



Hazard Mitigation  
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(HMGP) project  
number 4340-0054:  
Coral Bay Hydrology  
and Hydraulics (H&H)

Final Report  
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SUBMITTED TO:

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## 3. Glossary of Terms

**Best Management Practice (BMP)-** BMPs are practices that manage stormwater runoff to improve water quality and reduce stormwater volume and velocity. Examples of BMPs include gravel wetlands, infiltration basins, and bioretention practices.

**Detention BMP-** A BMP that stores stormwater for a defined length of time before it eventually drains to the receiving water body. Stormwater is not retained in the practice permanently. The objective of a detention BMP is to reduce the peak discharge from the BMP to reduce channel erosion and settle out pollutants from the stormwater. Some of these practices also include additional water quality benefits. Examples include gravel wetlands, detention ponds, and non-infiltration-dependent bioretention practices.

**Drainage Area-** The area contributing runoff to a specific point. Generally, this term is used for the area that drains to a BMP or other feature like a stormwater pipe.

**Gabion Dam-** A metal mesh basket filled with stone, often installed in a swale or along another drainage path, that decreases the velocity of stormwater, reduces erosion, and encourages the settling and deposition of sediment.

**Hydrologic Soil Group-** A Natural Resource Conservation Service classification system for the permeability of soils. They are categorized into four groups (A, B, C, and D) with “A” having the highest permeability and “D” having the lowest.

**Infiltration/Infiltration Rate-** Stormwater percolating into the ground surface. The rate at which this occurs (infiltration rate) is generally presented as inches per hour.

**Infiltration BMP-** A BMP that allows for the infiltration of stormwater into the subsurface soil as groundwater, which returns to the stream as baseflow. Mapped soils of Hydrologic Group A or B (sandy, well-drained soils) are an indicator of infiltration potential. Infiltration reduces the amount of surface storage required. Typical infiltration BMP practices include infiltration trenches, bioretention practices, subsurface infiltration chambers, infiltration basins, and others.

**Outfall-** The point where stormwater discharges from a system like a pipe.

**Sheet Flow-** Stormwater runoff flowing over the ground surface in a thin layer.

**Stabilization-** Vegetated or structural practices that prevent erosion from occurring.



**Stormwater/Stormwater Runoff-** Precipitation that runs off the ground surface.

**Swale-** An open vegetated channel used to convey runoff, often designed to filter pollutants and sediments.

**Total Suspended Solids (TSS)-** The total soil particulate matter suspended in the water column.

**Watershed-** The area contributing runoff to a specific point.

**Water Quality Volume (WQv)-** The stormwater volume generated from the first inch of runoff. This runoff is known as the 90th percentile rainfall event and contains the majority of pollutants or “first flush”.

## 4. Acknowledgements

This project was funded under Hazard Mitigation Grant Program (HMGP) project number 4340-0054 and was completed with the valuable guidance and insight of the Coral Bay Community Council.

## 5. Report and Data Usage

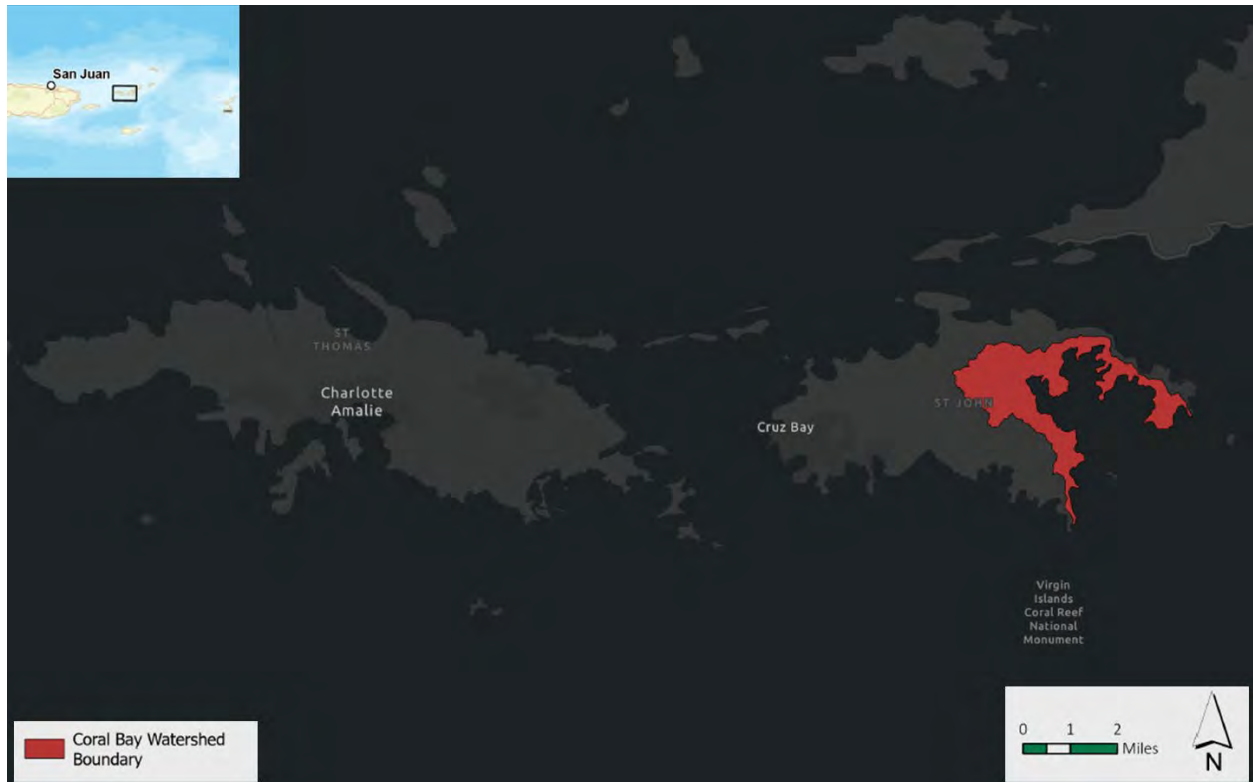
This report and the data and models produced are intended to be both educational and provide valuable information for current and future studies and development in Coral Bay. The data catalog and models produced are intended for use by planners, engineers, and scientists. Modeling and other related data is provided in appendices that can be accessed through the links embedded in this document.

This report is also intended for anyone concerned about the water quality and flooding conditions in Coral Bay, anyone who wants to better understand the relationship between development and hydrology, and anyone who is currently or will in the future develop property in Coral Bay or a location with similar characteristics.

## 6. Introduction

### 6.1. Background

St. John, one of the three islands that make up the United States Virgin Islands (USVI), experiences many environmental hazards such as hurricanes, droughts, storm surges, and rain-induced flooding. The Coral Bay watershed (Figure 1), located on the eastern end of St. John, is a remote and rural watershed. However, due to the unique topography, development patterns, frequent disconnection of drainage pathways from stable guts, impermeable soils, and high intensity rainfall events, land-based sources of pollution (LBSP) are predominantly a result of nonpoint source pollution (NPS) due to unmanaged stormwater runoff coupled with unstable steep slopes.



**Figure 1. The Coral Bay watershed, shown above in red, is located on the eastern end of St. John in the United States Virgin Islands.**

The Coral Bay watershed has experienced significant environmental pressures in the past 30 years due to population growth, urbanization, and natural disasters. Starting in the 1990s, the increase in population density and resulting land development outpaced the capacity of the local government to provide appropriate public services and infrastructure that could support proper management of stormwater runoff and environmental hazards.

While all hazards are disruptive and damaging in varying ways, the most frequently experienced of these issues is stormwater-related damage and flooding. These events can damage infrastructure such as buildings, roads, utilities, and drainage structures like culverts. Due to the anticipated increases in the frequency and severity of rain events associated with climate change, these events are only predicted to increase, and these changing precipitation patterns are already being felt on the island.





Stormwater runoff is precipitation that runs off the land. In undeveloped areas, much of the precipitation is soaked into the ground, taken up by plants, or evaporated back into the atmosphere. However, when human development limits or completely prevents this natural sponge-like effect of the land, generally through the introduction of impervious areas such as roads, parking lots, or buildings, the volume of stormwater runoff increases, sometimes dramatically. Stormwater impacts are also intensified as historic drainage patterns are interrupted and stormwater is redirected down roads and away from stable guts (Figure 2). In addition to the increased volume of stormwater runoff, the runoff is also frequently laden with pollutants such as sediment, nutrients, oils, and pathogens, particularly as the increased volume and velocity of stormwater leads to increased erosion. These stormwater runoff related issues decrease aquatic habitat health, increase flooding and erosion, threaten infrastructure, and prevent use and enjoyment of water resources.



**Figure 2. Pollutant laden stormwater runoff often flows down roads as development has redirected flows away from guts (photo by CBCC).**

To better understand the impacts and extents of stormwater runoff related issues, hydrologic and hydraulic (H&H) modeling within the Coral Bay watershed was completed at multiple scales. The importance of this H&H study was highlighted by the wake of destruction experienced following the two back-to-back Category Five hurricanes that struck the area in 2017, Irma and Maria. This study was also a result of several of the management strategies recommended in the 2021 Coral Bay Watershed Management Plan (WMP). The modeling completed during the development of the WMP yielded several key findings:

- Impervious cover reduction alone will not be enough to reduce peak stormwater flows sufficiently to prevent or even significantly reduce erosion and flooding.



- It is recommended that flows patterns are managed at the neighborhood scale with the installation of best management practices (BMPs) such as sediment ponds.
- A focus on disconnection between impervious surfaces and restoration of natural flow patterns should be pursued.
- The subwatersheds most in need of mitigation flow into Coral Harbor and are the most highly developed subwatersheds within Coral Bay.

This study focuses on several key tasks to better understand the stormwater-related issues in Coral Bay, prioritize BMPs to address issues, and provides preliminary conceptual design and modeling information for five selected priority sites. This effort also includes updating modeling input data to reflect the most accurate and up to date information possible. Datasets that were created or updated during this study include stormwater infrastructure, subwatershed boundaries, land cover, rainfall, contributing drainage areas for priority projects, and preliminary design information for the five priority projects. This study involves analysis of current conditions and seeks to further the development of stormwater solutions, prioritizing water quality improvement, flood mitigation, erosion reduction, and pollution prevention using strategic BMPs and allocating limited resources in a planned and methodical way.

## 7. Preliminary Data Research

### 7.1. *Data Library and Gaps*

A data library was prepared and enhanced throughout the project as data gaps were identified and filled. Key resources included the 2021 Coral Bay WMP and associated models and model input data, existing GIS-based information including subwatershed boundaries and guts, rainfall information, as well as previously identified potential project locations. Aerial imagery was obtained through the Hexagon imagery program and publicly available LiDAR sourced from NOAA Digital Coast. The aerial imagery, collected in 2019, has a spatial resolution of 15 cm. [A complete data library was provided to CBCC for reference.](#)

Inaccuracies in the available data and the absence of critical information necessary for the project's completion were identified upon review of the data library. Identified data gaps included the following:

- **Stormwater infrastructure data.** The previously available data only included culverts and was collected several years ago (collection date unknown). It did not include linear features including swales and ditches, surface crossings, catchbasins, pipes, or outfalls. Infrastructure condition and ability to convey stormwater volumes as designed was also unknown, so a condition assessment was also needed.
- **Current very high spatial resolution (< 5 cm) imagery** is needed for developed areas of priority subwatersheds where development or other landscape changes have occurred since the 2019 imagery (or 2018 LiDAR data) were collected.
- **Land cover** data reflected conditions in 2017 and needed to be updated to reflect post-2017 land cover changes.
- **Contours** need to be developed to reflect the most current U.S Geological Survey (USGS) LiDAR elevation data collected in 2018. The available contours reflected elevation data from 2013.
- **Subwatershed boundaries** failed to account for current drainage patterns in some areas. This included drainage along roads, stormwater infrastructure that routed drainage to areas outside of the subwatershed as delineated, or drainage breaks that were unable to be detected prior to the collection of 2018 LiDAR data.



- **Development plans** for the reconstruction of Centerline Road were not available.
- **Updated rainfall** information was needed.

## **7.2. Data Collection Strategic Plan**

A strategic plan was developed and carried out to address the identified data gaps. The specific tasks are summarized below, and several tasks are expounded upon in the following sections of this report.

- Stormwater infrastructure was mapped via a GPS-based field inventory. Assets mapped included catchbasins, culverts, inlets, outlets, surface crossings, swales, ditches, outfalls, and any other observed relevant features. During data collection, field teams cataloged the size and condition of infrastructure such as culverts where possible. This information can be used to guide future repair and replacement efforts.
- A fixed wing WingtraOne Gen II was utilized to collect very high spatial resolution (< 5 cm) imagery for the key developed areas of the priority subwatersheds. The collected data was used to assess the priority subwatersheds and improve and update land cover data
- The existing land cover dataset was modified to reflect the on-the-ground conditions found in the watershed and account for changes in development.
- Updated contours were developed for 2018 LiDAR data, critical in creating accurate delineations for the drainage areas for identified BMPs and revisions to subwatershed boundaries to best understand the volume of water flowing to a collection point.
- Development plans for Centerline Road were requested from the USVI Department of Public Work (DPW). However, DPW indicated that plans for specific drainage improvements are in process and not yet available. The anticipated date for plan acquisition was also not available.
- Updated rainfall information was acquired from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14. Precipitation information was analyzed in the report entitled “Natural Hazard Risk Analysis for the U.S. Virgin Islands” (RMSI, 2021) and these analyses were also utilized to determine appropriate rainfall data to be utilized in this study.





## 8. Data Collection and Model Development

### 8.1. Updated Land Cover

One key input parameter for the H&H modeling was land cover data. Previous land cover data were available for the study area. However, it did not reflect up to date conditions in the watershed in all areas, which would reduce the accuracy of the modeling that was completed. The land cover data previously generated utilizing post-hurricane 2017 imagery as a part of the 2021 Coral Bay WMP was used as a basis for this land cover update. The dataset was enhanced using the most recently available imagery collected in 2019 by Hexagon Geospatial, which has a 15cm resolution. This vector data layer was manually edited with a minimum mapping scale of 1:1500.



**Figure 3. A WingtraOne Gen II UAS was used to collect up to date very high-resolution imagery in key areas.**

This updated dataset better reflected current watershed conditions but was only current through 2019. As such, additional data was collected via a fixed wing WingtraOne Gen II (Figure 3) unmanned aircraft system (UAS). This UAS was used to collect very high spatial resolution imagery over key areas of the study area in March of 2023. Data collection was focused on areas where changes in land cover were expected or suspected to have occurred since the 2019 imagery was collected with a focus on drainage areas for priority projects (see Section 9).

