sand is transported and stored in new sandbars; and overwash occurs where storm-induced waves and surge transport and deposit sand landward.[1] Erosion can be identified in the aerial photos with indicators such as scarping, channel incision, and the disappearance of sandy areas. Deposition can be identified by new areas of sand deposits. Overwash can be identified by areas where sand was pushed inland of the original beach.

3.2.3.2 Areas of Expected 1-Percent-annual-Chance Storm Induced Erosion

The effective FIS was used to identify areas of potential 1-percent-annual-chance level storm-induced erosion. Areas that had no erosion modeled during the effective study were not covered, however this does not mean that areas not covered by the effective study are not at risk to storm-induced erosion. A GIS polygon coverage was created to identify the areas of erosion modeled in the effective study. The polygons were bounded by the updated shoreline developed for this effort from the 2013 LiDAR and the area subject to erosion.

For coastal areas where sand veneer overlays rocky ledges, a non-standard erosion methodology was applied in the effective FIS and the sandy veneer was removed to varying depths. **Appendix C** describes the non-standard erosion from the effective FIS and describes how the methodology was applied to the flood hazard modeling transects.

[1] USGS St. Petersburg Coastal and Marine Science Center.

The polygons were delineated landward based on either visual inspection of the sandy beach area, extent of erosion identified in the effective CHAMP database transects, or documentation from the effective FIS. The seaward extent was drawn along the updated shoreline established from 2013 LiDAR and then extended to either side of each transect. The alongshore extent was determined by a visually apparent change in beach morphology (coast type and/or composition) or other coastline characteristics such as changes in vegetation, shoreline orientation, presence of shoreline protection structures, or shoreline steepness. In cases where none of these factors provided a clear breakpoint, the zone was extended to the approximate midpoint of the next adjacent transect.

3.2.3.3 Storm Induced Erosion Product Limitations / Assumptions

The information produced by this analysis will provide a useful resource for identifying areas subject to coastal storm erosion in support of the recovery effort. The following are data limitations and associated considerations:

1. The Hurricane Maria and Irma storm-induced erosion areas are solely based on aerial imagery analysis; no ground verification was performed.
2. The storm induced erosion areas include the effects of both Hurricanes Maria and Irma because aerial imagery was not collected between those two storm events.
3. Areas indicated as experiencing erosion from Hurricanes Maria and Irma may recover from the erosion as time passes and the erosion identified may not be visible. Sand may be transported back to a beach from offshore deposits, or, similarly, overwashed sand may be removed from inland areas through both natural and man-made processes.
4. The expected 1-percent-annual-chance storm erosion areas are based on the analysis performed in the effective coastal FIS; no changes to the erosion type and analysis for current conditions were made.
5. The storm erosion potential areas are based on the effective FIS transect locations with interpolation between transects applied.

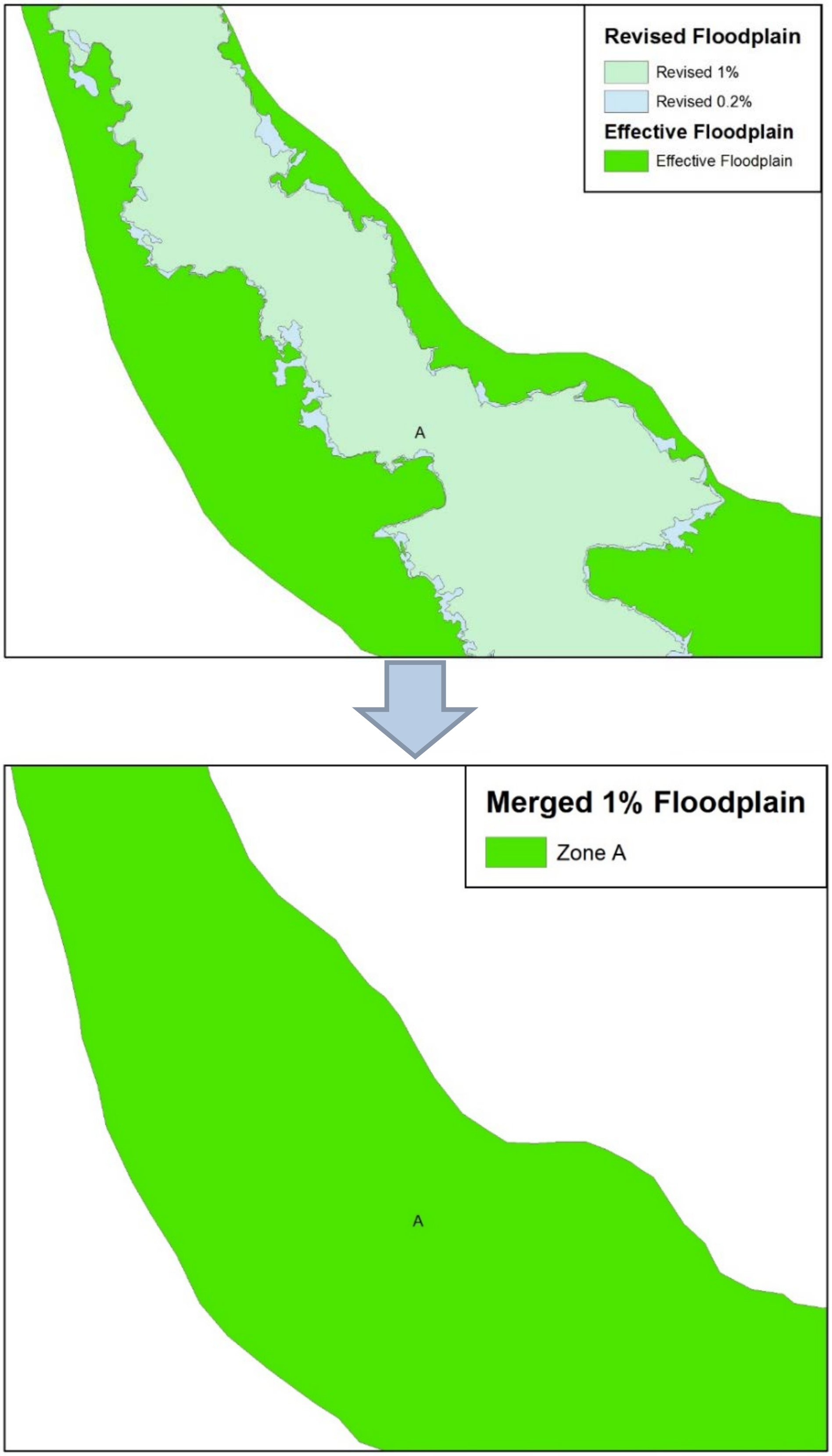
3.3 Supporting Advisory Products

3.3.1 Floodplain Product Development

3.3.1.1 Merged 1-Percent and 0.2-Percent Floodplain Generation Process

In order to show the most conservative picture of flood hazards and to generate seamless 1-percent and 0.2-percent floodplain advisory products, the new advisory floodplains were merged with the floodplains shown on the effective FIRM. Where the effective floodplain is wider than the newly computed advisory floodplain extent, the effective floodplain extent was retained as the more conservative advisory floodplain extent. Additionally, to ensure seamless transitions for the merged product coastal riverine tie-in areas were revisited. **Figure 8** shows an example of the merging process.

Figure 8: Merged Floodplain Generation Process Illustration



3.3.1.2 0.2-Percent Fringe Floodplains

For the 1-percent floodplains, a 0.2-percent shaded X Zone fringe was developed, similar to the standard FIRM floodplains. These 0.2-percent fringe areas were also built based on the most conservative floodplain respective to the effective or new advisory 0.2-percent mapping. Due to the new topographic information being used to map the advisory 0.2-percent floodplain boundaries, there were areas where the 0.2-percent floodplain extent was less than the effective 1-percent floodplains. As noted earlier, in those areas, the effective 1-percent floodplain extent was used, thereby covering the calculated 0.2-percent floodplain extent.

3.3.1.3 Merged Riverine Cross Sections

The USVI advisory maps contain riverine floodplains developed from multiple models that utilized effective detailed and advisory BLE methods. In certain areas, water surface elevations existed from both effective and advisory models, thereby requiring a hierarchal protocol for display of flood elevations on the advisory maps as follows:

1. The effective and advisory cross sections were combined (maintaining elevation information) into a single "merged cross section" feature.

2. Where advisory cross sections crossed multiple stream reaches, cross sections were clipped to the appropriate stream reach.

3. On the merged cross section dataset, stationing was assigned in the upstream direction of every stream reach.

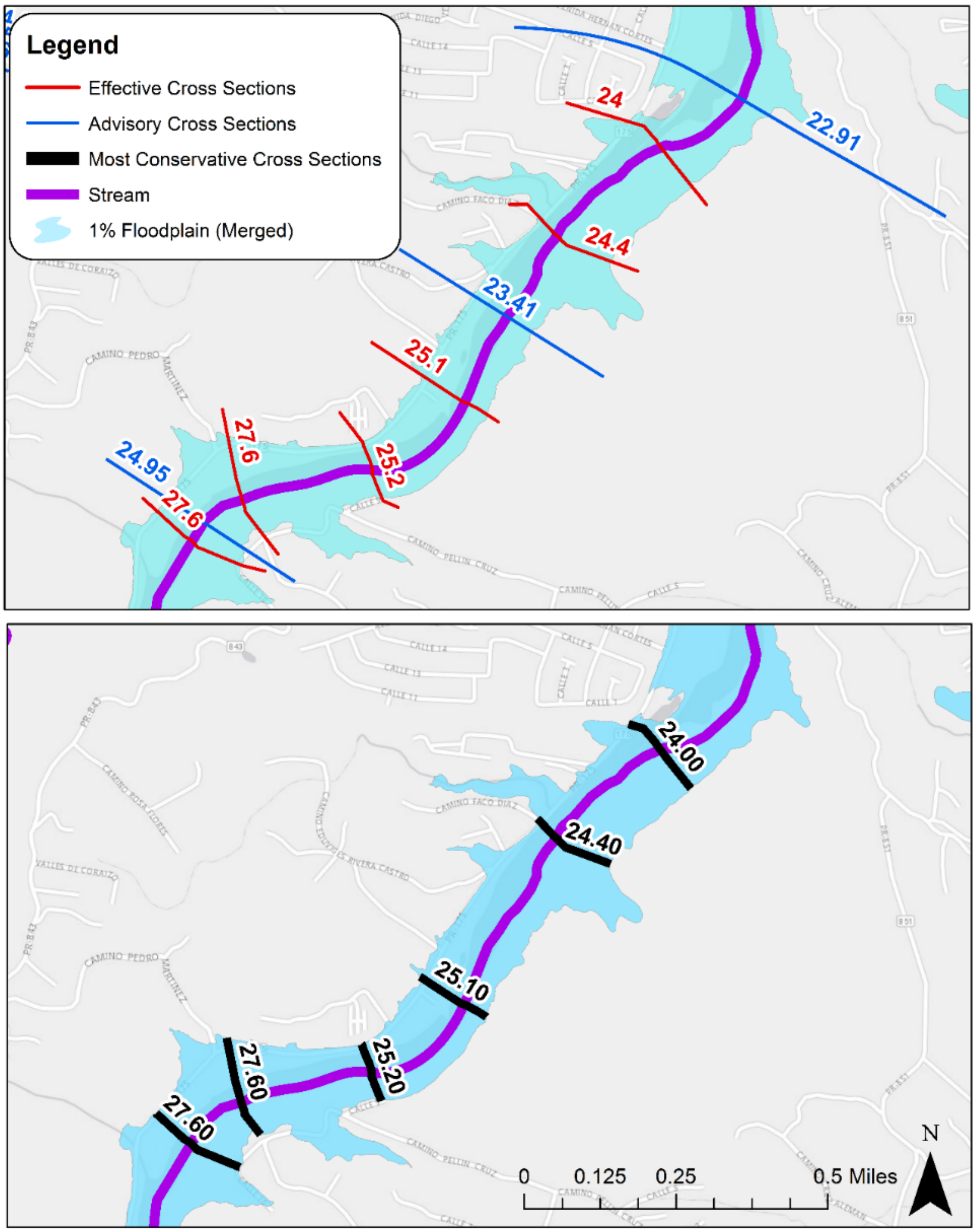
4. A Python script was developed that performed the following procedure on the merged cross section feature (with stream name and station number):

    a. Iteration through the dataset by stream name beginning with the first station (ascending) and testing each cross section. If the water surface elevation (WSE) was less than the previous cross section, the cross section was removed, and then it continued to the next upstream cross section. In this way, where two cross sections exist from differing models, the more conservative WSE was used in the final mapping product. The resulting GIS shapefile therefore represented a blended dataset providing the most conservative WSE in areas of conflicting data.

    b. In places where the effective cross section showed a higher WSE than the advisory model (and was therefore used as the more conservative information), these effective cross sections only had values for the 1-percent frequency. Because the advisory cross sections upstream and downstream of these effective cross sections are represented by 5 frequencies, a linear interpolation was used to populate the remaining frequencies. The methodology for this was as follows: 1) all frequencies were interpolated from the downstream advisory cross sections, 2) the 1-percent WSEs from the interpolated cross section and the effective cross section at this location were used to create a normalization factor, and 3) this normalization factor was applied to all of the frequencies on the effective cross section, resulting in a seamless WSE for the reach, with all frequencies attributed to all cross sections.

c. An interpolation check was performed to identify spaces in between the stationing that may have shown a higher water surface elevation if interpolation was performed on the unmerged, original datasets. In the areas where these interpolations would have resulted in a higher flood elevation, manual edits were made, and BFE lines were brought in from the effective. **Figure 9**: Selection of Most Conservative Riverine Water Surface Elevation Process shows an example of the BFE line selection process.

Figure 9: Selection of Most Conservative Riverine Water Surface Elevation Process



5. Manual clean-up was then performed as follows:

    a. Where cross sections overlapped, the more conservative cross section was maintained and the less conservative was removed or the cross section orientation was altered to avoid the overlap.

    b. The merged floodplain polygon was used to clip the cross sections so cross sections did not exist outside of the floodplain.

    c. Cross sections were extended where necessary to cover the floodplain and re-oriented to avoid cross section overlaps.

6. An independent quality review was performed on interpolated values, at junctions, at tie-ins, and at randomly sampled locations.

3.3.1.4 Final Floodplain Products

One merged floodplain product resulted from the merging of effective and advisory floodplain extents to present the most conservative floodplain and flood elevation for advisory purposes.

3.3.2 Map Change Products

The effective flood hazard data and the advisory 1-percent seamless flood hazard data were compared to analyze the changes in flood hazard zones. The analyses were developed using ESRI's ArcGIS software and its Geoprocessing tools. Spatial overlay tool "Union" was the primary function utilized for this analyses. The union function identified the differences between the effective and advisory flood zone information. This spatial analyses resulted in about 16 zone change (AE to A, VE to AE, A to X, etc.) combinations. To simplify the visualization and comprehension of this product, the change combinations were further grouped into 5 bins, attributed as "Change Description". **Table 3-9** summarizes the zone change combinations and the categories.

Table 3-9: Zone Change Combinations and Categories

Change Description	Zone Change Combination
ShadedX (SX) to SFHA	SX to A; SX to AE
UnShadedX (UX) to SFHA	UX to A; UX to AE; UX to AO
No Change to SFHA Designation	A to A; A to AE; AE to A; AE to AE; AE to VE; AO to A;AO to AO; VE to AE; VE to VE
No Change To ShadedX	SX to SX
UnShadedX to ShadedX	UX to SX

The map change product, which was in polygon GIS format, includes the results of the analyses. The dataset was attributed with above described zone change and change descriptions, including the source flood zone attribution from the effective flood zone and 1-percent advisory flood zone layers.

Additionally, a spreadsheet product was developed that included land area summaries that were based on the GIS change product, as the input. The spreadsheet products include the following land area summaries:

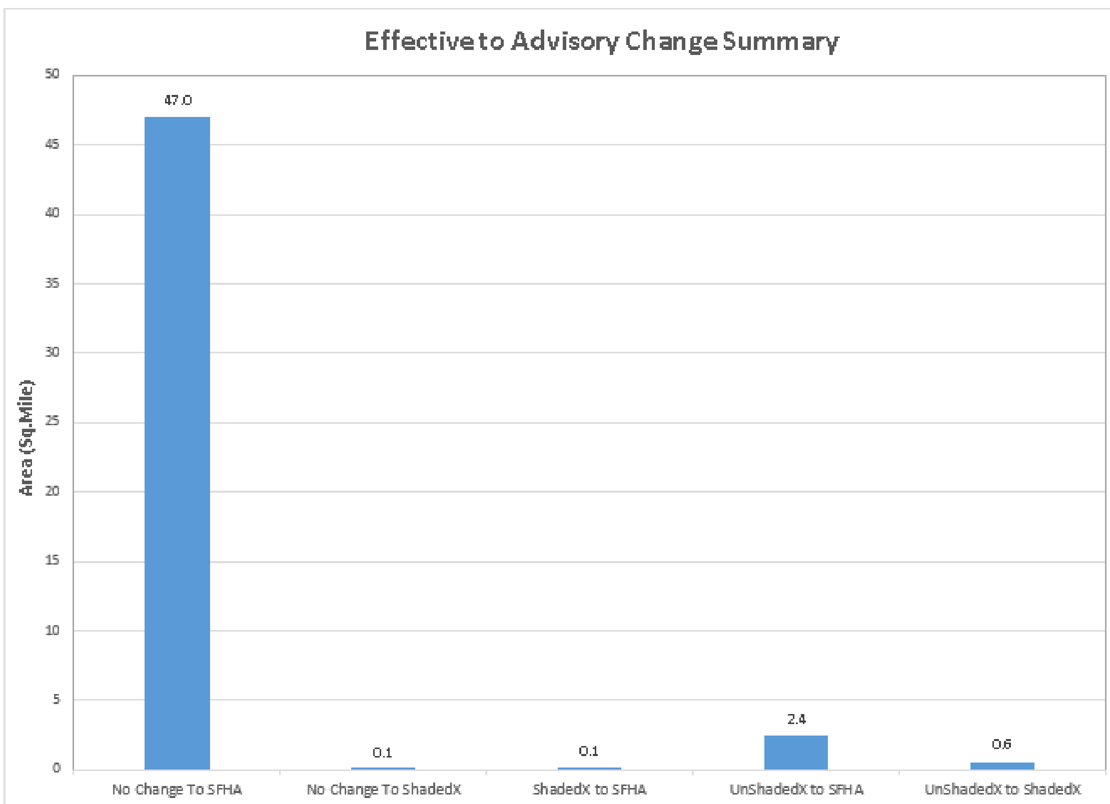
- Summary of Special Flood Hazard Area Change (Worksheet: SFHA_Change)
- Summary of Flood Zone Change, in Square miles (Worksheet: Zone_Change_SqMiles)
- Flood Zone Change summary in Acres (Worksheet: Zone_Change_Acres)

Provided below is a quick summary of the high-level discussion on change statistics (in square miles).

- Decreases to the 1-percent floodplain area: None
- Total 1-percent Floodplain Area Increase (Newly Added Areas to SFHA): 2.5 Sq. miles
    - o All increases are in the riverine areas
    - o No increases to coastal areas
- Area changed from UnShadedX to ShadedX: 0.6 Sq. mile

A graphical summary of floodplain changes is also provided in Error! Reference source not found..

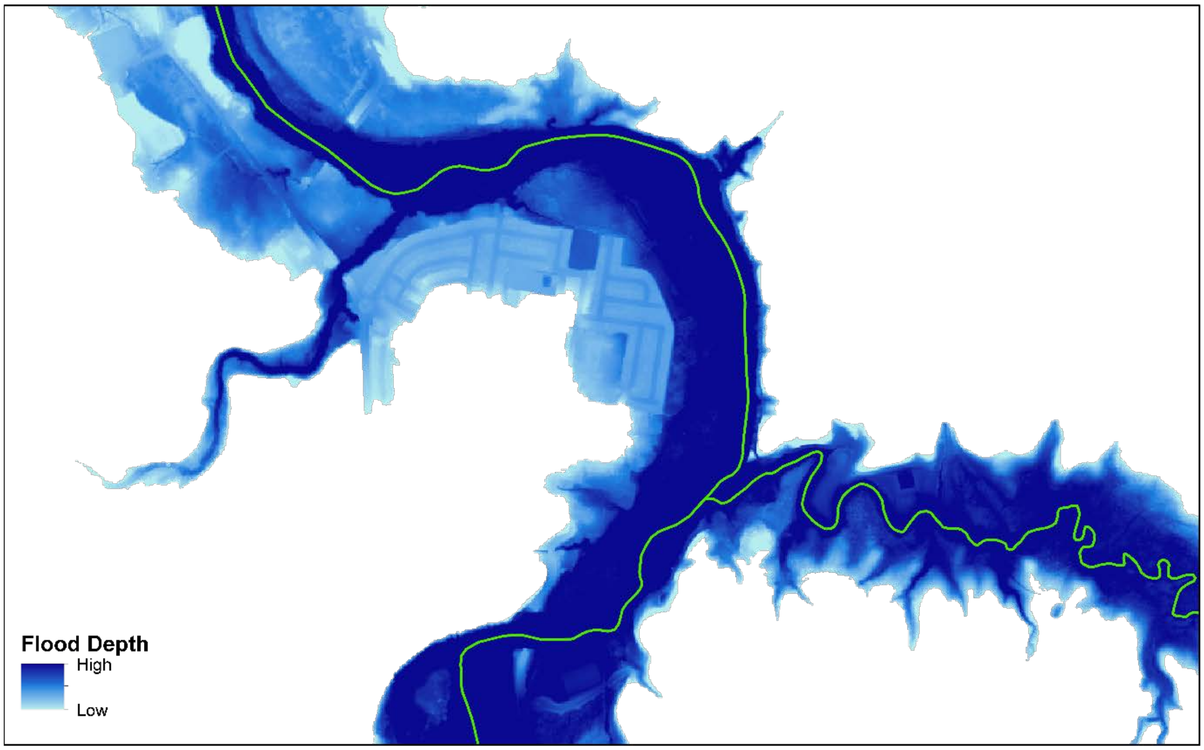
Figure 10: Flood Zone Change Summary



3.3.3 WSEL and Depth Grid Products

Flood depth and analysis grids are an ideal way to communicate more complete flood risk information for the new advisory mapping products. The value in each cell represents the magnitude of flooding in that particular area (see **Figure 11** where the darker blue areas represent greater flood depths). Flood depth grids are produced by taking the difference between water surface elevation (WSEL) grids and land topography. The following sections will describe the process for development of the WSEL and flood depth grids.