Following UAS data collection, the updated land cover data was further revised in areas of change. The land cover classes utilized for this layer were classes compatible with HydroCAD, an H&H modeling software utilized in this study. An [overview map of the land cover data](#) can be found in Appendix A. Table 1 includes a summary of land cover changes from the previous dataset. The acres of change for each class are summarized. Note that the total acres included differ between the two datasets as the overall watershed boundary where data was developed was also updated during the subwatershed revision process. Overall, the most significant areas of change were observed in the Woods and Woods / Grass Combination classes where the wooded areas decreased by over 200 acres from the previous land cover dataset. The majority of that area was reassigned to the Woods / Grass Combination class to reflect the absence of cohesive tree canopy in certain areas. This could be a result of increased clearing of trees, higher resolution imagery more clearly showing these cleared areas, or a combination of both.



**Table 1. Summary of revisions to previous land cover data and acres of change (absolute value) for each class.**

| LULC Class              | Previous LULC from 2021 WMP (Acres) | Revised LULC (2023) (Acres) | Change (Acres) |
|-------------------------|-------------------------------------|-----------------------------|----------------|
| <50% Grass Cover, Poor  | 56.7                                | 49.8                        | 6.8            |
| >75% Grass Cover, Good  | 60.3                                | 78.9                        | 18.6           |
| Dirt Roads              | 27.9                                | 28.8                        | 0.9            |
| Newly Graded Area       | 0.0                                 | 19.5                        | 19.5           |
| Paved Parking           | 120.3                               | 128.8                       | 8.5            |
| Water                   | 22.9                                | 59.5                        | 36.6           |
| Woods, Good             | 2656.5                              | 2447.7                      | 208.7          |
| Woods/grass comb., Good | 0.0                                 | 192.8                       | 192.8          |

## 8.2. Stormwater Infrastructure Mapping

Stormwater infrastructure data including catchbasins, culverts, inlets, outlets, major drainages, and outfalls impact how stormwater flows within the Coral Bay watershed. This information is important as it determines where water is directed away from guts, where concentrated stormwater flows, what impervious areas such as roads act as conveyances for stormwater, and where areas are well connected to guts. While some infrastructure, specifically culvert point locations, was previously mapped, the majority of infrastructure locations were not well cataloged.

This detailed mapping is essential to determine drainage patterns in the priority subwatersheds, determine the feasibility of and develop solutions for identified issues, update subwatershed boundaries, and model stormwater flows. During data collection, field teams also cataloged the size and condition of infrastructure such as culverts where possible and collected photographic documentation. This information can be used to guide future repair, replacement, and maintenance efforts. Blocked or damaged infrastructure can limit





the passage of large stormwater volumes and cause flooding and infrastructure failure, which can be extremely destructive and costly.



**Figure 4. An example of the infrastructure data that was mapped in 2022.**

The infrastructure mapping effort for this study was split into field and desktop phases. Field data was collected with handheld GNSS equipment (primarily a Trimble TSC7) using the mobile data collection app ArcGIS Collector in June of 2022. Photo attachments were included for all data points if feasible. Notes were added about each feature such as the number and direction of pipe connections, condition, if



maintenance was needed, and size if possible. The desktop mapping stage focused on quality control and completeness of the map data. Pipe connections were drawn where field notes described, and cross culverts were completed with inlet/outlet pairs. During field visits in October 2022 and March 2023, additional verification was performed on previously mapped infrastructure with a focus on the contributing drainage areas of the five priority projects.

This dataset is the most complete and accurate mapping of the stormwater infrastructure within the watershed. An example of this data for one select area can be found in Figure 4. However, no mapping of this scale can capture all infrastructure. There are many private areas that were unable to be accessed in the field. It is also expected that there is some infrastructure that has become buried with sediment over time and is unable to be identified. As-built plans were unavailable, so in areas where field investigations were unable to be completed or where pipe connections were unclear, this data was unable to be captured.

The detailed mapping was utilized in determining drainage patterns in the priority subwatersheds, determining feasibility of and develop designs for proposed stormwater projects, and model stormwater flows.

An overview map of collected infrastructure data can be found in [Appendix B](#). A [web map](#) displaying this data was also created and provided to CBCC.

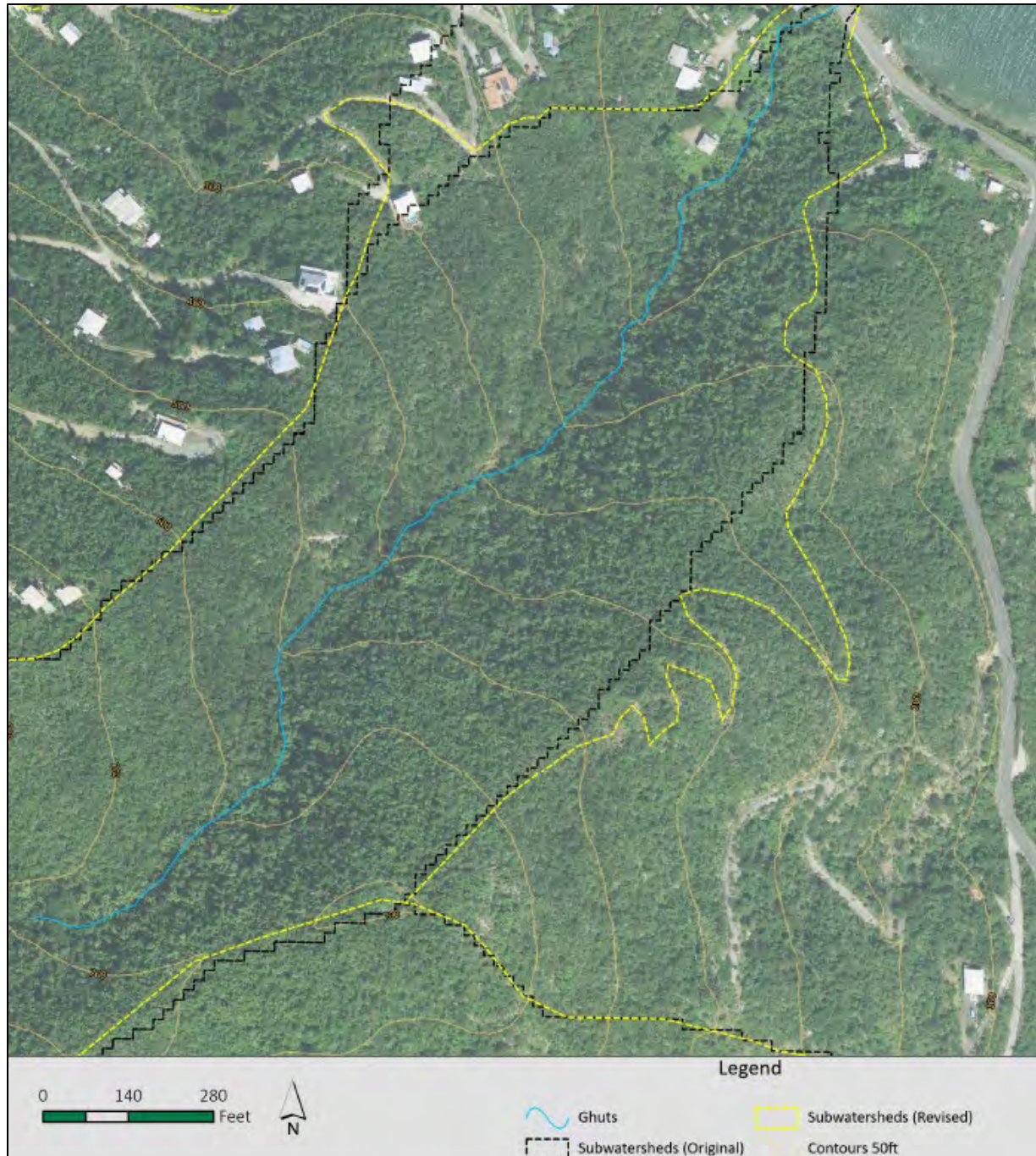
### **8.3. Subwatershed Boundary Refinement**

Subwatersheds were used as an area of analysis for the initial Coral Bay H&H modeling. A subwatershed data layer was provided by CBCC, which was the dataset utilized for the 2021 Coral Bay WMP. However, this previously generated data did not accurately reflect current on the ground conditions as determined by the mapped stormwater infrastructure data, 2018 LiDAR data, updated imagery (2019 Hexagon and UAS-collected), and field observations.

Revisions were particularly important in areas where subwatershed boundaries are actually determined by anthropogenic activities rather than topography. For example, some subwatershed boundaries were defined by areas where water flows down the road rather than down the hillslope. Boundaries were adjusted as shown in Figure 5. The steep roads of Coral Bay are highly influential to the nature of runoff in the watershed, and often direct runoff from large sections of hillside down paved swales, other depressions along the roadsides, or directly down the road itself. The presence or absence of catchbasins, turnouts, water bars, road culverts, or other stormwater infrastructure often dictates if runoff is constrained to or released from roadside flow paths.

Two subwatersheds present in the original dataset, Gerda Marsh and John's Folly, were divided further during this revision process. Gerda Marsh was divided into three subwatersheds: Gerda Marsh (Pond), Gerda Marsh (Road), and Gerda Marsh (Surface Crossing). Due to topography and existing infrastructure, these sections of Gerda Marsh are not hydrologically connected to the same discharge point, so each section was divided based on its discrete discharge point. Similarly, the original John's Folly subwatershed was comprised of two primary ghuts. These were split into John's Folly N (north) and John's Folly S (south) to separate them based where they discharge into Coral Bay. An overview map of the subwatersheds and the revisions made to the boundaries can be found in [Appendix C](#).





**Figure 5. An example of revisions (yellow) made to previous subwatershed boundaries (black) to reflect a better understanding of drainage patterns.**

#### **8.4. Rainfall Data**

Local rainfall data is used in hydrologic models to estimate the rainfall volumes during various storm intensities within the study area. NOAA's Atlas 14 Precipitation-Frequency Estimates are the standard reference for rainfall estimates in the United States. Atlas 14 describes the rainfall depths for specific rainfall durations at various frequency occurrences at a given location.



Rainfall estimates for the Coral Bay watershed were downloaded from NOAA's Atlas-14 Precipitation Frequency Data Server (PFDS). The point location used to query the Atlas 14 data was the centroid coordinate of the Coral Bay watershed (Latitude: 18.3419°, Longitude: -64.7082°). Ten different storm intensities were utilized for this modeling, whose depths are described below in Table 2.

**Table 2. Atlas 14 24-hour rainfall depths for the Coral Bay watershed.**

| Average Recurrence Interval (years) | 24-hour Rainfall Depth (inches) |
|-------------------------------------|---------------------------------|
| 1                                   | 3.11                            |
| 2                                   | 4.23                            |
| 5                                   | 6.37                            |
| 10                                  | 8.19                            |
| 25                                  | 10.90                           |
| 50                                  | 13.20                           |
| 100                                 | 15.70                           |
| 200                                 | 18.40                           |
| 500                                 | 22.50                           |
| 1000                                | 25.80                           |

This rainfall data was imported into HydroCAD to inform the H&H modeling described below.

## 9. Subwatershed-Scale H&H Modeling

Subwatershed-scale hydrologic models were prepared for 22 subwatersheds within the greater Coral Bay watershed. Inputs to these models included the refined land cover and subwatershed boundary data described above. Additionally, the hydrologic soil groups outlined in NRCS soils data was used in tandem with land cover to estimate runoff throughout a given drainage area via the Soil Conservation Service (SCS) runoff curve number method<sup>1</sup>. Time of concentration for each subwatershed was estimated using the watershed lag method, which is informed by the slope of the subwatershed and the length of its longest flow path<sup>2</sup>.

Peak flows for each subwatershed were estimated in HydroCAD for the ten different storm intensities described in Table 2. Peak flow is measured in cubic feet per second (cfs) and is indicative of how quickly stormwater drains through an area of analysis (in this case a subwatershed). High peak flows are problematic because these flows drive erosion and flooding as stormwater flows in fast moving, concentrated channels from high to low elevations. Generally, watersheds or subwatersheds with higher peak flows are likely to have been altered from their natural state as determined by impervious cover and other land cover classes reflective of development (i.e., grass as opposed to wooded). Other determinants of the intensity of peak flow include drainage area size, hydrologic soil group (reflective of the infiltration capacity of underlying soils), and slope.