Figure 11: Flood Depth Grid Example



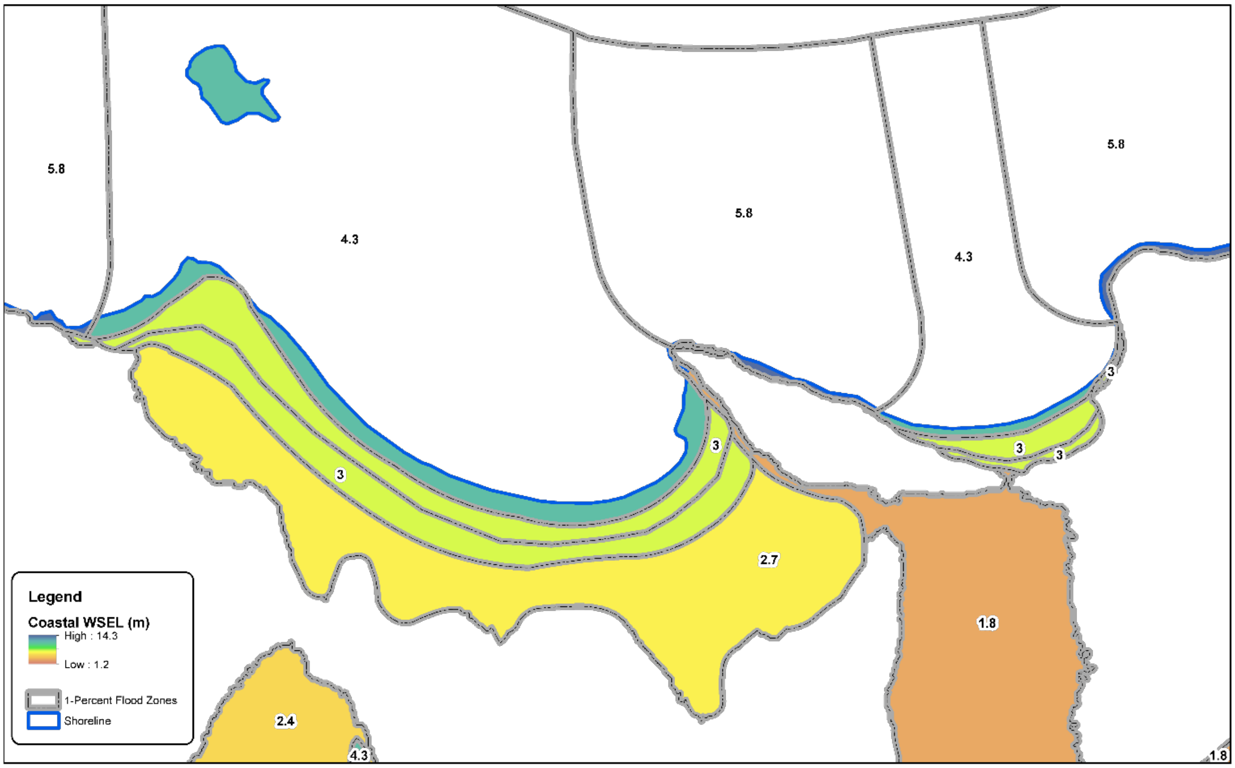
3.3.3.1 Water Surface Elevation (WSEL) Grid Development

WSEL grids were developed for both the 1-percent and 0.2-percent annual chance events. Each WSEL grid provides the WSEL values within the inundation extent of that particular flood event (the merged 1-percent and 0.2-percent floodplain products described in Section 3.3.1.1). Following FEMA guidance for flood risk analysis and mapping, the cell resolution for the WSEL grids were less than 10 feet x 10 feet. Specifically, a 5-foot cell resolution was chosen to ensure the grid complemented the geometry of the floodplain polygons.

3.3.3.1.1 Coastal WSEL Grid

The coastal WSEL grids were generated from the static base flood elevations (BFE) from the final merged floodplain polygons. According to FEMA guidance, while coastal water surface mapping may produce outputs that appear unnatural, the stair-step effect between coastal zones is considered normal and acceptable since the product is intended to yield results that most closely match the floodplain maps. The coastal WSEL was clipped to the USVI shoreline developed for this project**. Figure 12** shows example of a pure coastal WSEL grid.

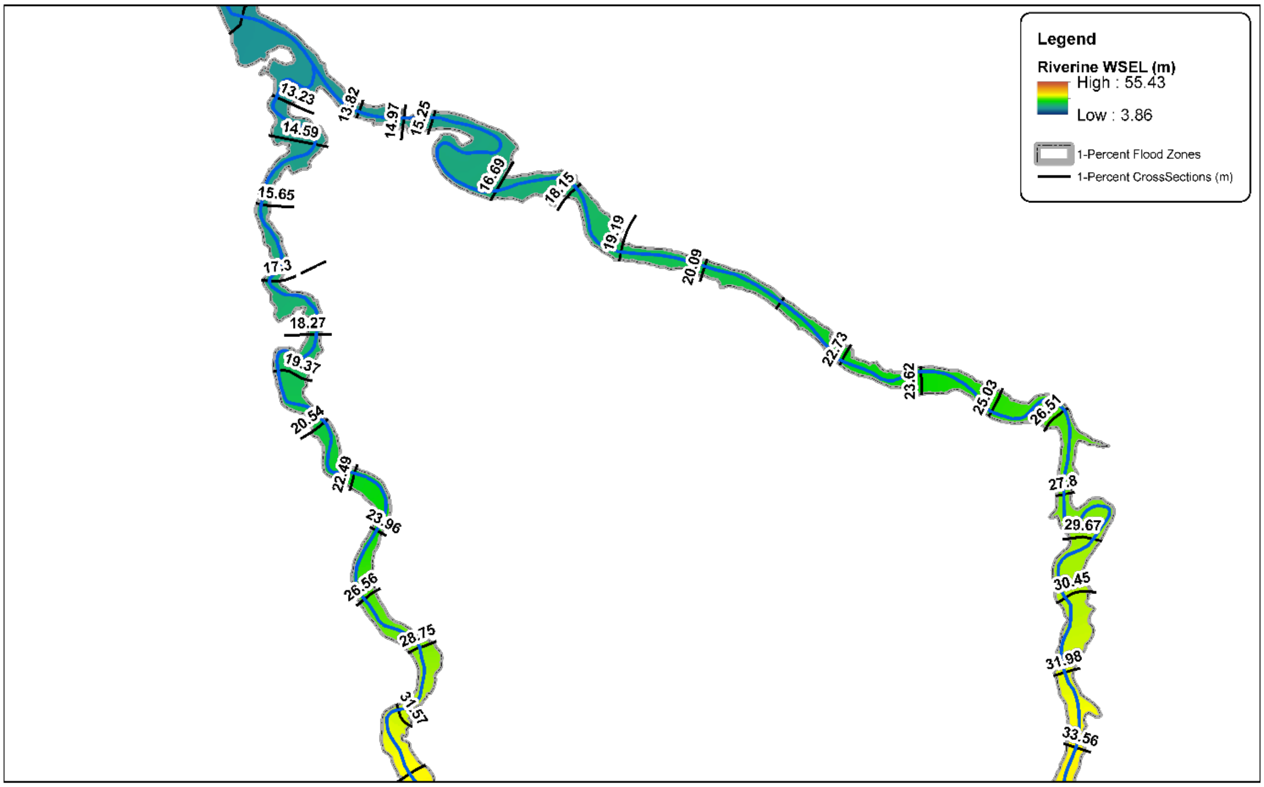
Figure 12: Coastal WSEL Grid Example



3.3.3.1.2 Riverine WSEL Grids

The riverine WSEL grids were developed using the merged riverine cross section dataset. This was accomplished by generating a Triangulated Irregular Network (TIN) from the vector water surface features and attributes (the water surface elevation, in meters). The TINs were created on a stream by stream basis to avoid some of the problems experienced in confluence areas, and then the individual TINs were converted to raster format and mosaicked together. The result is a continuous WSEL grid confined within the riverine floodplain (**Figure 13**).

Figure 13: Riverine WSEL Grid Example

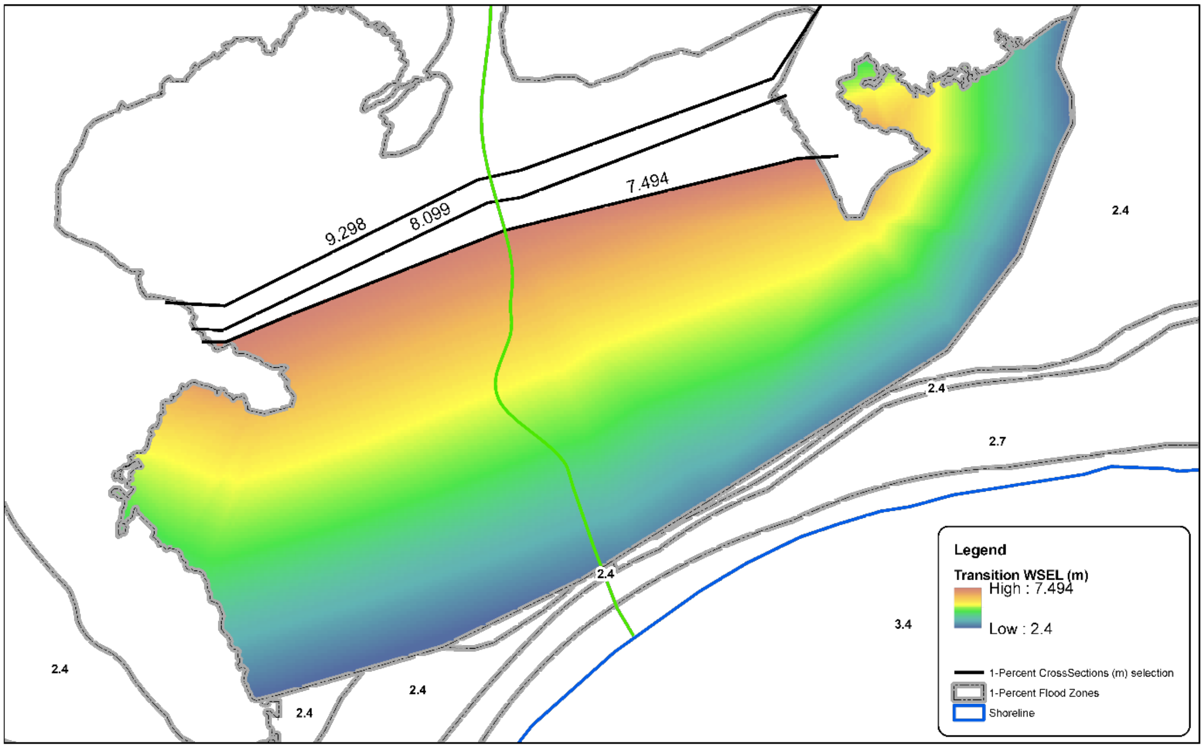


3.3.3.1.3 Quality Considerations

Several quality considerations were taken into account during development of the riverine and coastal WSEL girds.