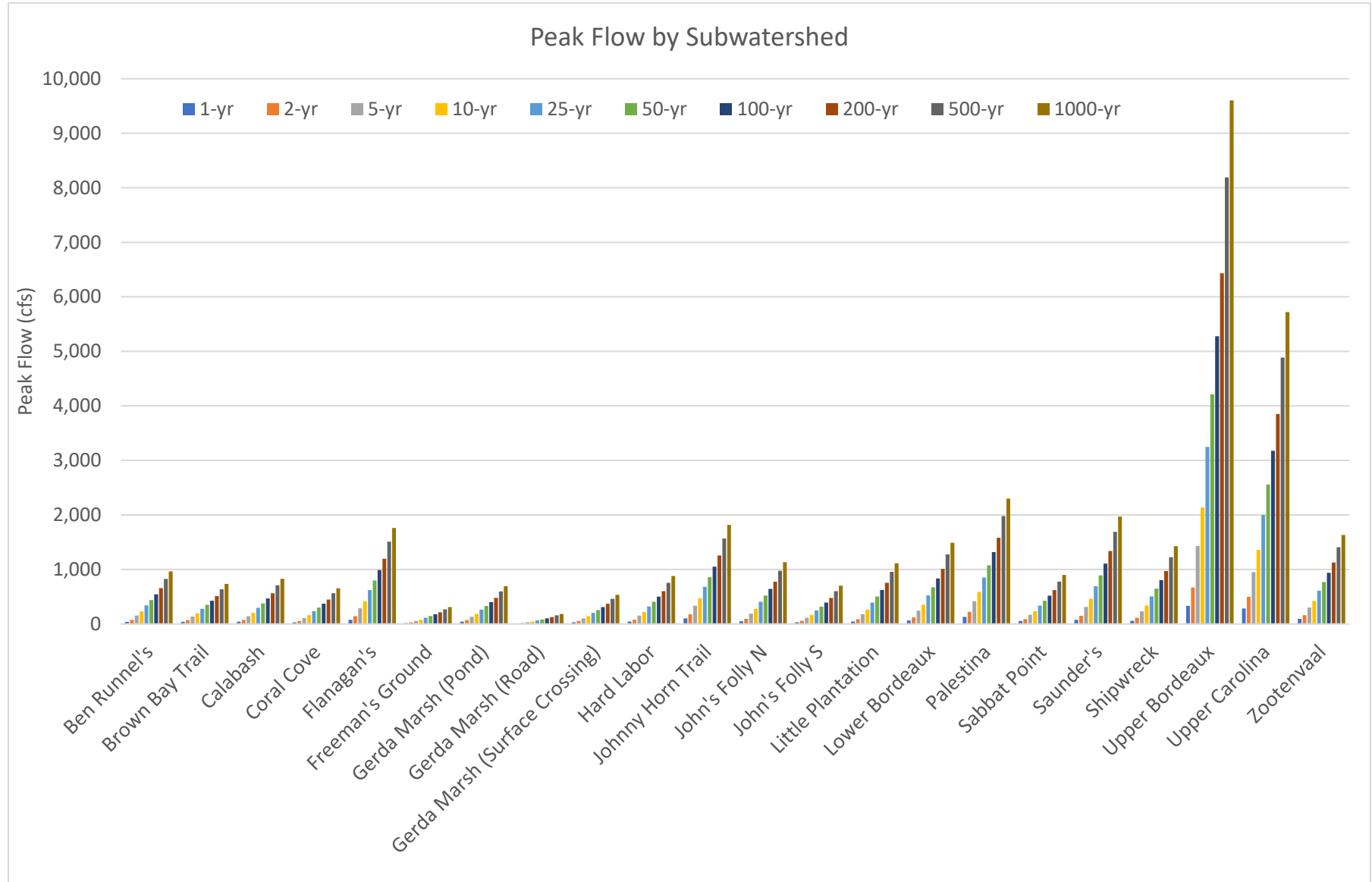
<sup>1</sup> [https://www.nrcs.usda.gov/Internet/FSE\\_DOCUMENTS/stelprdb1044171.pdf](https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf)

<sup>2</sup> <https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=27002.wba>



**Table 3: Table summarizing the modeled peak flows (cubic feet per second or cfs) by subwatershed for 10 recurrence intervals.**

| Subwatershed                   | Average Recurrence Interval (years) |        |         |         |         |         |         |         |         |         |
|--------------------------------|-------------------------------------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
|                                | Rainfall Depth (inches)             |        |         |         |         |         |         |         |         |         |
|                                | 1-yr                                | 2-yr   | 5-yr    | 10-yr   | 25-yr   | 50-yr   | 100-yr  | 200-yr  | 500-yr  | 1000-yr |
|                                | 3.11                                | 4.23   | 6.37    | 8.19    | 10.90   | 13.20   | 15.70   | 18.40   | 22.50   | 25.80   |
|                                | Peak Flow (cfs)                     |        |         |         |         |         |         |         |         |         |
| Ben Runnel's                   | 38.89                               | 75.66  | 156.30  | 229.83  | 342.43  | 438.92  | 543.85  | 656.87  | 827.60  | 964.24  |
| Brown Bay Trail                | 42.18                               | 73.31  | 137.56  | 193.89  | 278.24  | 349.61  | 426.77  | 509.62  | 634.60  | 734.63  |
| Calabash                       | 44.16                               | 75.22  | 141.85  | 202.60  | 296.68  | 378.13  | 467.31  | 563.92  | 710.72  | 828.79  |
| Coral Cove                     | 29.58                               | 55.25  | 110.64  | 160.68  | 236.92  | 302.08  | 372.87  | 449.08  | 564.19  | 656.32  |
| Flanagan's                     | 76.28                               | 142.50 | 287.18  | 419.13  | 622.88  | 798.31  | 989.86  | 1196.81 | 1510.39 | 1761.94 |
| Freeman's Ground               | 16.49                               | 29.21  | 55.94   | 79.71   | 115.59  | 146.09  | 179.14  | 214.67  | 268.31  | 311.24  |
| Gerda Marsh (Pond)             | 44.16                               | 73.27  | 132.78  | 184.79  | 263.26  | 330.04  | 402.48  | 480.49  | 598.53  | 693.23  |
| Gerda Marsh (Road)             | 9.98                                | 16.98  | 31.98   | 45.54   | 66.46   | 84.55   | 104.35  | 125.79  | 158.36  | 184.54  |
| Gerda Marsh (Surface Crossing) | 33.28                               | 55.89  | 102.32  | 142.99  | 203.96  | 255.61  | 311.53  | 371.62  | 462.36  | 535.02  |
| Hard Labor                     | 45.08                               | 80.05  | 153.99  | 220.11  | 321.01  | 407.42  | 501.43  | 602.80  | 756.23  | 879.28  |
| Johnny Horn Trail              | 102.51                              | 178.01 | 335.02  | 473.59  | 682.00  | 858.85  | 1050.53 | 1256.38 | 1567.10 | 1815.83 |
| John's Folly N                 | 49.91                               | 94.06  | 189.66  | 276.19  | 408.15  | 520.97  | 643.55  | 775.50  | 974.79  | 1134.29 |
| John's Folly S                 | 31.64                               | 58.29  | 115.57  | 167.47  | 247.92  | 317.59  | 393.82  | 476.35  | 601.71  | 702.51  |
| Little Plantation              | 45.29                               | 87.06  | 178.81  | 262.83  | 392.18  | 503.57  | 625.08  | 756.24  | 954.76  | 1113.89 |
| Lower Bordeaux                 | 66.52                               | 122.04 | 242.82  | 353.48  | 524.74  | 672.91  | 835.02  | 1010.45 | 1276.70 | 1490.57 |
| Palestina                      | 130.09                              | 223.10 | 417.17  | 589.39  | 851.05  | 1074.92 | 1318.53 | 1581.31 | 1979.30 | 2298.73 |
| Sabbat Point                   | 54.58                               | 91.19  | 167.51  | 235.24  | 337.70  | 425.06  | 519.94  | 622.15  | 776.72  | 900.60  |
| Saunder's                      | 75.97                               | 149.95 | 313.50  | 463.38  | 693.73  | 891.58  | 1107.02 | 1339.23 | 1690.23 | 1971.23 |
| Shipwreck                      | 59.86                               | 113.82 | 232.27  | 340.45  | 506.49  | 649.07  | 804.34  | 971.73  | 1224.81 | 1427.47 |
| Upper Bordeaux                 | 332.21                              | 668.83 | 1429.59 | 2137.94 | 3247.01 | 4214.04 | 5277.63 | 6432.70 | 8189.82 | 9603.20 |
| Upper Carolina                 | 284.06                              | 498.24 | 951.81  | 1360.82 | 1999.35 | 2558.50 | 3176.87 | 3851.95 | 4884.58 | 5719.56 |
| Zootenvaal                     | 94.26                               | 162.03 | 301.88  | 424.74  | 610.57  | 768.99  | 940.96  | 1126.17 | 1406.40 | 1631.18 |



**Figure 6. Graph summarizing the modeled peak flows (cubic feet per second or cfs) by subwatershed for multiple recurrence intervals.**

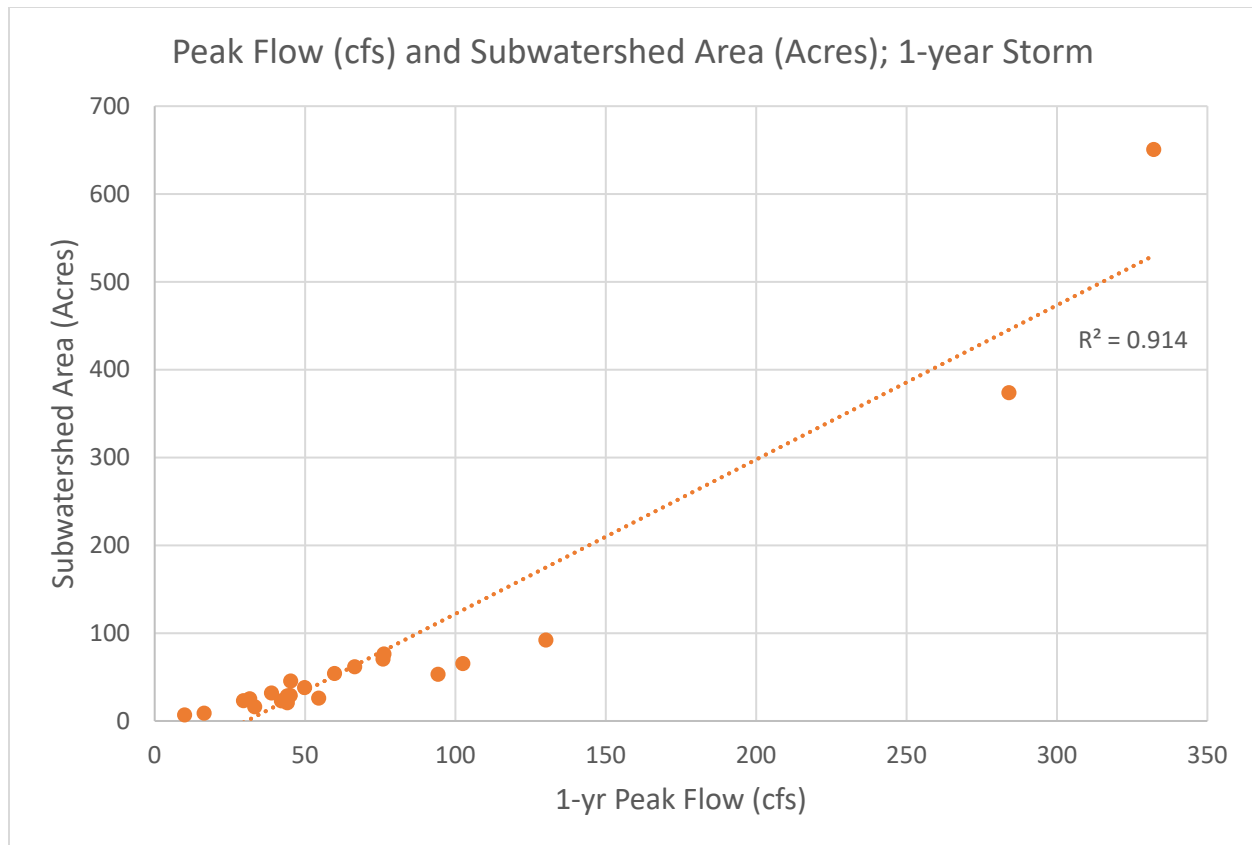


Peak flows are not only problematic for water quality in the Bay itself, but also present a localized risk to infrastructure like roads, bridges, and culverts. Therefore, it is important to know which subwatersheds have the highest total peak flow to identify areas that are particularly vulnerable to extreme flooding and erosion. Complete peak flow modeling information (modeling reports, summary memo, and HydroCAD model) can be found in Appendix D.

The subwatersheds of Upper Bordeaux and Upper Carolina have the highest peak flows in all storm events assessed (Figure 6). This is expected given that they are significantly larger than the rest of the subwatersheds—Upper Bordeaux is 650.5 acres while Upper Carolina is 373.5 acres (Table 4). In general, peak flows are well correlated to subwatershed size as demonstrated by the graph in Figure 7. In order to better understand the relative contributions of the other factors that contribute to the peak flows, the values were normalized by subwatershed area.

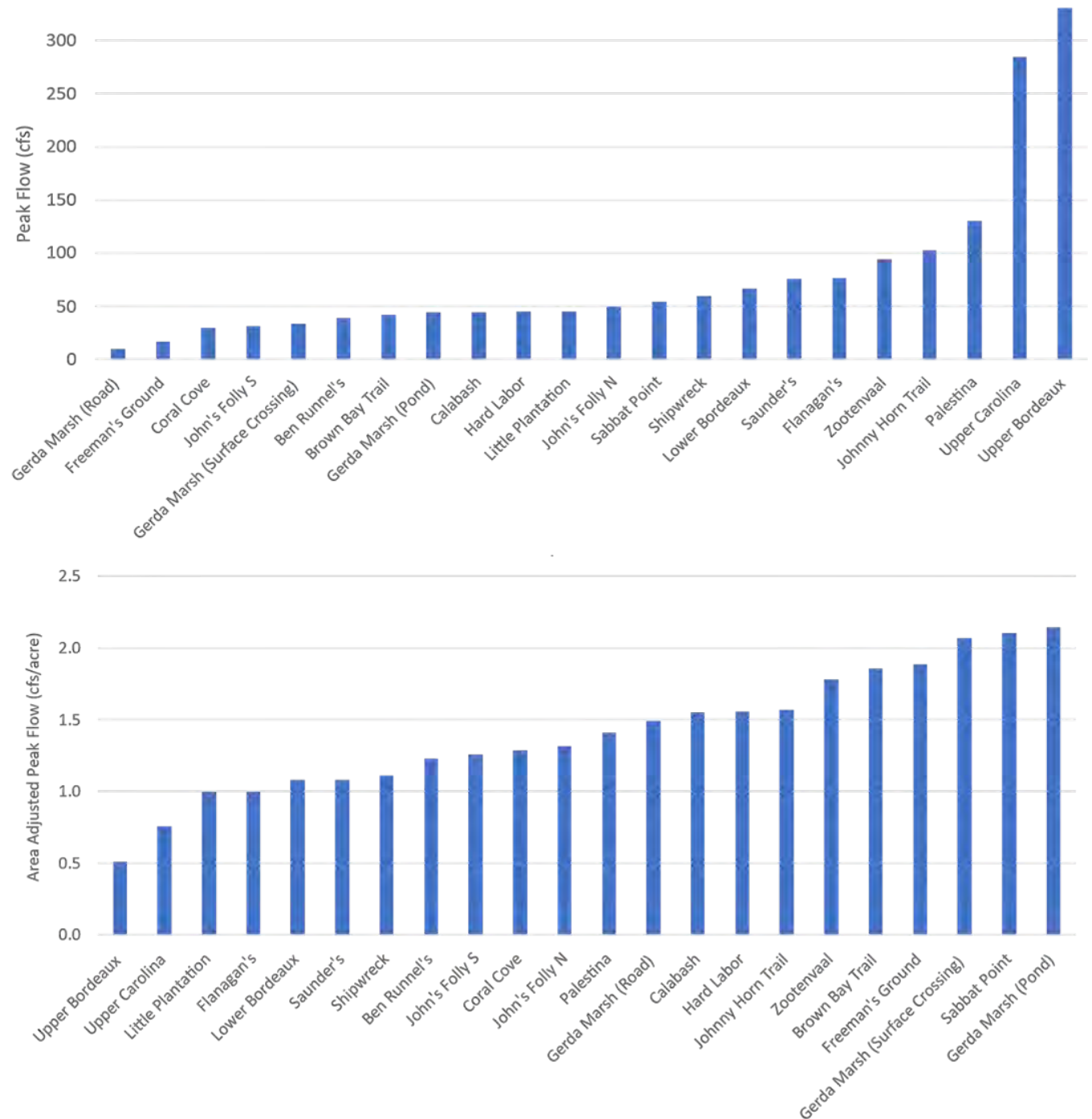
**Table 4. Subwatershed area in acres is shown from largest to smallest.**

| Subwatershed      | Area (Acres) | Subwatershed                   | Area (Acres) |
|-------------------|--------------|--------------------------------|--------------|
| Upper Bordeaux    | 650.5        | Ben Runnel's                   | 31.7         |
| Upper Carolina    | 373.5        | Hard Labor                     | 28.9         |
| Palestina         | 92.0         | Calabash                       | 28.5         |
| Flanagan's        | 76.2         | Sabbat Point                   | 25.9         |
| Saunders's        | 70.2         | John's Folly S                 | 25.2         |
| Johnny Horn Trail | 65.2         | Coral Cove                     | 22.9         |
| Lower Bordeaux    | 61.6         | Brown Bay Trail                | 22.7         |
| Shipwreck         | 53.9         | Gerda Marsh (Pond)             | 20.6         |
| Zootenvaal        | 52.9         | Gerda Marsh (Surface Crossing) | 16.1         |
| Little Plantation | 45.4         | Freeman's Ground               | 8.7          |
| John's Folly N    | 38.0         | Gerda Marsh (Road)             | 6.7          |