- **Backwater areas:** A script was developed to ensure that backwater areas and side channels were interpolated properly; specifically, that the side channel was not interpolated to an elevation higher than the upstream cross section.
- **Coastal-riverine transition areas:** Individual TINs were developed for the coastal-riverine transition areas to ensure a smooth transition between these two different flood sources. **Figure 14** shows an example of a transition area.

Figure 14: Coastal-Riverine Transition WSEL Grid Example



- **Isolated/disconnected floodplain areas:** TINs were not automatically generated for floodplain polygons that were not connected to the main floodplain and that did not have an intersecting riverine cross section. These areas were manually assigned a WSEL value based on the nearest cross section and using engineering judgement. Isolated floodplain located farther than 200 feet from the main floodplain were assigned a "NULL" value to avoid making an incorrect judgement based on proximity.

3.3.3.2 Depth Grid Development

The riverine, coastal, and riverine-coastal transition WSELs were merged together to produce seamless WSEL grids for the 1- and 0.2-percent annual chance events. To generated depth grids, the 2013 LiDAR DEM was subtracted from the WSEL grids using a 5-foot cell resolution to match the DEM. Two additional steps were required to finalize the 1- and 0.2-percent depth grids:

- **AO Zones:** Since AO zones already represent depth of flooding, these polygons were converted to grids based on the Zone AO depths and then mosaicked into the depth grid.
- **Negative Depths:** As described earlier, the advisory products represent a merge of the detailed effective and new advisory floodplains and riverine cross sections. As a result, the depth grids produced negative depths in some areas – especially in areas where the effective floodplain was wider than the advisory floodplain mapped using the updated LiDAR DEM. These negative depths were converted to 0.1 foot to represent that these areas are still located within the regulatory FEMA floodplain even though no true depth of flooding was calculated.

3.3.4 Critical Facility Flood Risk Summaries

A critical facility provides services and functions essential to a community, especially during and after a disaster. *FEMA Fact Sheet: Critical Facilities and Higher Standards* notes that critical facilities can include a variety of facility types such as police stations, fire stations, critical vehicle and equipment storage facilities, and emergency operations centers. Individual communities typically determine the types of facilities that are considered "critical" to be included in a list of this sort. Although the US Virgin Islands include three primary islands as well as other smaller archipelago islands, the scope of work for this project did not include soliciting responses from each individual island as to which facility types would be considered critical to each. Rather, the project team utilized the aforementioned fact sheet to determine critical facility types that would be included in the effort. In support of defining critical facility types, a variety of point features were utilized to help identify critical facility building footprints. Priority was given to capturing individual buildings and data specific to each building at critical facility sites across the entirety of the US Virgin Islands. **Table 3-10** includes the list of site types considered for inclusion.

Table 3-10: Critical Facilities Site Types

Data Type	Source	Circa Date	GIS Data Layer
Police Stations	JFO Provided	2018	State_Police_CAD
	HIFLD Freedom	2018	Local_Law_Enforcement_Locations
Fire Stations	JFO Provided	2018	Fire_Stations_CAD
	HIFLD Freedom	2018	FireStations
Vehicle Storage Facilities	No Data	2018	Typically only able to be detected via streetview; separately tagged.
Equipment Storage Facilities	No Data	2018	Typically only able to be detected via streetview; separately tagged.
Emergency Operations Centers	HIFLD Freedom	2018	State_Emergency_Operations_Centers_EOC
Medical Facilities	JFO Provided	2018	USVI_HC.shp
			Health_Care_Facilities_CAD
			USVI_VeteransHealthAdmin.shp
	HIFLD Freedom	2018	Hospitals
			Urgent_Care_Facilities *(empty Feature class)*
			Veterans_Health_Administration_Medical_Facilities
Nursing Homes	HIFLD Freedom	2018	Nursing_Homes
Blood Banks	No Data	2018	Only separate from Hospital where identified.

Data Type	Source	Circa Date	GIS Data Layer
Medical Records Facilities	No Data	2018	Only separate from Hospital where identified.
Schools	JFO Provided	2018	VI_Schools_corrected.shp
		2018	Schools_USVI
		2018	Schools_USVI_1
	HIFLD Freedom	2018	Colleges_and_Universities
		2018	Private_Schools
		2018	Public_Schools
		2018	Supplemental_Colleges
Day Care Centers	HIFLD Freedom	2018	Day_Care_Centers
Power Generation Centers	No Data	2018	HIFLD is secure & HIFLD Data ONLY covers continental US.
Wastewater Treatment Plants	JFO Provided	2018	Wastewater_20171127_update.shp
	JFO Provided	2018	WasteWater.shp
Water Treatment Plants	No Data	2018	HIFLD is secure.
Volatile / Flammable / Explosive / Toxic Facilities	HIFLD Freedom	2018	EPA_Comprehensive_Environmental_Response_Compensation_and_Liability_Information_System_Facilities
			EPA_Emergency_Response_ER_Facility_Response_Plan_FRP_Facilities
			EPA_Emergency_Response_ER_Risk_Management_Plan_RMP_Facilities
			EPA_Emergency_Response_ER_Toxic_Substances_Control_Act_TSCA_Facilities
			EPA_Resource_Conservation_and_Recovery_Act_Treatment_Storage_and_Disposal_Facilities_RCRATSD
Pharmacies	JFO Provided	2018	USVI_Pharm.shp
Airports	JFO Provided	2018	Airports_CAD
Shelters	JFO Provided	2018	Shelters_USVI_Certified_2014
NationalShelterSystem	HIFLD Freedom	2018	NationalShelterSystem
FEMA Facilities	JFO Provided	2018	FEMA_CAD

Data Type	Source	Circa Date	GIS Data Layer
VITEMA Facilities	JFO Provided	2018	VITEMA
EMS_Stations	HIFLD Freedom	2018	EMS_Stations
Seaplane_usvi	JFO Provided	2018	Seaport_seaplanes_usvi.shp
Seaport_usvi	JFO Provided	2018	Seaport_seaplanes_usvi.shp
Public_Health_Departments	HIFLD Freedom	2018	Public_Health_Departments
Pharmacies	HIFLD Freedom	2018	Pharmacies
State_Capitol_Buildings	HIFLD Freedom	2018	State_Capitol_Buildings
Major_State_Government_Buildings	HIFLD Freedom	2018	Major_State_Government_Buildings
FDIC_Insured_Banks	HIFLD Freedom	2018	FDIC_Insured_Banks
Solid_Waste_Landfill_Facilities	HIFLD Freedom	2018	Solid_Waste_Landfill_Facilities
FEMA_CAD	JFO Provided	2018	FEMA_CAD

Point data listed in Table 3-10 established known available critical facility sites and were utilized to locate likely critical facilities. Primary site data resources included various data provided by the FEMA Joint Field Office (JFO) and also various data from HIFLD Open 2018 Data.

After sites were located that intersect the Advisory Floodplains, building footprints were extracted for the site and processed for inclusion. Open Streetmap HOTSOM Building Footprints downloaded in May 2018 were utilized as the source footprint layer. Identified facilities include a photograph; priority was placed on capturing a 'Street-level' picture where available or alternatively capturing a planimetric overhead photo. Source images are embedded in the GIS data which is accessible in ArcGIS 10.3 or higher; the user can access the photographs directly through the "Attachment Manager". GIS users are encouraged to utilize the ArcGIS Help files on how to open and view attachments.

Attributes such as name, address, city and zip were sporadic in the source data. Data were backfilled to the extent possible. Latitude and Longitude in decimal degrees exist based on the centroid of the building footprint. Lowest Adjacent Grade (LAG) and Highest Adjacent Grade (HAG) were extracted from the 2013 Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) along the perimeter of the building footprint. Advisory base flood elevations (1% and 0.2% annual chance or ABFE100 and ABFE500) represent the maximum elevation from the combination of both the water surface elevation grids intersecting each building footprint for locations where both effective BFE's and new advisory modeling water elevations exist. However please note the following exceptions:

1. Because the coastal BFE's come directly from effective floodplains and BFE's, there will be no ABFE value for the 0.2% Annual Chance or the 500-Year.

2. Because effective approximate zone mapping (ZONE A) does not include effective BFE's, the Advisory base flood elevations (1% and 0.2% annual chance or ABFE100 and ABFE500) represent only the newly modeled advisory water surface elevations.

The GIS database includes results of a risk analysis that was performed based on the following parameters:

- Damage percentages are computed based on the maximum depth at each building footprint per the following:
  - Depth values are established by the depth grids delivered.
  - Depth-Damage function selection was based on typical Hazus-MH Flood Model parameters which means the following were assigned for each respective building:
    - Occupancy
    - Number of Stories (Where 2010 building footprints intersected the critical facility building footprint utilized, the height value was transferred to establish stories assuming a 10-foot ceiling height. All other building heights were assumed to be 1-story).
    - First-Floor-Height (All buildings were assumed to have a first-floor height of 0.5 feet).
    - Foundations Type (All buildings were assumed to be Slab-On-Grade)
    - Core Construction Type (All buildings were assumed to be Concrete)
    - In addition, the newly created ABFE Floodplain Zones were utilized to establish whether a building touched a coastal zone and therefore, coastal depth-damage functions were applied.

Notably, future building-specific work would benefit from making distinctions in varied occupancies within a larger building, however because dollar values are not being considered as part of the risk assessment (only estimated damage percentages), the results being produced as part of this project will not be over- or under-stating estimated ($) value. Operators would therefore be free to consider building and contents value in light of the estimated maximum damage percentages. Furthermore, additional work efforts at the building-level would benefit from a detailed analysis of the first-floor elevation or height. A cursory review of the difference between the LAG and HAG elevations as extracted from the elevation grid included too wide a range of values to utilize the difference value as a proxy for the first-floor height of the building without a detailed analysis therefore, a first-floor height of 0.5 feet was assumed for all buildings and is believed to represent the highest potential risk for each building.

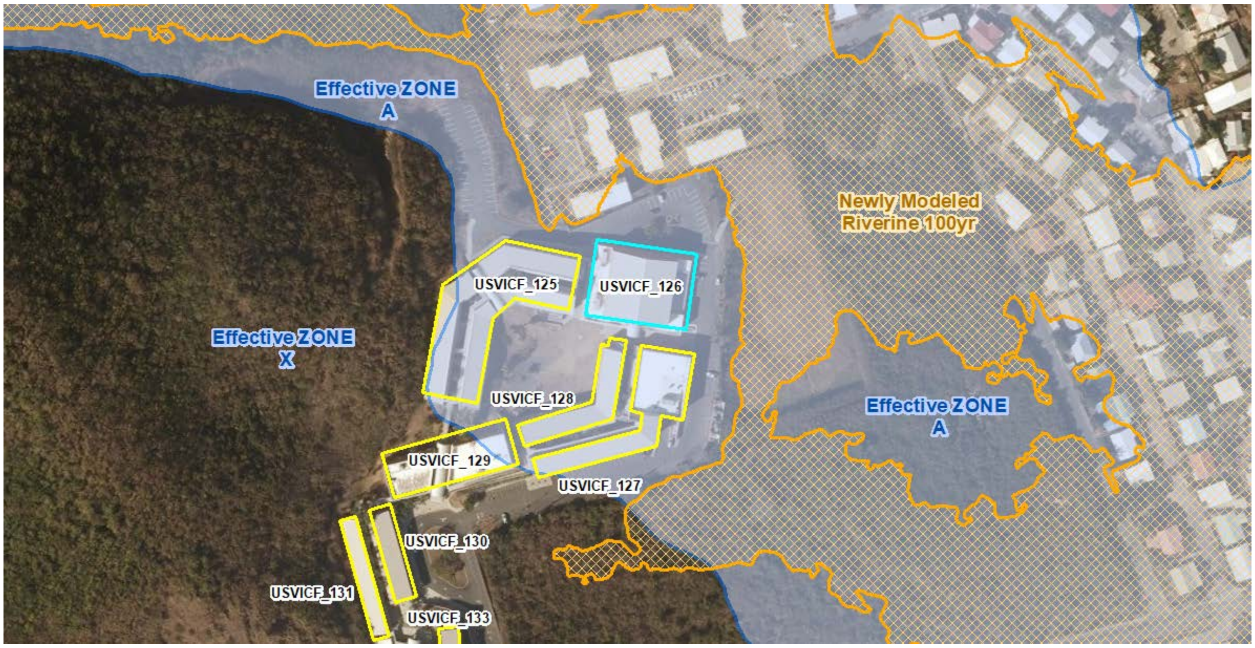
The Critical Facility Flood Summary documents represent a handout product that can be provided to operators and includes core recommendations from the most recent FEMA post-event guidance documents along with key contacts and publications thus providing operators with avenues for appropriately considering options. Each of the elements on the Critical Facility Summary document are drawn from a customized python module that can be executed on a CSV export of the GIS data should additional work be required in the future.

Specific to the Critical Facility Summary documents (in relation to the flood hazard data), notes have been added to clarify situations where key differences exist between the effective flood hazard data and the new advisory data:

- "None" represents buildings that do not intersect the effective 1% floodplain.
- "No Data" represents areas where Water Surface and Depth Grids that are required to calculate losses were not produced per the scope of work.

Figure 15 demonstrates an example where the building in-question intersects the effective approximate zone (ZONE A) but is outside the newly modeled advisory floodplain. It is important to recognize that the most conservative floodplain mapping was retained for the final ABFE mapping products:

Figure 15: Effective and ABFE Merged Floodplain Example



Based on the example above, the Critical Facility Flood Summary document has been designed to show damages as “None”:

Figure 16 shows a sample Critical Facility Flood Summary report.

Figure 16: Sample Critical Facility Flood Summary Report

FEMA

U.S. Virgin Islands Advisory Data

Critical Facility Flood Summary

Note: the building that this Summary represents is outlined in blue

Type: School
Name:
BERTHA C BOSCHULTE JUNIOR HIGH SCHOOL
Address:
9-1 & 12A BOVONI ST THOMAS 00802
Lat/Long: 18.3186, -64.890309

Lowest Adjacent Grade (ft.)*	Highest Adjacent Grade (ft.)*
64.7	73.6

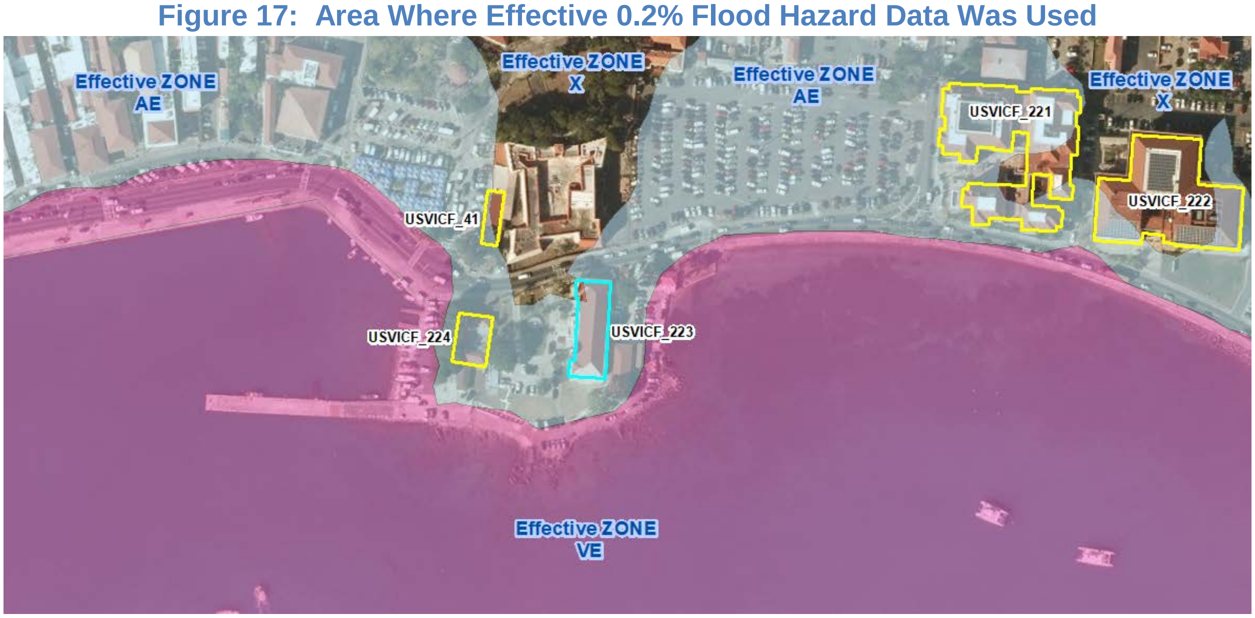
Flood Frequency	Advisory Flood Elevation (ft.)*	Estimated Building Damage	Estimated Contents Damage
1 Percent	63.0	None	None
0.2 Percent	63.9	N/A	N/A

Recommendations:

- Building owners should have a vulnerability assessment performed by a qualified architectural and engineering team (FEMA 543).
- A vulnerability assessment should be performed for all facilities older than 5 years (FEMA 543).
- It is particularly important to perform a vulnerability assessment if a facility is located in a building not originally designed for critical occupancy (FEMA 543).

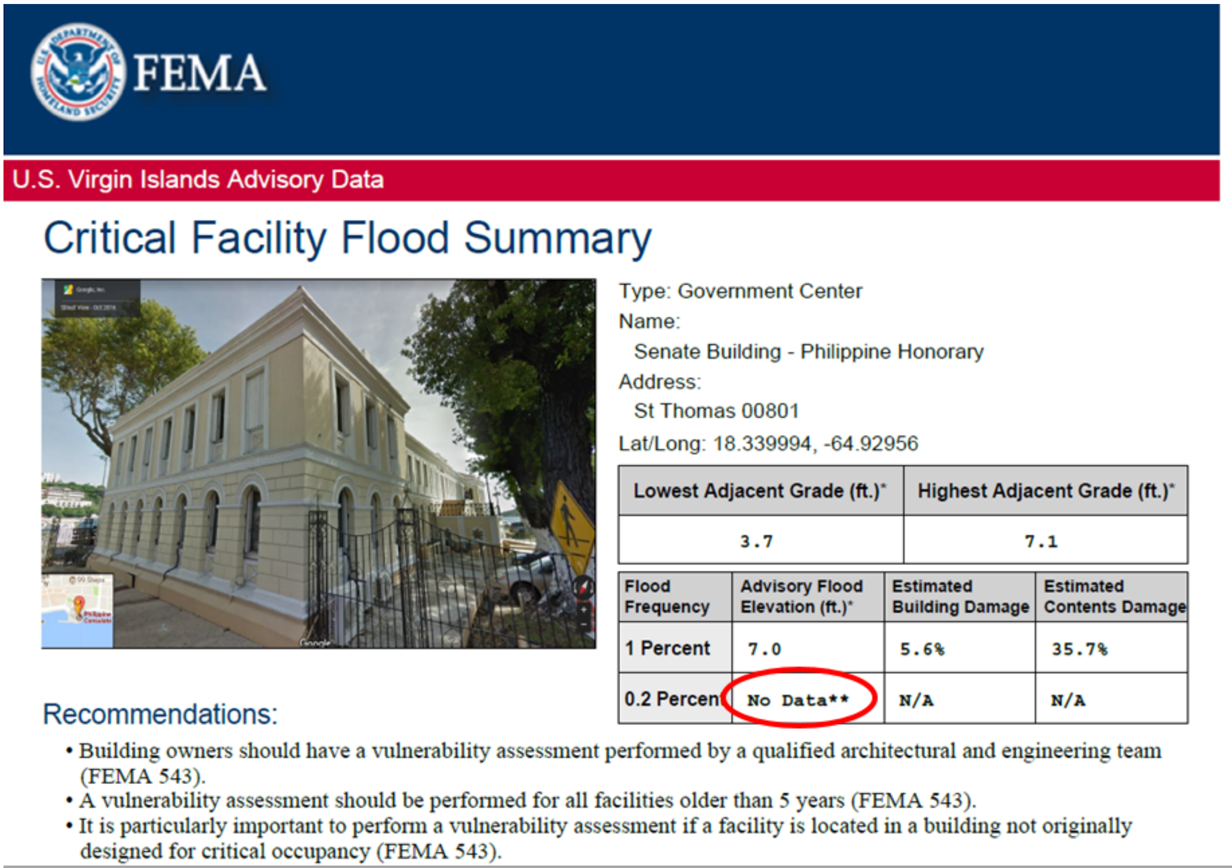
Another example includes where the coastal 0.2% analysis year was not part of the ABFE scope of work and therefore shows "No Data" exists as shown in **Figure 17**:

Figure 17: Area Where Effective 0.2% Flood Hazard Data Was Used



Based on the example above, the Critical Facility Flood Summary document has been designed to show damages as "No Data" as shown in **Figure 18**:

Figure 18: Critical Facility Where 0.2% Water Surface Grid Not Created



FEMA

U.S. Virgin Islands Advisory Data

Critical Facility Flood Summary

Type: Government Center

Name:

Senate Building - Philippine Honorary

Address:

St Thomas 00801

Lat/Long: 18.339994, -64.92956

Lowest Adjacent Grade (ft.)*	Highest Adjacent Grade (ft.)*
3.7	7.1

Flood Frequency	Advisory Flood Elevation (ft.)*	Estimated Building Damage	Estimated Contents Damage
1 Percent	7.0	5.6%	35.7%
0.2 Percen	No Data**	N/A	N/A

Recommendations:

- Building owners should have a vulnerability assessment performed by a qualified architectural and engineering team (FEMA 543).
- A vulnerability assessment should be performed for all facilities older than 5 years (FEMA 543).
- It is particularly important to perform a vulnerability assessment if a facility is located in a building not originally designed for critical occupancy (FEMA 543).