**Figure 7. Subwatershed area is well correlated to peak flow. An  $R^2$  value of 0.914 means that the line of best fit explains a significant amount of the variation in the peak flow values (91.4%).**

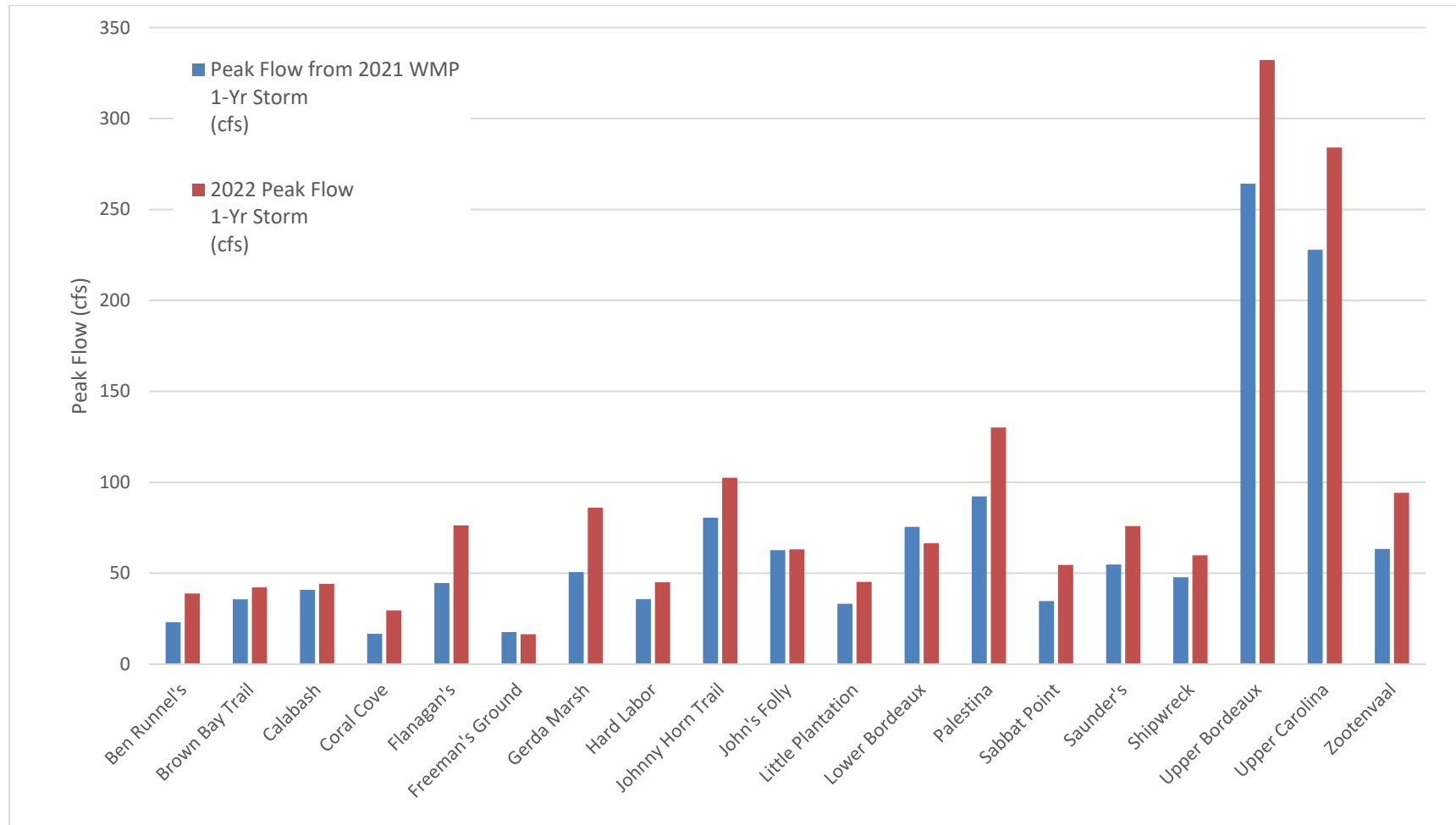
If other inputs were equal, it would be expected that peak flows when adjusted by area would be consistent across all subwatersheds. However, as shown in Figure 8, the highest peak flows from the modeling (upper) are seen in different subwatersheds when normalized by area (lower).



**Figure 8. Peak flows (cfs) for the 1-year storm event as modeled (upper) and adjusted by the subwatershed area (lower).**



A similar subwatershed-scale analysis was completed during the development of the 2021 Watershed Management Plan (WMP). The results from the two analyses (Figure 5) reflect updated input data, particularly updates to the land cover data, subwatershed boundaries, and rainfall data. Note that the subwatersheds that were divided for this H&H study (Gerda Marsh and John's Folly) were recombined for this comparison to reflect the assessment units presented in the 2021 WMP. This comparison highlights the importance of utilizing the most recent and accurate data possible.



**Figure 9. A comparison of peak flows (cfs) from the 1-year storm event as modeled in the 2021 Watershed Management Plan (blue) and with updated data in 2022 (red).**





Upper Bordeaux and Upper Carolina have the highest peak flows, 264.2 and 227.9 cfs respectively (Figure 42). This is unsurprising given that they are significantly larger than the rest of the subwatersheds—Upper Bordeaux is 657.9 acres and Upper Carolina is 392.7 acres while the next largest subwatershed, Lower Bordeaux, is only 85.38 acres. Barring Upper Bordeaux and Upper Carolina, where high peak flow is clearly the result of a large drainage area, subwatershed peak flow is most influenced by soil infiltration capacity. Johnny Horn Trail, 64.4 ac, is smaller in area than Lower Bordeaux, 84.5 ac, yet its peak flow is 5 cfs higher than Lower Bordeaux. This is likely because soils in Lower Bordeaux have a higher infiltration capacity than soils in Johnny Horn Trail; 86% of the Johnny Horn Trail is comprised of HSG D soils while Lower Bordeaux has only 11% HSG D soils (Table 13). However, it should be noted that actual infiltration capacity is site specific and can vary throughout a watershed.

Impervious development is most problematic when it directs water away from natural drainage ghuts or connects previously isolated impervious surfaces.

The updated rainfall data (Atlas-14) reflects increased rainfall totals for assessed storm events as compared to the data utilized for the 2021 WMP (Natural Resources Conservation Service (NRCS) Type II rainfall event database; Table 5). The updated data better reflects more recent climate change influenced rainfall patterns and highlights the importance of both updated rainfall data for modeling tasks as well as the need to increase stormwater management in the future as rainfall depths and intensities increase during storm events. Generally, all subwatersheds show increases in peak flow as a result of the increased rainfall depths from the 2021 WMP modeling unless other changes in the watershed have resulted in reduced flows. This was observed in Lower Bordeaux and Freeman’s Ground subwatersheds, both of which had smaller contributing subwatersheds as a result of revisions to the subwatershed boundaries.

**Table 5. Rainfall depths utilized in 2022 H&H modeling as compared to rainfall data utilized in previous 2021 WMP modeling.**

| Average Recurrence Interval (years) | 2022 Modeling Data:<br>24-hour Rainfall Depth (inches) | 2021 WMP Data:<br>24-hour Rainfall Depth (inches) |
|-------------------------------------|--|---|
| 1                                   | 3.11   | 2.8   |
| 2                                   | 4.23   | 3.9   |
| 5                                   | 6.37   | 5.5   |
| 10                                  | 8.19   | 6.6   |
| 25                                  | 10.90  | 8   |
| 50                                  | 13.20  | 9.2   |
| 100                                 | 15.70  | 10.5  |



## 10. Project Prioritization

### 10.1. *Project Identification*

A potential project list was provided by CBCC, which outlined areas with known drainage, erosion, and/or flooding issues and reflected the FEMA VITEMA Mitigation Grant project parameters as well as possible within the watershed. This potential project list was refined and expanded during several meetings with CBCC, USVI government agencies, and other stakeholders.

Stormwater best management practices (BMPs) improve water quality both by removing pollutants through filtration, infiltration, or settling, and by reducing the volume and velocity of runoff entering guts and coastal waters. As land development continues in the USVI and precipitation patterns are impacted by climate change, stormwater management practices will play an even more important role in reducing flooding, protecting water quality and marine ecosystem health, reducing peak discharge, and more closely approximating the hydrology of undeveloped lands.

### 10.2. *Project Ranking*

Projects were ranked based on four criteria, all of which were assigned a High/Medium/Low qualitative score. These criteria included:

- *Priority & Feasibility*: This criterion was based on input on project priority received from CBCC received at various project meetings. This factor also incorporates the feasibility of implementing the proposed project. Given the importance of this criterion, scoring scaled from 0 (low) to 4 (high).
- *Flood Mitigation*: The potential for the proposed project to mitigate flooding was ranked from 0 (low) to 2 (high). This was based on description of known flooding issues at the site including vertical flooding or if projects were located in lower-elevation floodplain areas of the watershed.
- *Erosion Prevention*: The potential for the proposed project to reduce or prevent erosion was ranked from 0 (low) to 2 (high). Areas that ranked highest were areas with documented erosion issues that would be mitigated by the proposed practice(s).
- *Water Quality Benefits*: The potential water quality benefit of the proposed project was ranked from 0 (low) to 2 (high). Projects that would reduce large amounts of sediment or pollutant loads ranked highest.

An overview map of the proposed project locations is included below in Figure 10. The results of this ranking process are included in Table 6.

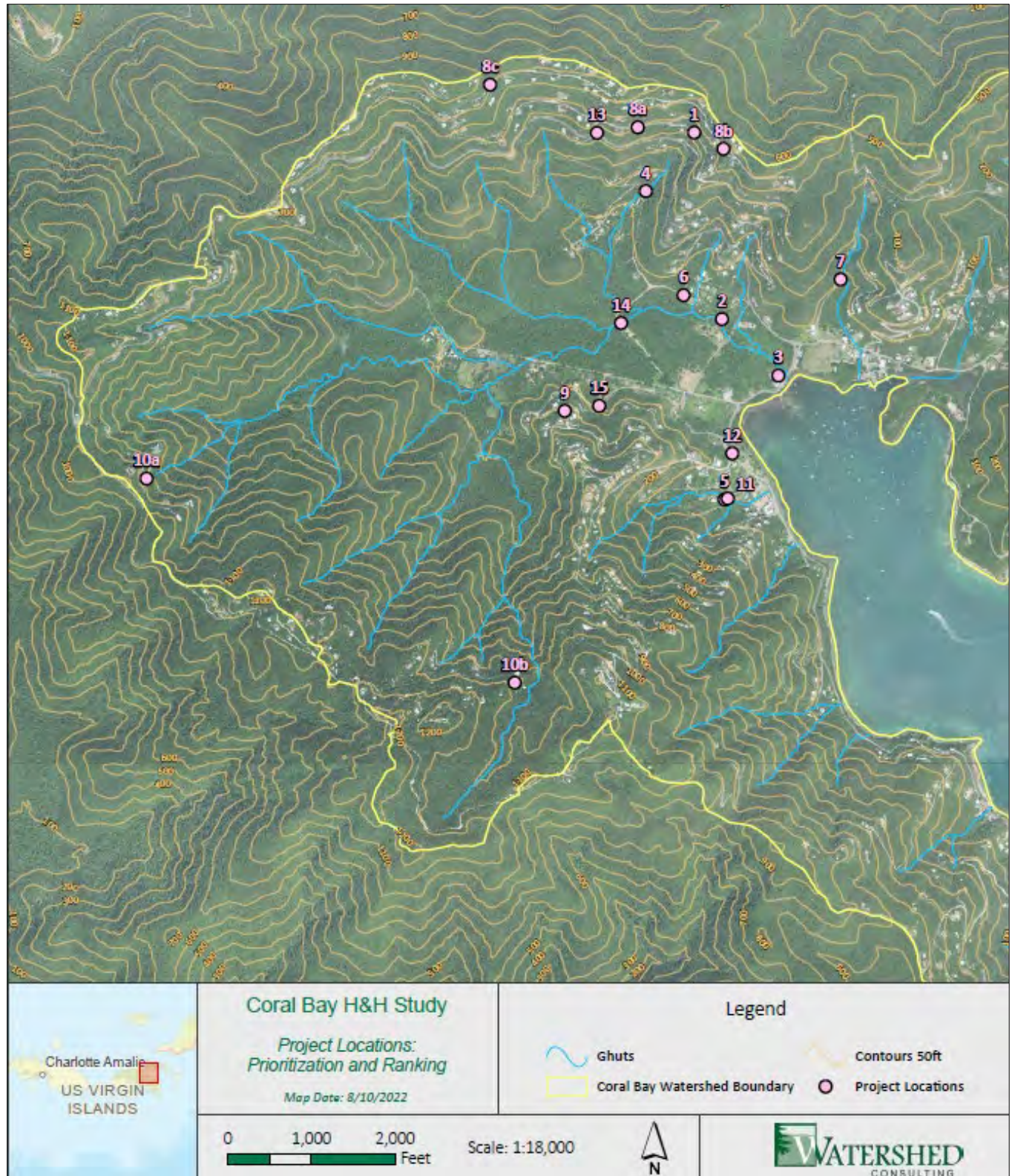


Figure 10. Overview map of potential project locations.





**Table 6. A project prioritization and ranking summary table was developed. The top five ranked projects are shown highlighted in blue. Note that bolded names are those used throughout the rest of the report to refer to these projects.**

| Map ID(s)  | Site Name / Description  | Priority & Feasibility | Priority & Feasibility Score | Flood Mitigation | Flood Mitigation Score | Erosion Prevention | Erosion Prevention Score | Water Quality Benefits | Water Quality Benefits Score | Total Score |
|------------|--|------------------------|------------------------------|------------------|------------------------|--------------------|--------------------------|------------------------|------------------------------|-------------|
| 1          | <b>Ironwood Road Culvert</b>   | High                   | 4                            | Medium           | 1                      | High               | 2                        | High                   | 2                            | 9           |
| 2          | <b>6-4 Carolina</b> ; Includes sediment detention, roads, and public use areas | High                   | 4                            | High             | 2                      | Medium             | 1                        | High                   | 2                            | 9           |
| 3          | <b>Pickles</b> - Reduce flooding at Carolina Main Ghut (Pickles) on Route 107  | High                   | 4                            | High             | 2                      | Medium             | 1                        | High                   | 2                            | 9           |
| 4          | <b>Lala Land</b> Road and dirt roads above                                     | High                   | 4                            | Low              | 0                      | High               | 2                        | High                   | 2                            | 8           |
| 5          | <b>Spring Garden</b> / Lower Bordeaux / Spring Garden                          | High                   | 4                            | High             | 2                      | Medium             | 1                        | Medium                 | 1                            | 8           |
| 6          | Estate 6 Road intersection with Sugar Apple Road                               | Medium                 | 2                            | Medium           | 1                      | High               | 2                        | Medium                 | 1                            | 6           |
| 7          | Johnny Horn Trail/Route 109  | Medium                 | 2                            | Medium           | 1                      | High               | 2                        | Medium                 | 1                            | 6           |
| 8a, 8b, 8c | Other Carolina roads   | Medium                 | 2                            | Low              | 0                      | High               | 2                        | Medium                 | 1                            | 5           |



| Map ID(s) | Site Name / Description  | Priority & Feasibility    | Priority & Feasibility Score | Flood Mitigation | Flood Mitigation Score | Erosion Prevention | Erosion Prevention Score | Water Quality Benefits | Water Quality Benefits Score | Total Score |
|-----------|--|---------------------------|------------------------------|------------------|------------------------|--------------------|--------------------------|------------------------|------------------------------|-------------|
| 9         | Gerda Marsh paving extension, planned by HOA in 2022                         | Medium                    | 2                            | Low              | 0                      | High               | 2                        | Medium                 | 1                            | 5           |
| 10a, 10b  | Upper Bordeaux Watershed Estate roads  | Medium                    | 2                            | Low              | 0                      | High               | 2                        | Medium                 | 1                            | 5           |
| 11        | Proposed land acquisition for sedimentation and flood management basins      | Low                       | 0                            | High             | 2                      | Medium             | 1                        | Medium                 | 1                            | 4           |
| 12        | Route 108 intersection with Route 107; Sediment deposition box - 12 Carolina | Low                       | 0                            | Medium           | 1                      | Medium             | 1                        | High                   | 2                            | 4           |
| 13        | Upper Carolina landslides  | Low                       | 0                            | Low              | 0                      | High               | 2                        | Medium                 | 1                            | 3           |
| 14        | Main ghut crossing   | Low                       | 0                            | High             | 2                      | Medium             | 1                        | Low                    | 0                            | 3           |
| 15        | Gerda Marsh entrance asphalt road  | Currently being completed | --                           | --               | --                     | --                 | --                       | --                     | --                           | --          |



## 11. Top Five Projects

Five priority projects were selected for further assessment and modeling. The assessed sites were ranked, and a discussion was held with CBCC to determine the projects that would be selected for further assessment and modeling. The selected projects are those that will provide significant water quality and quantity benefits while also having a high likelihood of implementation and future funding. CBCC's local knowledge was critical in determining implementation feasibility.

One site, the Ironwood Rd Culvert, was pre-selected as a priority as CBCC released a request for proposals (RFP) for engineering design of the retrofit of this culvert to improve drainage as part of another FEMA VITEMA HMGP funded project. The other four sites that were selected include 6-4 Carolina, Pickles, Spring Garden, and Lala Land. Each of these project sites are described in detail below. The locations of the sites within the Coral Bay watershed can be viewed in Figure 11. All five sites are located in the central more developed area of Coral Bay. With the exception of Spring Garden, the remaining four sites all drain via the same main gut and, as such, the drainages for each of these four sites are related. From most upstream to most downstream, the projects are the Ironwood Road culvert, Lala Land, 6-4 Carolina, and Pickles.

Two types of H&H models were completed, depending on site conditions. All sites were modeled using HydroCAD, a hydrology and hydraulics (H&H) software for modeling stormwater runoff and designing stormwater management systems. Two of the sites (Pickles and Spring Garden) were also modeled using the Hydrologic Engineering Center River Analysis System (HEC-RAS) program to complete a detailed flood routing analysis of the existing gut and floodplain conditions. The other three sites were not modeled using HEC-RAS because these sites are steeper and do not have the same floodplain conditions as the two sites selected for HEC-RAS modeling so this additional modeling would not be useful.

In HydroCAD, each priority site was assessed at a range of rainfall events. These events are modeled over a 24-hour time period and were developed using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14<sup>3</sup> precipitation frequency estimates, which are based on long term local rainfall records. This data is the official peer-reviewed record of precipitation frequency estimates in the USVI and the rest of the United States. It is produced by the National Weather Service (NWS) Office of Water Prediction, which is a part of NOAA. The precipitation information provides summaries of precipitation amount by location with a range of recurrence intervals. For example, a "10-yr" storm event has a 1-in-10 chance of being exceeded in any given year and on average will occur once every 10 years. The water quality volume (WQv) includes the first one inch of rainfall and research has shown that this first flush of rainfall carries the majority of pollutants that wash off the land. The recurrence intervals and their associated rainfall depth assessed in this study can be found in Table 7.

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<sup>3</sup> [https://hdsc.nws.noaa.gov/hdsc/pfds/pfds\\_map\\_pr.html](https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_pr.html)





Figure 11. The five selected priority projects are indicated with a red circle.



**Table 7. Summary table of storm events assessed in HydroCAD including event recurrence intervals and rainfall event depth.**

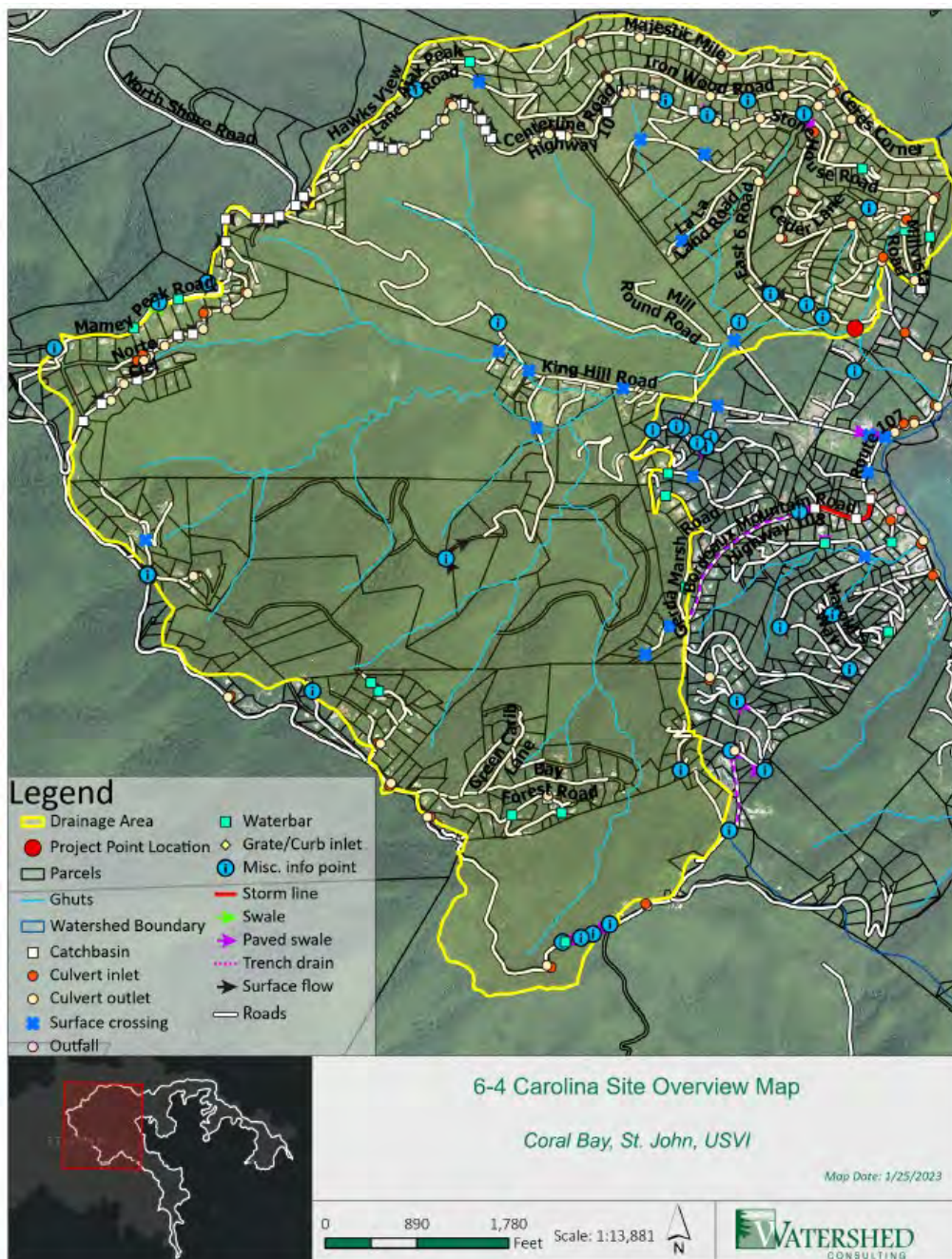
| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) |
|------------------------------------|---------------------------|
| WQv                                | 1                         |
| 1-yr                               | 3.11                      |
| 2-yr                               | 4.23                      |
| 5-yr                               | 6.37                      |
| 10-yr                              | 8.19                      |
| 25-yr                              | 10.9                      |
| 50-yr                              | 13.2                      |
| 100-yr                             | 15.7                      |
| 200-yr                             | 18.4                      |
| 500-yr                             | 22.5                      |
| 1000-yr                            | 25.8                      |





### 11.1. 6-4 Carolina

6-4 Carolina is a publicly owned parcel located in central Coral Bay. The drainage area to this site includes 990.8 acres of land, which is primarily a mix of residential development and undeveloped areas (Figure 12). This site was selected as a priority because it is one of the few publicly owned parcels in Coral Bay, a significant amount of drainage from the central portion of the watershed drains to this location, and it has open space ideal for a water quality and flood reduction practice. There is one existing stormwater management basin on the property already, in the southern portion of the parcel (hereafter referred to as



**Figure 12. Drainage area for 6-4 Carolina, highlighted in yellow, includes a significant amount of the developed areas in Coral Bay. The site location is shown with a red circle.**



a “bioretention basin”), as well as a second stormwater basin in the northwest section of the parcel (hereafter referred to as a “stormwater basin”). Both basins should be maintained to ensure they are functioning at maximum capacity. This parcel has been utilized to stockpile debris and other materials for decades.

There are plans to utilize the site for a generator and potentially other emergency services. The finalized layout for any development should be consulted prior to final design of the proposed water quality improvements. Likewise, other development of the site should include a water quality and flood reduction component. The proposed development is generally located at higher elevations on the parcel while the stormwater improvements are at lower elevations where the gut is already located, so these two uses should not be in conflict. However, continued coordination is recommended as plans advance.

The site is located on the edge of a floodplain adjacent to a large gut. NRCS mapping indicates the soils are non-hydric (CbB - Cinnamon Bay Loam 0-5% slopes and/or SoA -Solitude gravelly fine sandy Loam - 0-2% slopes). However, these soils can include components of Sandy Point and Sugar Beach soils, which are hydric soils. There is substantial fill on this site, deposited over decades from various development sites around Coral Bay, so the soils in some areas are unknown fill materials. NWI mapping indicates there are wetlands just to the east of the project site. This site should be investigated for potential wetlands and may need a wetlands delineation. See [Appendix E](#) for a map of the NWI for Coral Bay. A site survey was completed to define existing conditions including culvert inverts and drainage patterns. The contributing drainage area was also verified at this time. The existing condition survey can be found in Appendix F.

The project location is upstream from the Pickles site (see Section 11.2 for more information on this site), which is often overwhelmed by stormwater flows, even with the proposed stormwater improvements at this downstream location. The modeling for the Pickles site highlighted the need for additional stormwater controls upstream from the site, and the 6-4 Carolina site is an example of an opportunity for this type of practice. See the next section for more information on the Pickles site.

A HydroCAD model was developed to determine peak flows, assess flows through this area, conceptually design a retrofit of the bioretention basin and improvements to the stormwater basin, and assess peak flow benefits of the bioretention basin retrofit. Modeled peak flows for a range of storm events can be found below in Table 8.