Table 3-11 indicates overall statistics of average damage percentages by facility types. The data demonstrates that for the 1% event, Marine Facilities are generally at most risk and Emergency Operation Centers (with damage percentages averaging 0%) realizing the least risk. Users are cautioned to take note that not all facilities were analyzed for the 0.2% coastal and therefore the table does not show increasing risk between the 1% and 0.2% flood events.

Table 3-11: Summary of Critical Facility % Damage Average Estimates

Type	Building Count	Mean (AVG) Of All Facilities			
		Building Damage Percent (1%)	Building Damage Percent (0.2%)	Contents Damage Percent (1%)	Contents Damage Percent (0.2%)
Police Station	10	1%	0%	2%	0%
Fire Station	7	1%	0%	2%	0%

Type	Building Count	Mean (AVG) Of All Facilities			
		Building Damage Percent (1%)	Building Damage Percent (0.2%)	Contents Damage Percent (1%)	Contents Damage Percent (0.2%)
Power Generation Center	10	7%	0%	10%	0%
Wastewater Treatment Plant	32	6%	5%	9%	8%
Government Center	3	5%	2%	32%	10%
Airport	9	7%	0%	10%	0%
Emergency Operations Center	32	0%	0%	0%	0%
Medical Facilities	5	2%	1%	8%	4%
Pharmacy	5	10%	11%	35%	33%
Port	7	25%	0%	34%	0%
Marine Facilities	2	30%	7%	42%	9%
Shelter	14	3%	4%	17%	20%
School	90	2%	1%	11%	5%
TOTAL	**226**	**8%**	**2%**	**16%**	**7%**

4.0 References

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5.0 Appendices

5.1 Appendix A: Hydraulic Analysis Streams List

Table 5-1: Summary of Hydraulic Analyses

HEC-RAS Model Name	Flooding Source Name	Length (miles)
20016	Battery Gut (St. John Model #16)	0.63
10285	Bethlehem Gut (St. Croix Model #285)	2.68
10460	Caledonia Gut (St. Croix Model #460)	0.57
20046	Cob Gut (St. John Model #46)	1.31
20127	Coral Bay Gut (St. John Model #127)	0.61
10318	Creque Gut (St. Croix Model #318)	1.58
10400	Drainage Canal (St. Croix Model #400)	1.40
10403	Drainage Canal (St. Croix Model #403)	4.18
20021	Fish Bay Gut (St. John Model #21)	1.15
20005	Guinea Gut (St. John Model #5)	1.00
10595	Gut #1 (St. Croix Model #595)	0.97
10569	Gut #2 (St. Croix Model #569)	0.77
10609	Gut #3 (St. Croix Model #609)	0.98
10628	Gut #4 (St. Croix Model #628)	1.14
10076	Gut #5 (St. Croix Model #76)	3.88
10157	Gut #6 (St. Croix Model #157)	2.52
10128	Jolly Hill Gut (St. Croix Model #128)	2.24
20064	Reef Bay Gut (St. John Model #64)	1.95
10211	River Gut (St. Croix Model #211)	7.19
10675	Salt River (St. Croix Model #675)	3.23

HEC-RAS Model Name	Flooding Source Name	Length (miles)
10677*	Salt River Diversion Channel (St. Croix Model #677)*	1.12
30109	Turpentine Run (St. Thomas Model #109)	3.15
10148	Unnamed Stream (St. Croix Model #148)	0.98
10222	Unnamed Stream (St. Croix Model #222)	0.66
10229	Unnamed Stream (St. Croix Model #229)	1.24
10241	Unnamed Stream (St. Croix Model #241)	2.56
10264	Unnamed Stream (St. Croix Model #264)	4.37
10266	Unnamed Stream (St. Croix Model #266)	0.51
10272	Unnamed Stream (St. Croix Model #272)	0.29
10275*	Unnamed Stream (St. Croix Model #275)*	0.81
10301	Unnamed Stream (St. Croix Model #301)	2.16
10312	Unnamed Stream (St. Croix Model #312)	0.57
10033	Unnamed Stream (St. Croix Model #33)	2.56
10335	Unnamed Stream (St. Croix Model #335)	1.26
10336	Unnamed Stream (St. Croix Model #336)	0.53
10337	Unnamed Stream (St. Croix Model #337)	1.68
10340	Unnamed Stream (St. Croix Model #340)	0.64
10341	Unnamed Stream (St. Croix Model #341)	4.13
10342	Unnamed Stream (St. Croix Model #342)	0.79
10348	Unnamed Stream (St. Croix Model #348)	1.79
10036	Unnamed Stream (St. Croix Model #36)	0.57
10383	Unnamed Stream (St. Croix Model #383)	0.74
10386	Unnamed Stream (St. Croix Model #386)	0.63
10039	Unnamed Stream (St. Croix Model #39)	1.34

HEC-RAS Model Name	Flooding Source Name	Length (miles)
10426	Unnamed Stream (St. Croix Model #426)	3.20
10448*	Unnamed Stream (St. Croix Model #448)*	0.64
10455	Unnamed Stream (St. Croix Model #455)	0.49
10471	Unnamed Stream (St. Croix Model #471)	2.72
10481	Unnamed Stream (St. Croix Model #481)	1.69
10049	Unnamed Stream (St. Croix Model #49)	2.94
10500	Unnamed Stream (St. Croix Model #500)	1.93
10502	Unnamed Stream (St. Croix Model #502)	0.19
10506	Unnamed Stream (St. Croix Model #506)	0.38
10510	Unnamed Stream (St. Croix Model #510)	1.06
10511	Unnamed Stream (St. Croix Model #511)	0.32
10512	Unnamed Stream (St. Croix Model #512)	0.32
10524	Unnamed Stream (St. Croix Model #524)	0.26
10527	Unnamed Stream (St. Croix Model #527)	0.95
10530	Unnamed Stream (St. Croix Model #530)	0.41
10540	Unnamed Stream (St. Croix Model #540)	0.81
10542	Unnamed Stream (St. Croix Model #542)	0.64
10544	Unnamed Stream (St. Croix Model #544)	1.15
10551	Unnamed Stream (St. Croix Model #551)	1.20
10555	Unnamed Stream (St. Croix Model #555)	1.25
10560	Unnamed Stream (St. Croix Model #560)	0.54
10579	Unnamed Stream (St. Croix Model #579)	0.49
10584	Unnamed Stream (St. Croix Model #584)	0.83
10060	Unnamed Stream (St. Croix Model #60)	1.56

HEC-RAS Model Name	Flooding Source Name	Length (miles)
10601	Unnamed Stream (St. Croix Model #601)	0.71
10626	Unnamed Stream (St. Croix Model #626)	0.60
10634	Unnamed Stream (St. Croix Model #634)	0.83
10635	Unnamed Stream (St. Croix Model #635)	0.33
10650	Unnamed Stream (St. Croix Model #650)	0.65
10681	Unnamed Stream (St. Croix Model #681)	1.18
10686	Unnamed Stream (St. Croix Model #686)	0.42
10689*	Unnamed Stream (St. Croix Model #689)*	0.86
10692	Unnamed Stream (St. Croix Model #692)	0.65
10707	Unnamed Stream (St. Croix Model #707)	0.61
10712*	Unnamed Stream (St. Croix Model #712)*	1.53
10719	Unnamed Stream (St. Croix Model #719)	0.47
10729	Unnamed Stream (St. Croix Model #729)	2.58
10740	Unnamed Stream (St. Croix Model #740)	1.19
10748	Unnamed Stream (St. Croix Model #748)	0.42
10756	Unnamed Stream (St. Croix Model #756)	1.00
10757	Unnamed Stream (St. Croix Model #757)	0.55
10763	Unnamed Stream (St. Croix Model #763)	1.06
10770	Unnamed Stream (St. Croix Model #770)	1.57
10782	Unnamed Stream (St. Croix Model #782)	0.65
10793	Unnamed Stream (St. Croix Model #793)	0.31
10795	Unnamed Stream (St. Croix Model #795)	0.41
10084	Unnamed Stream (St. Croix Model #84)	1.52
10093	Unnamed Stream (St. Croix Model #93)	1.02

HEC-RAS Model Name	Flooding Source Name	Length (miles)
10095	Unnamed Stream (St. Croix Model #95)	1.03
20116	Unnamed Stream (St. John Model #116)	1.47
20123	Unnamed Stream (St. John Model #123)	0.60
20190	Unnamed Stream (St. John Model #190)	0.50
20029	Unnamed Stream (St. John Model #29)	1.00
20036	Unnamed Stream (St. John Model #36)	0.50
20038	Unnamed Stream (St. John Model #38)	0.45
20039	Unnamed Stream (St. John Model #39)	0.20
20058	Unnamed Stream (St. John Model #58)	1.30
20061	Unnamed Stream (St. John Model #61)	0.30
20007	Unnamed Stream (St. John Model #7)	0.56
20072	Unnamed Stream (St. John Model #72)	0.57
20077	Unnamed Stream (St. John Model #77)	1.28
20084	Unnamed Stream (St. John Model #84)	0.88
20086	Unnamed Stream (St. John Model #86)	0.40
30103	Unnamed Stream (St. Thomas Model #103)	1.10
30119	Unnamed Stream (St. Thomas Model #119)	1.18
30132	Unnamed Stream (St. Thomas Model #132)	0.54
30138*	Unnamed Stream (St. Thomas Model #138)*	0.52
30014	Unnamed Stream (St. Thomas Model #14)	0.25
30140*	Unnamed Stream (St. Thomas Model #140)*	0.40
30143	Unnamed Stream (St. Thomas Model #143)	0.60
30016	Unnamed Stream (St. Thomas Model #16)	0.45
30160*	Unnamed Stream (St. Thomas Model #160)*	0.45

HEC-RAS Model Name	Flooding Source Name	Length (miles)
30164	Unnamed Stream (St. Thomas Model #164)	1.31
30166	Unnamed Stream (St. Thomas Model #166)	0.33
30167	Unnamed Stream (St. Thomas Model #167)	0.61
30177	Unnamed Stream (St. Thomas Model #177)	1.40
30184	Unnamed Stream (St. Thomas Model #184)	0.44
30190	Unnamed Stream (St. Thomas Model #190)	0.81
30202	Unnamed Stream (St. Thomas Model #202)	0.85
30204	Unnamed Stream (St. Thomas Model #204)	0.61
30211	Unnamed Stream (St. Thomas Model #211)	1.01
30215	Unnamed Stream (St. Thomas Model #215)	0.36
30219	Unnamed Stream (St. Thomas Model #219)	0.27
30222	Unnamed Stream (St. Thomas Model #222)	0.30
30023	Unnamed Stream (St. Thomas Model #23)	0.81
30233	Unnamed Stream (St. Thomas Model #233)	0.49
30242	Unnamed Stream (St. Thomas Model #242)	1.05
30246	Unnamed Stream (St. Thomas Model #246)	0.60
30025	Unnamed Stream (St. Thomas Model #25)	0.79
30264	Unnamed Stream (St. Thomas Model #264)	1.10
30270	Unnamed Stream (St. Thomas Model #270)	0.97
30032	Unnamed Stream (St. Thomas Model #32)	0.61
30033	Unnamed Stream (St. Thomas Model #33)	0.16
30035	Unnamed Stream (St. Thomas Model #35)	0.40
30039	Unnamed Stream (St. Thomas Model #39)	0.43
30049	Unnamed Stream (St. Thomas Model #49)	0.82