**Table 8. 6-4 Carolina HydroCAD peak flow summary table.**

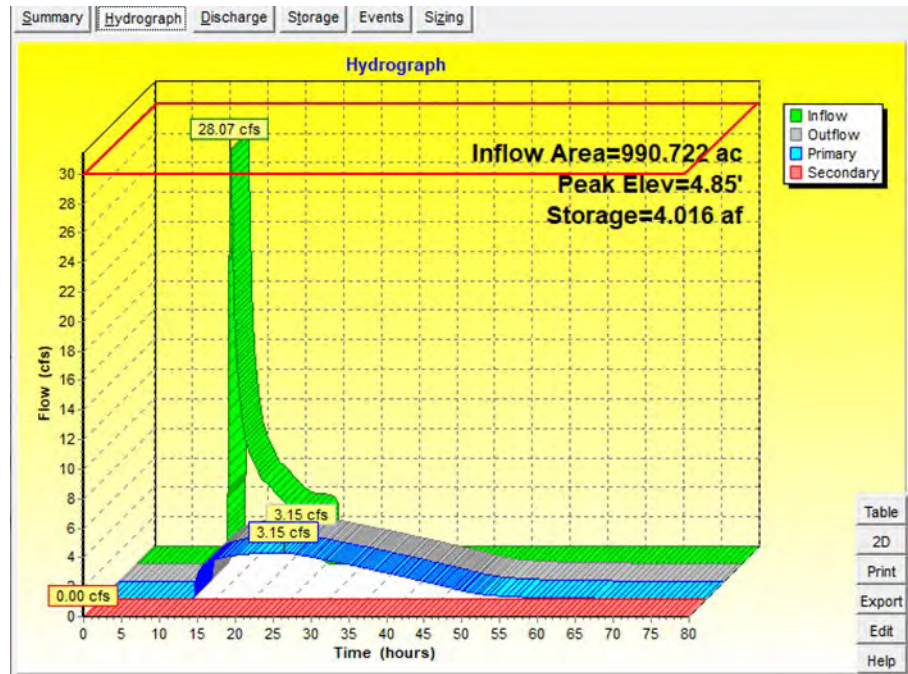
| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) | Peak Flow (cfs) |
|------------------------------------|---------------------------|-----------------|
| WQv                                | 1                         | 28.07           |
| 1-yr                               | 3.11                      | 515.46          |
| 2-yr                               | 4.23                      | 982.22          |
| 5-yr                               | 6.37                      | 2,011.60        |
| 10-yr                              | 8.19                      | 2,963.82        |
| 25-yr                              | 10.9                      | 4,454.23        |
| 50-yr                              | 13.2                      | 5,756.11        |
| 100-yr                             | 15.7                      | 7,191.38        |
| 200-yr                             | 18.4                      | 8,752.69        |
| 500-yr                             | 22.5                      | 11,135.02       |
| 1000-yr                            | 25.8                      | 13,055.41       |



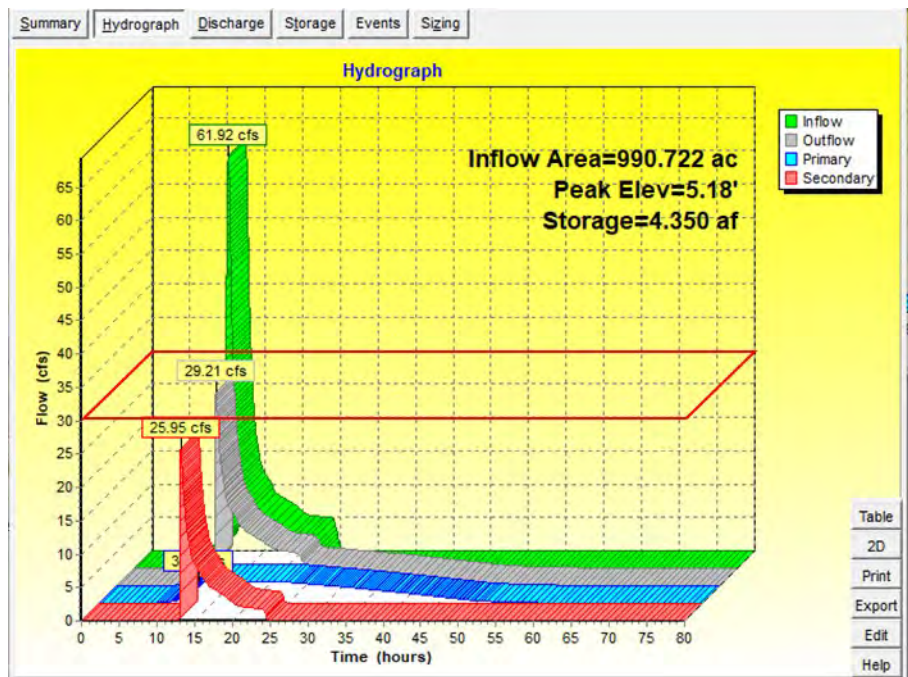


HydroCAD modeling was utilized to conceptually design and size a retrofit to the bioretention basin to manage the drainage at this location and provide additional water quality and flood reduction benefits. This bioretention basin was sized to manage the water quality storm event or the first one inch of rainfall, which includes the majority of pollutants that are washed off of the land surface (known as non-point source pollution or land-based sources of pollution). The existing bioretention basin has a lower capacity. This proposed bioretention basin is approximately 100ft wide, 300ft long, and 6ft deep. In the one-inch storm event, the peak flow from the contributing drainage area is 28.07 cfs. With the addition of this conceptual expanded bioretention basin, the peak flow is reduced significantly to 3.15 cfs and the timespan of this flow is extended as flow is slowed down in the basin. This not only allows pollutants to settle out of suspension, but it also reduces the erosive force of the stormwater flows in this location and downstream. The hydrograph for this bioretention basin can be found in Figure 14. In this figure, the inflow (the water entering the area) arrives and leaves the site quickly (green line on the hydrograph). With the addition of the bioretention basin, the water

is significantly slowed down and has a much lower velocity (gray line on hydrograph). Note that the blue line on each of the hydrographs is associated with a low flow controlled outlet to the basin. The red line



**Figure 14. Peak flows are reduced from 28.07 cfs (green line) to 3.15 cfs (gray line) with the addition of a stormwater basin during the one-inch storm event. A red line is shown at 30cfs to allow for easier comparison between graphs.**



**Figure 14. Peak flows are reduced from 61.92 cfs (green line) to 29.21 cfs (gray line) with the addition of a stormwater basin during the 1.5-inch storm event. Peak flow from the primary outlet (blue line) is 3.26 cfs. A red line is shown at 30cfs to allow for easier comparison between graphs.**



shows water passing through an emergency overflow or bypass. The gray line is the combined outflow, which includes flows shown in both the blue and red lines. Time is shown on the x-axis of the graphs and flow (cfs) is shown on the y-axis.

The 1.5-inch storm event was also assessed in HydroCAD to determine reductions in peak flows. In the HydroCAD model, the peak flows and length of time the water is stored are still significantly reduced (61.92 cfs to 29.21 cfs; Figure 14). While reductions in peak flow are not as significant in larger storm events due to the limited land available for flood storage, this highlights the need for additional practices distributed throughout the drainage area to further reduce and manage flows before they reach this location and also downstream of this area, including the existing stormwater basin. In general, peak flow reductions during larger storm events are not significant.

The recommended interventions for this site include (see Figure 15):

1. Expand the bioretention basin along the southern section of the parcel to manage flows from the gut, provide water quality benefits, and reduce peak discharge and downstream flooding. This would require excavation of the raised benches along the gut.
2. Preserve and enhance the existing stormwater basin that is currently managing drainage from along Centerline Road.
3. Remove trash including junk cars that may be leaking oil and other harmful fluids onto the ground, which then is either infiltrated into groundwater or washed off the land into the gut.
4. Remove invasive species to allow native species to revegetate the area.
5. Provide a recreational area within the proposed bioretention basin during dry periods.
6. Provide a parking area so that visitors can access this recreational amenity.
7. Install a cistern in the bottom of the existing stormwater basin to collect and store rainwater. This water can then be used to irrigate the recreational area during dry periods.
8. Reserve an area for additional development such as installation of a generator.
9. Preserve and protect the existing unpaved road that bisects the parcel. This road is a key route out of the residential areas to the west of the parcel in emergency events, which have blocked off evacuation from the area in previous large storm events.

A large-scale plan showing these proposed improvements is provided in [Appendix G](#). Note that the bioretention basin shown on this plan is larger than the basin that was previously modeled to maximize the water quality and flood reduction benefits within the available space. As such, this bioretention basin would be able to provide additional flood storage and water quality benefits beyond those described above. There is significant fill in this area, and the future plans for the site will also need to take this into consideration.









## 11.2. Pickles

Pickles, located along Route 107, is another site of major concern in terms of water quality and flooding issues. The drainage area to this site is very large (1,021 acres) and drains the majority of the central area of Coral Bay (Figure 16). This drainage includes the drainage area for the 6-4 Carolina site described above as well as the Lala Land and Ironwood Rd culvert sites.

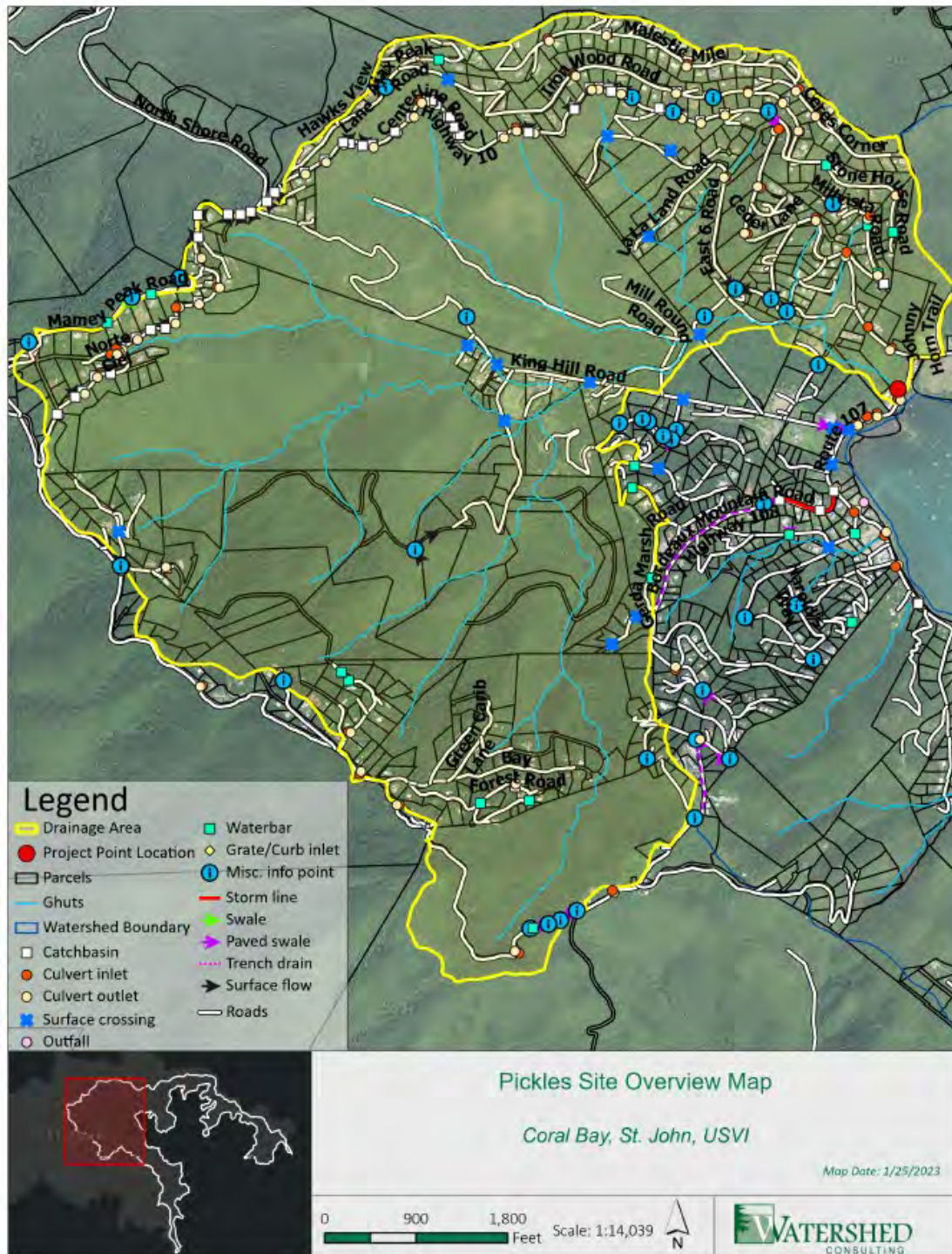
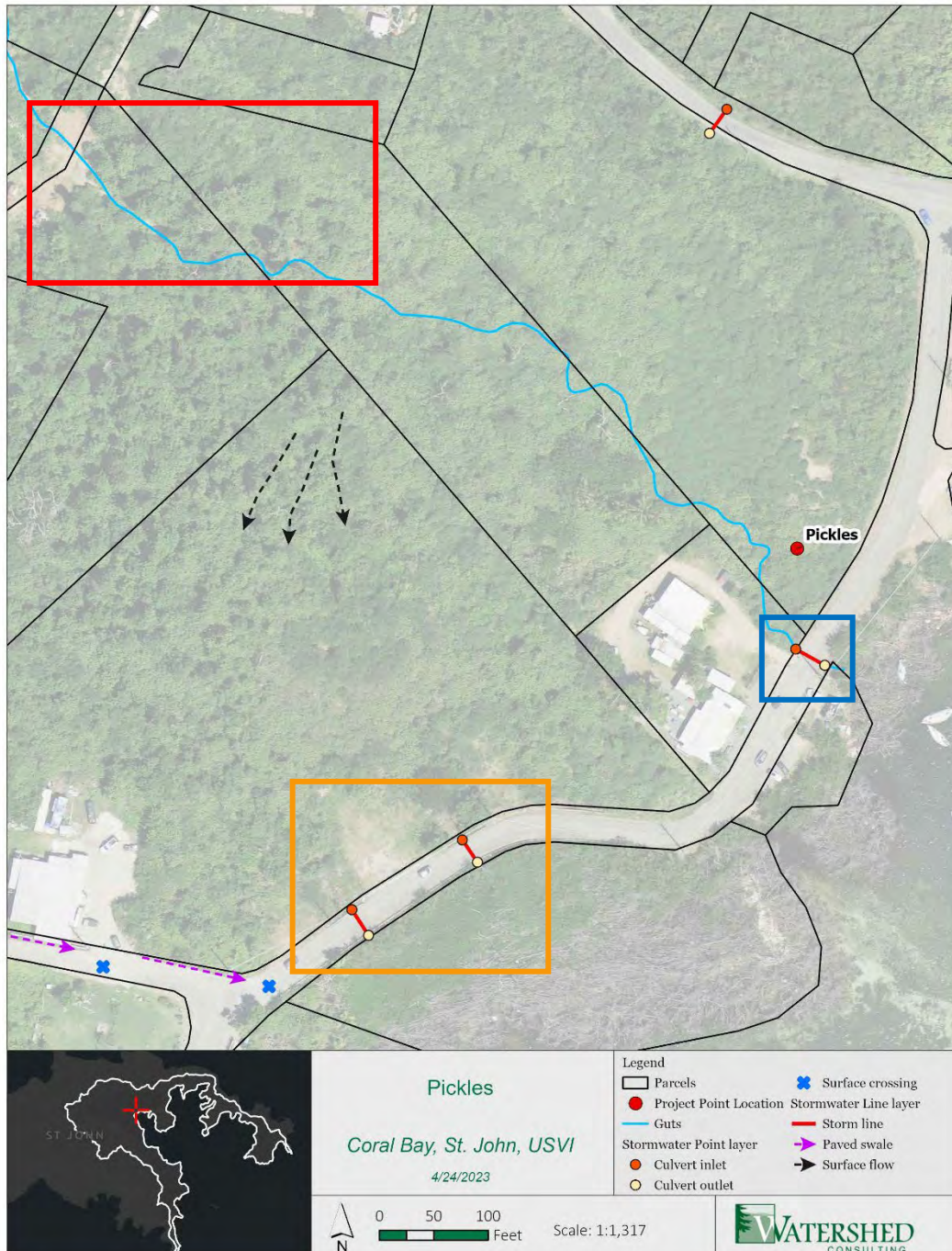


Figure 16. The Pickles drainage area, highlighted in yellow, includes the majority of the central developed areas in the Coral Bay watershed. The site location is shown with a red circle.





This site experiences frequent and repeated flooding during significant rainfall events. Historically, the gut would spill out of the gut channel and distribute over the ground surface to access three culverts along Route 107. Now, this flow is generally confined to a single culvert potentially except in very large storms (see blue box in Figure 17) due to berming that occurred to redirect flows away from private property (see



**Figure 17.** The Pickles site location is shown zoomed in to show the confinement of the gut flow more clearly to the north of the site. The red box highlights the area where anthropogenic topographic changes have resulted in gut confinement, which results in the majority of flows only crossing Route 107 in a single culvert (see blue box). The two culverts where flow was historically distributed are shown in an orange box.



red box in Figure 17). The two culverts where flow was historically distributed are shown in an orange box in Figure 17.

The culvert is located in a floodplain area adjacent to Coral Harbor. NRCS mapping indicates the soils are hydric (SBA - Sandy Point and Sugar Beach soils 0-2% slopes). NWI mapping indicates that there are Estuarine and Marine wetlands at the culvert outlet and Freshwater Forested/shrub wetlands to the northwest of the culvert inlet. The site visit confirmed wetlands are present at the culvert outlet and potentially the culvert inlet as well. During final design, this site should have a formal wetland delineation completed. See [Appendix E](#) for a map of the NWI for Coral Bay. A site survey was completed to define existing conditions including culvert inverts and drainage patterns. The contributing drainage area was also verified at this time. The existing condition survey can be found in [Appendix F](#).

Two modeling programs were utilized for this site. First, a HydroCAD model was developed to determine peak flows, assess flows through this area, conceptually design a stormwater basin, and assess peak flow reduction benefits of this basin. Modeled peak flows for a range of storm events can be found below in Table 9. Secondly, a HEC-RAS model was completed to assess the extent and depth of flooding in the existing conditions and with the proposed basin.

**Table 9. Modeled peak flows at the Pickles site.**

| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) | Peak Flow (cfs) |
|------------------------------------|---------------------------|-----------------|
| WQv                                | 1                         | 27.6            |
| 1-yr                               | 3.11                      | 514.2           |
| 2-yr                               | 4.23                      | 976.03          |
| 5-yr                               | 6.37                      | 1,996.52        |
| 10-yr                              | 8.19                      | 2,939.08        |
| 25-yr                              | 10.9                      | 4,413.2         |
| 50-yr                              | 13.2                      | 5,700.33        |
| 100-yr                             | 15.7                      | 7,119.05        |
| 200-yr                             | 18.4                      | 8,663.37        |
| 500-yr                             | 22.5                      | 11,018.16       |
| 1000-yr                            | 25.8                      | 12,916.17       |

HydroCAD modeling was utilized to identify and size a basin to manage the drainage at this location and provide water quality and flood reduction benefits. This basin was sized to manage the water quality storm event or the first one inch of rainfall, which includes the majority of pollutants that are washed off of the land surface (known as non-point source pollution or land-based sources of pollution). This basin is approximately 180ft wide, 300ft long, and 5ft deep. Note that depending on landowner approval and commitment, this basin could be expanded to provide additional flow reduction benefits. In the one-inch storm event, the peak flow from the contributing drainage area is 27.6 cfs. With the addition of this conceptual basin, that peak flow is reduced significantly to 3.43 cfs and the timespan of this flow is extended as flow is slowed down in the basin. This not only allows pollutants to settle out of suspension,

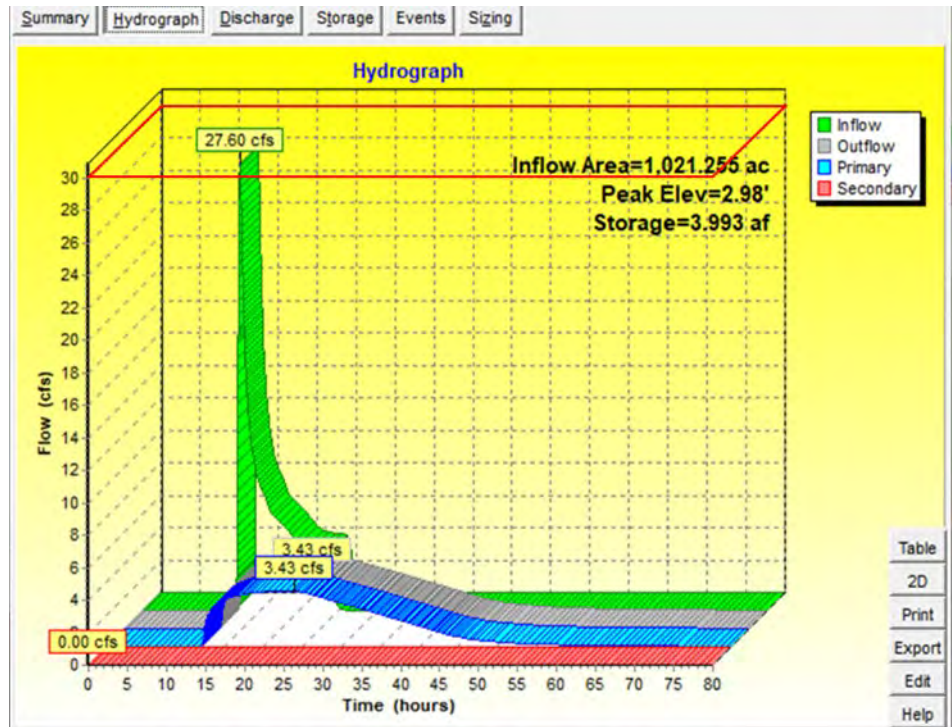




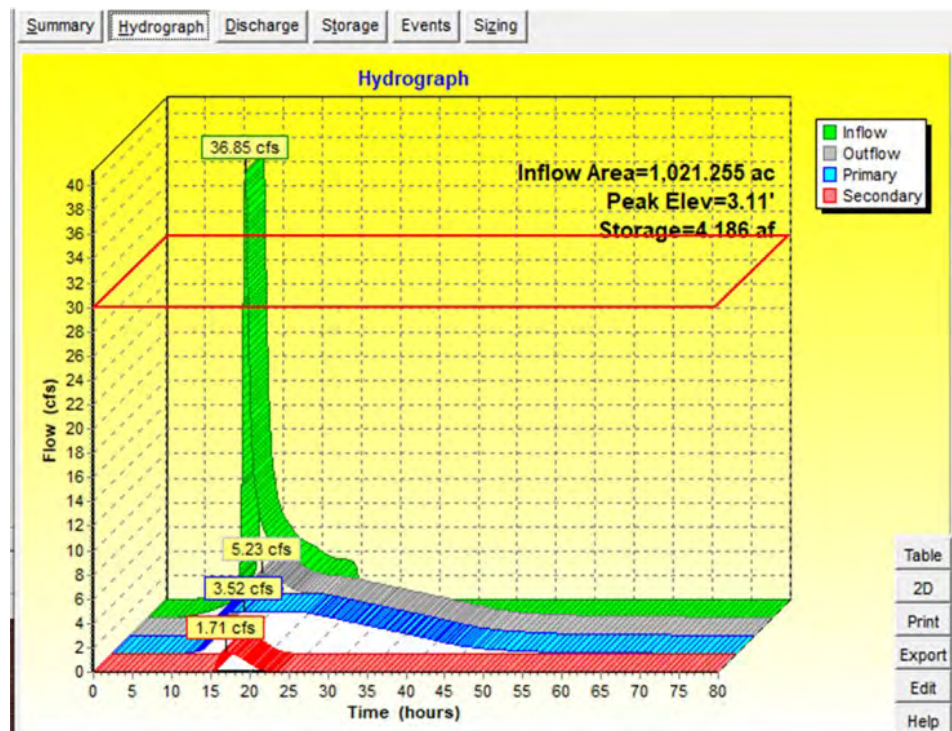
but it also reduces the erosive potential of the stormwater flows. The hydrograph for this basin during this 1-year storm event can be found in Figure 19.

The 1.25-inch storm event was also assessed in HydroCAD to determine reductions in peak flows. In the HydroCAD model, the peak flows and length of time the water is stored are still significantly reduced (36.85 cfs to 5.23 cfs; Figure 19). Likewise, flows are significantly reduced in the 1.5-inch storm event from 63.43 cfs to 26.35 cfs. While reductions in peak flow are not as significant in larger storm events due to the relatively small size of the basin and limited land available for flood storage, this highlights the need for additional practices distributed throughout the drainage area to further reduce and manage these flows before they reach this location. Additionally, if landowners are amenable, this proposed basin could be expanded to provide additional flood storage benefits.

Additional modeling was also completed in



**Figure 19.** Peak flows are reduced from 27.6 cfs (green line) to 3.43 cfs (gray line) with the addition of a stormwater basin during the one-inch storm event. A red line is shown at 30cfs to allow for easier comparison between graphs.



**Figure 19.** In the 1.25-inch storm event, peak flows decrease from 36.85 cfs (green line) to 5.23 cfs (gray line). A red line is shown at 30cfs to allow for easier comparison between graphs.



the modeling program HEC-RAS to better understand existing and proposed conditions at this location. The extent and depth of flooding in this location during the 1.25-inch storm event can be seen in Figure 20 as compared to Figure 21, which includes the proposed stormwater basin. When the proposed stormwater basin is included in the HEC-RAS model, the extent of the flooding is reduced during this storm event. Likewise, the depth of the flooding that does occur is also reduced.

In larger storm events, the proposed stormwater basin is less effective at reducing flooding extent and depth, as was also indicated by the peak flow reductions included in the HydroCAD modeling. This finding also supports the implementation of additional stormwater controls throughout the drainage area and expanding the proposed basin.

One issue noted at this location was the confinement of flow to the northernmost culvert. When flows are large enough that this confinement as modeled is not as effective, HEC-RAS modeling shows that the flow is able to spread out over a larger floodplain area. Figure 22 shows the modeled depth and extent of flooding for the 2-year storm event, which is 4.23 inches of rainfall in a 24-hour time period.

Expanding the gut floodplain, removing gut confinement, and restoring historic flows in this area is another recommended strategy to further reduce flooding impacts and improve water quality prior to discharge to the bay. This results in the flows being less confined, slower, and less erosive. Water quality is improved as flows are slowed down and spread out over this floodplain area and suspended pollutants and sediment are allowed to settle out of suspension, erosion is reduced, some of the water infiltrates and is stored in this floodplain area due to microtopography when stormwater flows cease, and native vegetation in this area provides filtration of stormwater flows. This recommendation was not modeled at this time as landowner support has not yet been sought to support this proposed augmentation to existing drainage conditions.

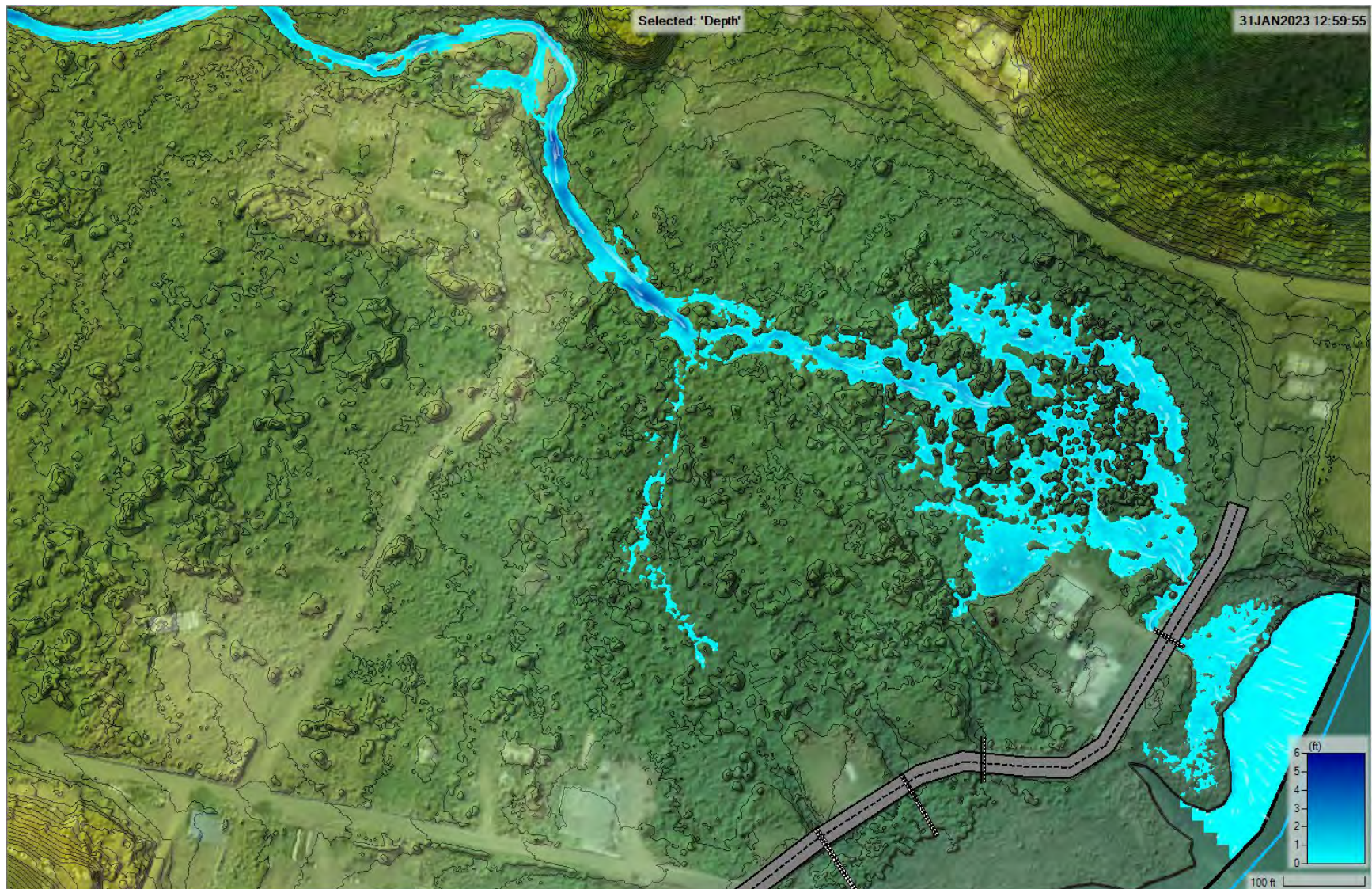
Animations of the flows during the 1.25-inch storm (with and without the proposed stormwater pond), 1-year, and 2-year storm events are included in [Appendix H](#).