HEC-RAS Model Name	Flooding Source Name	Length (miles)
30060	Unnamed Stream (St. Thomas Model #60)	0.92
30069	Unnamed Stream (St. Thomas Model #69)	0.66
30070	Unnamed Stream (St. Thomas Model #70)	0.21
30071	Unnamed Stream (St. Thomas Model #71)	0.25
30072	Unnamed Stream (St. Thomas Model #72)	0.30
30079	Unnamed Stream (St. Thomas Model #79)	1.31
30008	Unnamed Stream (St. Thomas Model #8)	0.77
30087	Unnamed Stream (St. Thomas Model #87)	0.72
30009	Unnamed Stream (St. Thomas Model #9)	0.26
	TOTAL	160.61

***** Newly Modeled Flooding Source

5.2 Appendix B: Manning's n Values

Table 5-2: Summary of Manning's n Values

Class	Description	Utilized n-Value
0	Background/water	0.013
1	High-Medium Density Urban	0.085
2	Low-Medium Density Urban	0.065
3	Herbaceous Agriculture - Cultivated Lands	0.04
4	Active Sun Coffee and Mixed Woody Agriculture	0.06
5	Pasture, Hay or Inactive Agriculture (e.g. abandoned sugar cane)	0.045
6	Pasture, Hay or other Grassy Areas (e.g. soccer fields)	0.04
7	Drought Deciduous Open Woodland	0.12
8	Drought Deciduous Dense Woodland	0.12
9	Deciduous, Evergreen Coastal and Mixed Forest or Shrubland with Succulents	0.12
10	Semi-Deciduous and Drought Deciduous Forest on Alluvium and Non-Carbonate Substrates	0.12
11	Semi-Deciduous and Drought Deciduous Forest on Karst (includes semi-evergreen forest)	0.12
12	Drought Deciduous, Semi-deciduous and Seasonal Evergreen Forest on Serpentine	0.12
13	Seasonal Evergreen and Semi-Deciduous Forest on Karst	0.12
14	Seasonal Evergreen and Evergreen Forest	0.12
15	Seasonal Evergreen Forest with Coconut Palm	0.12
16	Evergreen and Seasonal Evergreen Forest on Karst	0.12
17	Evergreen Forest on Serpentine	0.12
18	Elfin, Sierra Palm, Transitional and Tall Cloud Forest	0.1
19	Emergent Wetlands Including Seasonally Flooded Pasture	0.045
20	Salt or Mud Flats	0.03
21	Mangrove	0.12

22	Seasonally Flooded Savannahs and Woodlands	0.09
23	Pterocarpans Swamp	0.05
24	Tidally Flooded Evergreen Dwarf-Shrubland and Forb Vegetation	0.05
25	Quarries	0.03
26	Coastal Sand and Rock	0.03
27	Bare Soil (including bulldozed land)	0.03

5.3 Appendix C: USVI Non-Standard Erosion Methodology

5.3.1 General Overview

The non-standard erosion methodology applied to the beaches of St. Thomas and St. John was the same one applied to the beaches of St. Croix. The following appendix originated from a St. Croix Coastal Study memo dated November 18, 2002.

5.3.2 Introduction

The sandy beaches of St. Croix were characterized by 1-3 foot veneer of sand overlaying rocky ledges. Through examination of pre- and post-storm photographs, it was determined that a portion of this sand veneer was removed by wave action to expose the rocky ledge beneath.

This assumption was verified by a review of available literature (Hubbard, D. K., et al, 1991, "The Effects of Hurricane Hugo on the Reefs and Associated Environments of St. Croix, U.S. Virgin Islands – A preliminary Assessment," Journal of Coastal Research, Vol. 8, pp 33-48), conversations with specialists in the field (Dr. Dennis Hubbard, November, 4, 2002), and site investigation (August, 2002). The erosion module of the CHAMP database did not have the capabilities to account for this type of storm-induced erosion. It was therefore determined that a non-standard approach to erosion modeling must be applied to the sandy beaches of St. Croix. The following is a brief description of the proposed methodology to model erosion on the sandy beaches of St. Croix:

5.3.3 Methodology

1. It was assumed that the mean amount removed from the sand veneer would be 2 feet along the beach, the mean value of the veneer depth. To model this, 1 foot would be removed from the 2 feet elevations and 2 feet would be removed from the landward elevations. The shoreline (0 foot station) would be preserved. Erosion modeling would stop at the first obstruction, defined as the limit of substantial vegetation or development, or where the eroded slope intersected the existing profile.

2. Elevation changes would be applied to the Adjusted Transect within CHAMP, thereby leaving the original Transect unchanged for comparison.

3. The limit of vegetation or development would be determined by examination of aerial imagery and photographs taken during site investigation. Consideration would be given to the type and amount of vegetation as it affected its ability to withstand erosion.

4. If the first obstruction occurred within 50 feet of a station, that station would be the extent of the erosion. If the distance between the first obstruction and the previous station was greater than 50 feet, a station would be added to the Adjusted Transect, at the location of the obstruction, to define the extent of storm-induced erosion.

Tables 5-3 through 5-5 itemize the type of storm induced erosion applied to the Transects of the USVI in the effective coastal study.

Table 5-3: Storm Induced Erosion Applied in St. John

Transect No.	Description
USVI St. John	
1	Vertical rock cliff; no vegetation
2	Station at elevation 6 has been considered the limit of erosion due to vegetation. Station 4 ft. elevation is eroded 2 ft., station 2 ft. elevation is eroded 1 ft.
3	Steep and rocky beach; no need for erosion analysis.
4	Station at elevation 8 has been considered the limit of erosion due to resort facility in the area represented by the transect. Stations 6 and 4 ft. elevation are eroded 2 ft., station 2 ft. elevation is eroded 1 ft.
5	Steep and rocky beach; no need for erosion analysis.
6	Considering the transect description, no erosion has been applied.
7	Vegetation starts at 10 feet elevation. Stations 10, 8, 6, and 4 feet elevation have eroded to 2 feet and 2 feet elevation has eroded to 1 foot.
8	Vegetation starts at 2 feet elevation. Station 2 feet elevation has eroded to 1 foot.
9	Vegetation starts at 8 feet elevation. Stations 8, 6, 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
10	Erosion has not been performed since vegetation starts at the shoreline.
11	Vegetation starts at 8 feet elevation. Stations 8, 6 and 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
12	Vegetation starts at 6 feet elevation. Stations 6 and 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
14	Vegetation starts at 8 feet and a point with the distance of 70 feet and elevation of 8 feet has been added to the data. Stations 8, 6 and 4 feet elevation have been eroded 2 feet and 2 feet elevation has been eroded to 1 foot.
15	Due to the steep slope of the shore no erosion has been applied
16	Dense vegetation starts at 2 feet elevation. The 2 feet elevation has been eroded 1 foot.
17	Due to the rocky and steep slope of the shore no erosion has been applied.
18	Due to the dense vegetation the 2 foot elevation has been eroded to 1 foot.
19	Due to the dense vegetation which starting at the landward edge of the beach, the 2 foot elevation has been eroded to 1 foot.
20	Shoreline has been adjusted
21	Due to the steep slope and dense vegetation of the shore no erosion has been applied

Transect No.	Description
22	Due to the rocky and steep slope of the shore no erosion has been applied
23	Due to the vertical rock no erosion has been applied
24	Due to the vertical rock no erosion has been applied.
25	Vegetation starts at 12 feet elevation. Stations 12, 8, 6, and 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
26	Due to the steep slope of the shore and rocky surface of the beach no erosion has been applied.
27	Vegetation starts at 8 feet elevation. Stations 8, 6 and 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot
28	There is sufficient vegetation to limit beach erosion at station 34.1 elevation 10 ft. Therefore, stations at elevation 8, 6, 4 are eroded by 2 ft. and station at elevation 2 by 1 ft.
29	Vegetation starts at 4 feet elevation. Stations 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
30	Pocket beach is confined inland by rocky cliff starting at station 25.39 elevation 8 ft. This station represents the limit of erosion. Stations at elevation 6 and 4 are eroded by 2 ft., station at elevation 2 by 1 ft.
31	Limit of erosion is represented by rocky cliff behind short beach. Station 28.51 at elevation 8 ft. represents the limit. Stations at elevation 6 and 4 ft. are eroded by 2 ft., station at elevation 2 is eroded by 1 ft.
32	Due to the dense vegetation no erosion applied.
33	Due to the dense vegetation no erosion applied.
34	Due to the steep slope dense vegetation no erosion applied.
35	Vegetation starts at 4 feet elevation. The 4 feet elevation has eroded 2 feet and 2 feet elevation has eroded to 1 foot.
36	Vegetation starts at 2 feet elevation. The 2 feet elevation has eroded to 1 foot
37	Due to rocky surface and steep slope of the beach no erosion analysis applied.
38	Vegetation starts at 8 feet elevation and a point with the elevation of 7 feet and distance of 50 feet added. Stations 6 and 4 feet elevations have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
39	Vegetation starts at 6 feet elevation. Stations 6 and 4 feet elevation have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
40	Steep and rocky slope; no erosion applied.
41	Vegetation starts at 10 feet elevation. Stations 8, 6 and 4 feet elevations have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
42	Vegetation starts at 12 feet elevation. Stations 12, 10, 8, 6 and 4 feet elevations have eroded 2 feet and 2 feet elevation has eroded to 1 foot.

Transect No.	Description
43	Vegetation starts at 6 feet elevation. Stations 6 and 4 feet elevations have eroded 2 feet and 2 feet elevation has eroded to 1 foot.
44	Steep and rocky slope; no erosion applied.
45	Vegetation starts at 6 feet elevation. Stations 6 and 4 feet elevations have eroded 2 feet and 2 feet elevation has eroded to 1 foot.

Table 5-4: Storm Induced Erosion Applied in St. Thomas

Transect No.	Description
USVI St. Thomas	
1	Rocky cliff/bluff; erosion treatment not necessary
2	Used non-standard erosion methodology. The Station 23, elevation 4 pair will be the limit of erosion. Only the 2 elevation will be eroded to 1.
3	Used non-standard erosion methodology. The Station 3, elevation 4 pair will be the limit of erosion. Only the 2 elevation will be eroded to 1.
4	Rocky cliff/bluff; erosion treatment not necessary
5	Rocky cliff/bluff; erosion treatment not necessary
6	Used non-standard erosion methodology. Inserted a point at station 55, elevation 2 pair and was used as the limit of erosion. Only the station 18, 2 elevation will be eroded to 1.
7	Rocky cliff/bluff; erosion treatment not necessary
8	Used non-standard erosion methodology. The Station 40, elevation 6 pair will be the limit of erosion and the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded to 1.
9	Used non-standard erosion methodology. The Station 41, elevation 4 pair will be the limit of erosion. Only the 2 elevation will be eroded to 1.
10	Rocky cliff/bluff; erosion treatment not necessary
11	Used non-standard erosion methodology. The Station 44, elevation 6 pair will be the limit of erosion and the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded to 1.
12	Rocky cliff/bluff; erosion treatment not necessary
13	Rocky cliff/bluff; erosion treatment not necessary
14	Rocky cliff/bluff; erosion treatment not necessary

Transect No.	Description
15	Used non-standard erosion methodology. The Station 44, elevation 6 pair will be the limit of erosion and the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded to 1.
16	Rocky cliff/bluff; erosion treatment not necessary
18	Rocky cliff/bluff; erosion treatment not necessary
19	Rocky cliff/bluff; erosion treatment not necessary
20	Used non-standard erosion methodology. Inserted a point at station 74.5, elevation 6 pair and was used as the limit of erosion. The station 6 and 4 elevations will be eroded 2 feet and the 2 foot elevation will be eroded to 1.
21	Rocky cliff/bluff; erosion treatment not necessary
22	Used non-standard erosion methodology. Inserted a point at station 52.6, elevation 8 pair and was used as the limit of erosion. The station 8, 6, and 4 elevations will be eroded 2 feet and the 2 foot elevation will be eroded to 1.
23	Rocky cliff/bluff; erosion treatment not necessary
24	Used non-standard erosion methodology. Inserted a point at station 67.8, elevation 6 pair and was used as the limit of erosion. The station 6, and 4 elevations will be eroded 2 feet and the 2 foot elevation will be eroded to 1.
25	Revetment; erosion treatment not necessary
26	Used non-standard erosion methodology. The Station 21, elevation 4 pair will be the limit of erosion and only the 2 elevation will be eroded to 1.
27	Docks; erosion treatment not necessary
28	Mangrove; erosion treatment not necessary
29	Used non-standard erosion methodology. Inserted a point at station 13.2, elevation 2 pair and was used as the limit of erosion. Only the 2 foot elevation will be eroded to 1.
30	Rocky cliff/bluff; erosion treatment not necessary
31	Used non-standard erosion methodology. The Station 16, elevation 4 pair will be the limit of erosion and only the 2 elevation will be eroded to 1.
32	Used non-standard erosion methodology. The Station 22, elevation 4 pair will be the limit of erosion and only the 2 elevation will be eroded to 1.
33	Rocky cliff/bluff; erosion treatment not necessary
34	Rocky cliff/bluff; erosion treatment not necessary

Transect No.	Description
35	Used non-standard erosion methodology. The Station 49, elevation 6 pair will be the limit of erosion and the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded to 1.
37	Rocky cliff/bluff; erosion treatment not necessary
38	Rocky cliff/bluff; erosion treatment not necessary
39	Docks; erosion treatment not necessary
40	Mangrove; erosion treatment not necessary
41	Mangrove; erosion treatment not necessary
42	Mangrove; erosion treatment not necessary
43	Mangrove; erosion treatment not necessary
44	Mangrove; erosion treatment not necessary
46	Rocky cliff/bluff; erosion treatment not necessary
49	Rocky cliff/bluff; erosion treatment not necessary
51	Seawall; erosion treatment not necessary
52	Seawall; erosion treatment not necessary
53	Seawall; erosion treatment not necessary
54	Seawall; erosion treatment not necessary
55	Revetment; erosion treatment not necessary
56	Rocky cliff/bluff; erosion treatment not necessary
57	Rocky cliff/bluff; erosion treatment not necessary
58	Armored shoreline; erosion treatment not necessary
59	Revetment; erosion treatment not necessary
60	Used non-standard erosion methodology. The Station 33, elevation 4 pair will be the limit of erosion and only the 2 elevation will be eroded to 1.
61	Rocky cliff/bluff; erosion treatment not necessary

Transect No.	Description
62	Rocky cliff/bluff; erosion treatment not necessary
67	Used non-standard erosion methodology. The Station 30, elevation 4 pair will be the limit of erosion and only the 2 elevation will be eroded to 1.

Table 5-5: Storm Induced Erosion Applied in St. Croix

Transect No.	Description
USVI St. Croix	
1	Erosion treatment not necessary
2	Although there are some ornamental palm trees out on the beach, there is not sufficient vegetation to protect the beach from storm-induced erosion, therefore, the erosion of the sandy beach should continue inland to the 90 foot station, where the main beach resort facility is located, seen in the aerial image. The Station 99, Elevation 12 pair will be the limit of erosion, just inland from the 90 foot station, and the 10, 8, 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
3	Erosion treatment not necessary
4	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 15 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 16, Elevation 4 pair will be the limit of erosion, just inland from the 15 foot station, and only the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
5	Erosion treatment not necessary
6	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 70 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 108, Elevation 8 pair will be the limit of erosion, just inland from the 70 foot station, and the 6 and 4 elevations will be eroded by 2 feet and only the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
7	Erosion treatment not necessary
8	Erosion treatment not necessary
9	There are sufficient vegetation and buildings to protect the beach from storm-induced erosion beginning at the 55 foot station, where the small beach meets vegetation and buildings, seen in the aerial image. The inserted Station 82, Elevation 8 pair will be the limit of erosion, and the 8, 6, and 4 elevations will be eroded by 2 feet and only the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.

Transect No.	Description
10	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 15 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 17, Elevation 4 pair will be the limit of erosion, just inland from the 15 foot station, and only the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile
11	Erosion treatment not necessary
12	Erosion treatment not necessary
13	Erosion treatment not necessary
14	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 20 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 21, Elevation 10 pair will be the limit of erosion, just inland from the 20 foot station, and the 8, 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
15	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 45 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 39, Elevation 10 pair will be the limit of erosion, just seaward of the 45 foot station, and the 8, 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
16	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 30 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 29.7, Elevation 6 pair (inserted point) will be the limit of erosion, the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
17	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 45 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 45, Elevation 6 pair (inserted point) will be the limit of erosion, the 4 elevation will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile
18	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 20 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 10, Elevation 4 pair will be the limit of erosion, just inland from the 10 foot station, the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
19	Erosion treatment not necessary
20	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 40 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 40, Elevation 6.1 pair (inserted point) will be the limit of erosion, the 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.

Transect No.	Description
21	Although there are some ornamental palm trees out on the beach there is not sufficient vegetation to protect the beach from storm-induced erosion, therefore, the erosion of the sandy beach should continue inland to the 57 foot station. The Station 57, Elevation 6.3 pair will be the limit of erosion where the small beach meets vegetation. 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
22	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 50 foot station, where the small beach meets dense vegetation, seen in the aerial image. The Station 73, Elevation 8 pair will be the limit of erosion, just seaward from the 73 foot station, and the 6, 4 elevations will be eroded by 2 feet and the 2 elevation will be eroded by 1 foot to preserve the shape of the beach profile.
23	Rocky bluff; erosion treatment not necessary
24	While there is not sufficient vegetation to protect the beach from storm-induced erosion, the erosion of the sandy beach should continue inland to Station 58 where buildings are located, as seen in the aerial image. The Station 58, Elevation 8.1ft pair (station/elevation point manually added to transect) will be the limit of erosion. The 8, 6, and 4ft elevations will be eroded by 2 feet, and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
25	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 73 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 97, Elevation 6ft pair will be the limit of erosion, and the 4ft elevation will be eroded by 2 feet (except for the Station 9.94, Elevation 2 ft. pair which was removed to remove berm crest) and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
26	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 25 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 26, Elevation 6ft pair will be the limit of erosion, and the preceding 6ft and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile. The Station 14.3, Elevation 6 and Station 17.8, Elevation 6 pairs will be removed to remove the berm crest
27	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 72 foot station, on the seaward face of the berm, as seen in the aerial image. The Station 72, Elevation 10ft pair will be the limit of erosion, and the 8, 6 and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
28	Mangrove area, erosion treatment not necessary
29	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 45 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 45, Elevation 14ft pair will be the limit of erosion, and the 12, 10, 8, 6 and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.

Transect No.	Description
30	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 89 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 89, Elevation 10ft pair will be the limit of erosion, and the 8, 6 and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile
31	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 140 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 140, Elevation 8ft pair (station/elevation point manually added to transect) will be the limit of erosion, and the 8ft, 6ft, and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
32	Rocky bluff; erosion treatment not necessary
33	Revetment; erosion treatment not necessary
34	Mangrove area; erosion treatment not necessary
35	Mangrove area; erosion treatment not necessary
36	Mangrove area; erosion treatment not necessary
37	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 53 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 53, Elevation 10ft pair will be the limit of erosion, and the 8ft, 6ft and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
38	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 73 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 73, Elevation 8ft pair will be the limit of erosion, and the 6ft and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
39	Rocky outcrop beach; erosion treatment not necessary
40	Rocky outcrop beach; erosion treatment not necessary
41	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 172 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 172, Elevation 4ft pair (station/elevation point manually added to transect) will be the limit of erosion, and the preceding 4ft elevation will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.

Transect No.	Description
42	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 38 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 45, Elevation 8ft pair will be the limit of erosion, and the 6ft and 4ft elevations will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
43	There is not sufficient vegetation to protect the beach from storm-induced erosion prior to the berm. The Station 196, Elevation 6ft pair will be the limit of erosion, the 8 ft elevations will be eroded by 1 feet, the 6 ft and 4ft elevation will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
44	Seawall; erosion treatment not necessary
45	Seawall; erosion treatment not necessary
46	While there is not sufficient vegetation to protect the beach from storm-induced erosion, the erosion of the sandy beach should continue inland to the 123 foot station where the road is located, as seen in the aerial image. The Station 123, Elevation 6ft pair will be the limit of erosion, and the 4ft elevation will be eroded by 2 feet, and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
47	Rocky outcrop beach; erosion treatment not necessary
48	There is sufficient vegetation to protect the beach from storm-induced erosion, beginning at the 73 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 73, Elevation 6ft pair (station/elevation point manually added to transect) will be the limit of erosion, and the Station 71, Elevation 4ft pair will be removed from the transect to smooth the slope. The 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
49	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 60 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 76, Elevation 4ft pair will be the limit of erosion, and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.
50	Rocky outcrop beach, erosion treatment not necessary
51	There is sufficient vegetation to protect the beach from storm-induced erosion beginning at the 40 foot station, where the small beach meets dense vegetation, as seen in the aerial image. The Station 51, Elevation 6ft pair will be the limit of erosion, and the 4ft elevation will be eroded by 2 feet and the 2ft elevation will be eroded by 1 foot to preserve the shape of the beach profile.