Figure 20. Flood depth during a 1.25-inch storm event at the Pickles site. Depth is indicated by blue shading with deeper flooding depths shown in darker blue. Note that water was observed flowing over the road in the model. The road is shown as a gray polygon due to how the model was prepared including the elevations of the road surface.





**Figure 21. Flood depth during a 1.25-inch storm event at the Pickles site with the proposed stormwater basin in place. Depth is indicated by blue shading with deeper flooding depths shown in darker blue.**



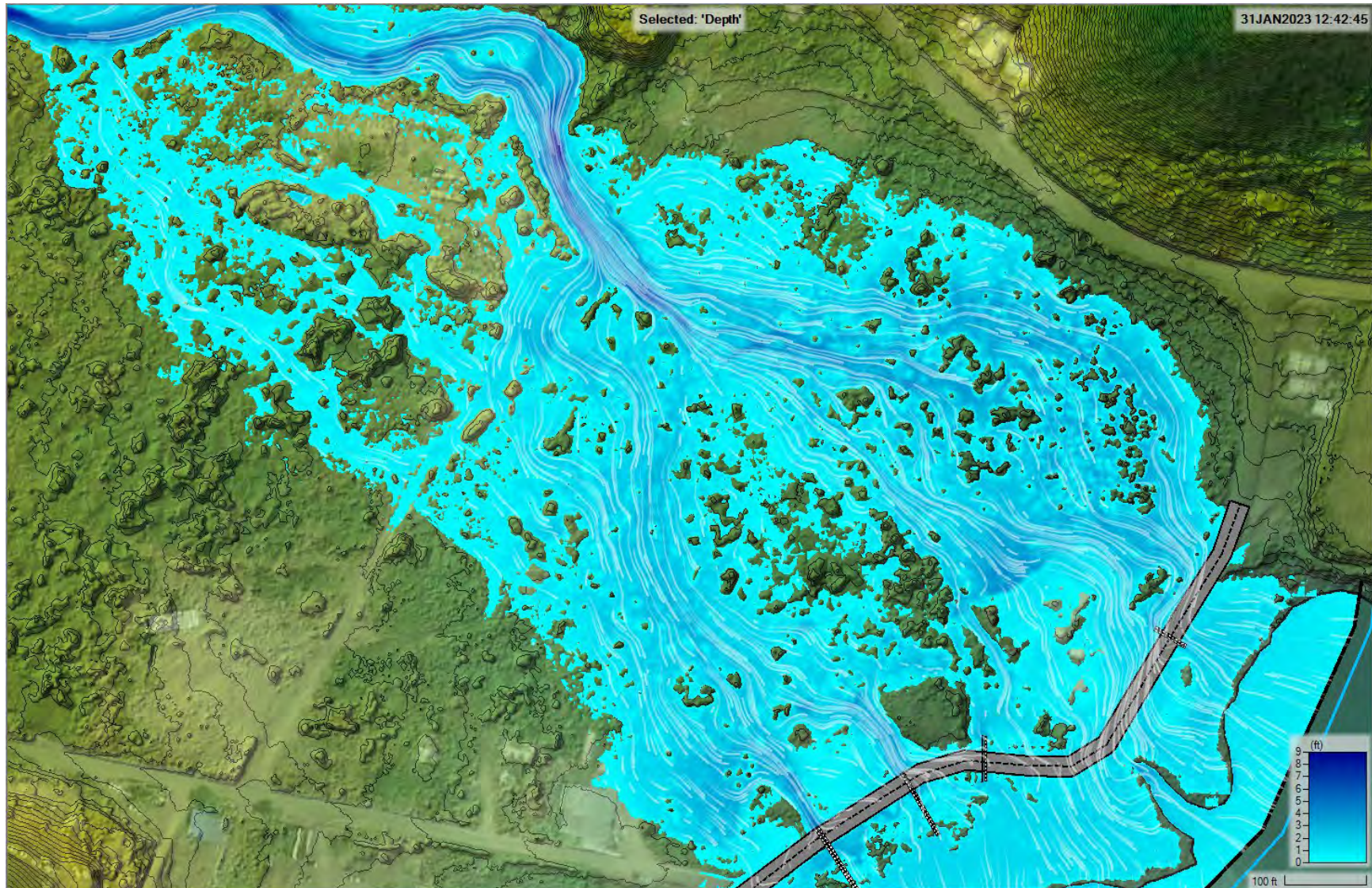


Figure 22. Modeling of the 2-year storm event indicates that when flows are able to bypass confinement, they spread out over a large floodplain area and access four culverts to cross Route 107. Note that water was observed flowing over the road in the model. The road is shown as a gray polygon due to how the model was prepared including the elevations of the road surface.



As discussed, it is recommended that additional practices are installed within the drainage area for the Pickles site including the proposed basin at 6-4 Carolina. These basins can work in concert to reduce flows and provide water quality benefits in flood prone areas like the Pickles site. As such, the benefits of both basins within this drainage area were assessed in the HydroCAD model. When just the Pickles basin was implemented, peak flows for the water quality (1-inch) storm event were reduced from 27.6 cfs to 3.43 cfs. With the inclusion of the 6-4 Carolina basin, the peak flow in this storm event at the Pickles site was reduced to 3 cfs and the Pickles basin further reduced that peak flow to 2.2 cfs (Figure 23). This modeling also shows that the maximum depth of water in the basin during the storm event was reduced by 1.54 ft (from 2.98 ft to 1.44 ft), which indicates that the basin now has excess storage in this storm event and thus a higher capacity to reduce flooding.

In the 1.5-inch storm event, the peak flows entering the Pickles site are still reduced significantly, from 63.43 cfs to 30.09 cfs when the 6-4 Carolina basin is in place. The flows leaving the Pickles site from the proposed basin are likewise reduced (from 26.35 cfs to 8.15 cfs) and the timespan where flows are discharged is also slowed down, indicating improved water quality and reduced flooding during this storm event (Figure 24). As previously described, these benefits decrease as larger storm events are assessed as the capacity of these basins is exceeded. However, this again highlights the recommendation that additional distributed practices within the drainage area and overall Coral Bay watershed are beneficial in reducing flooding and improving water quality in ever increasing storm events.



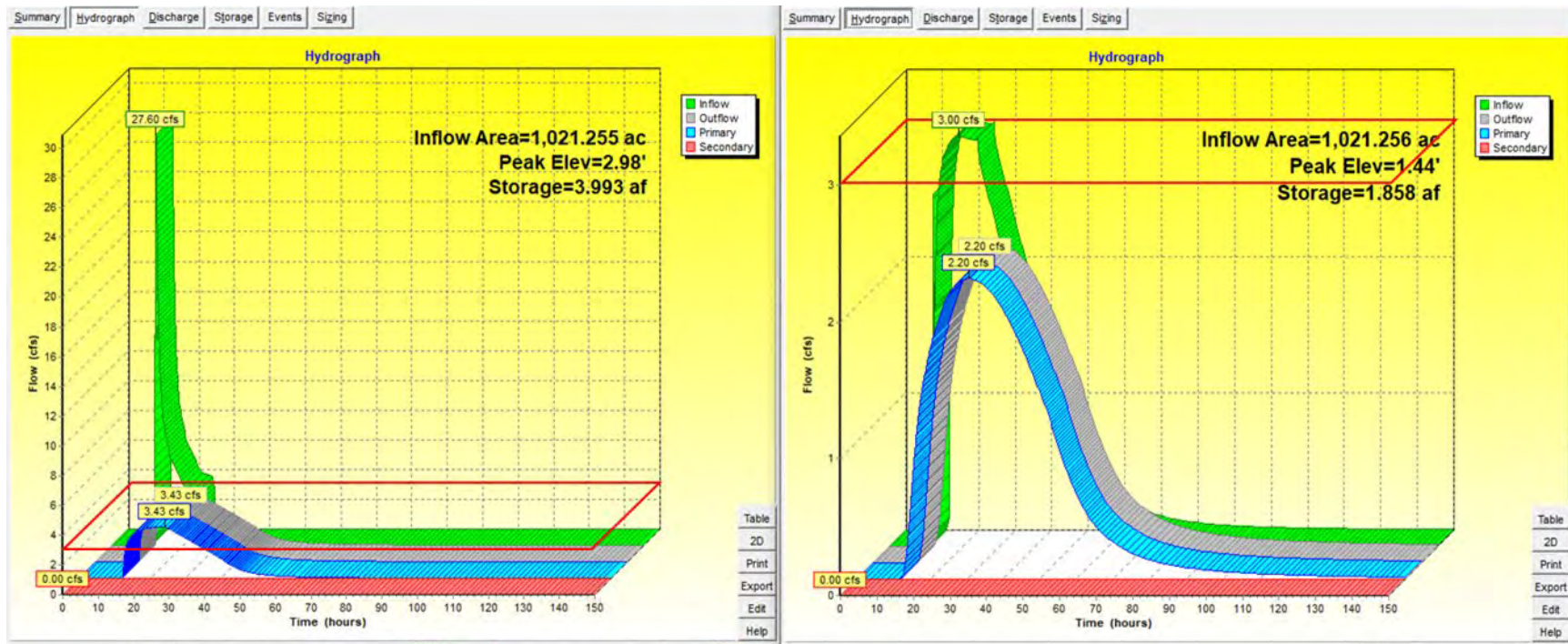


Figure 23. Peak flows during the 1-inch storm event are shown for the Pickles site with the proposed stormwater basin. The left graph shows the flows if no additional basins are constructed upstream of Pickles (inflow of 22.64 cfs; outflow of 3.43 cfs). The right graph shows the effect of implementation of the 6-4 Carolina basin (inflow of 3.0 cfs and outflow of 2.2 cfs). Also note that the depth of water in the basin is reduced from 2.98 ft (left) to 1.44 ft (right). Note that the y-axis scales are significantly different between the graphs. 3 cfs is highlighted with a red box on the hydrographs to illustrate this difference in scale.



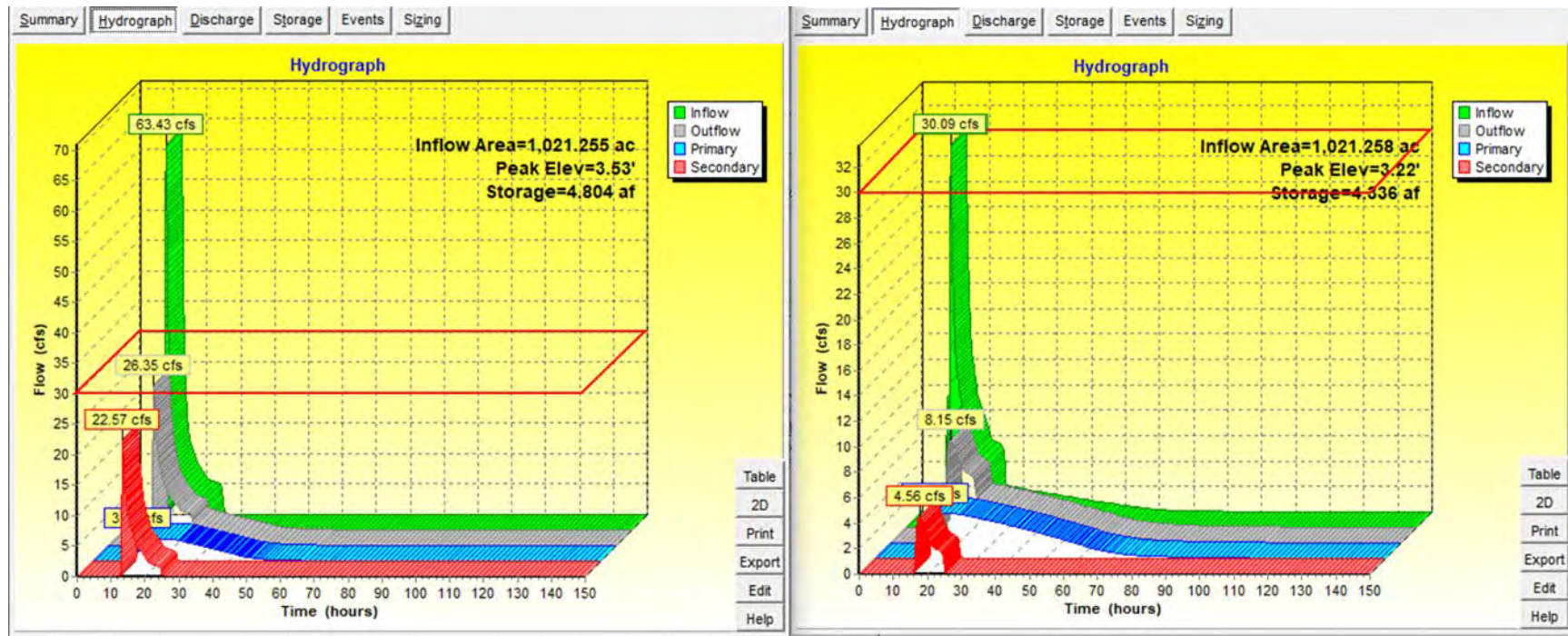
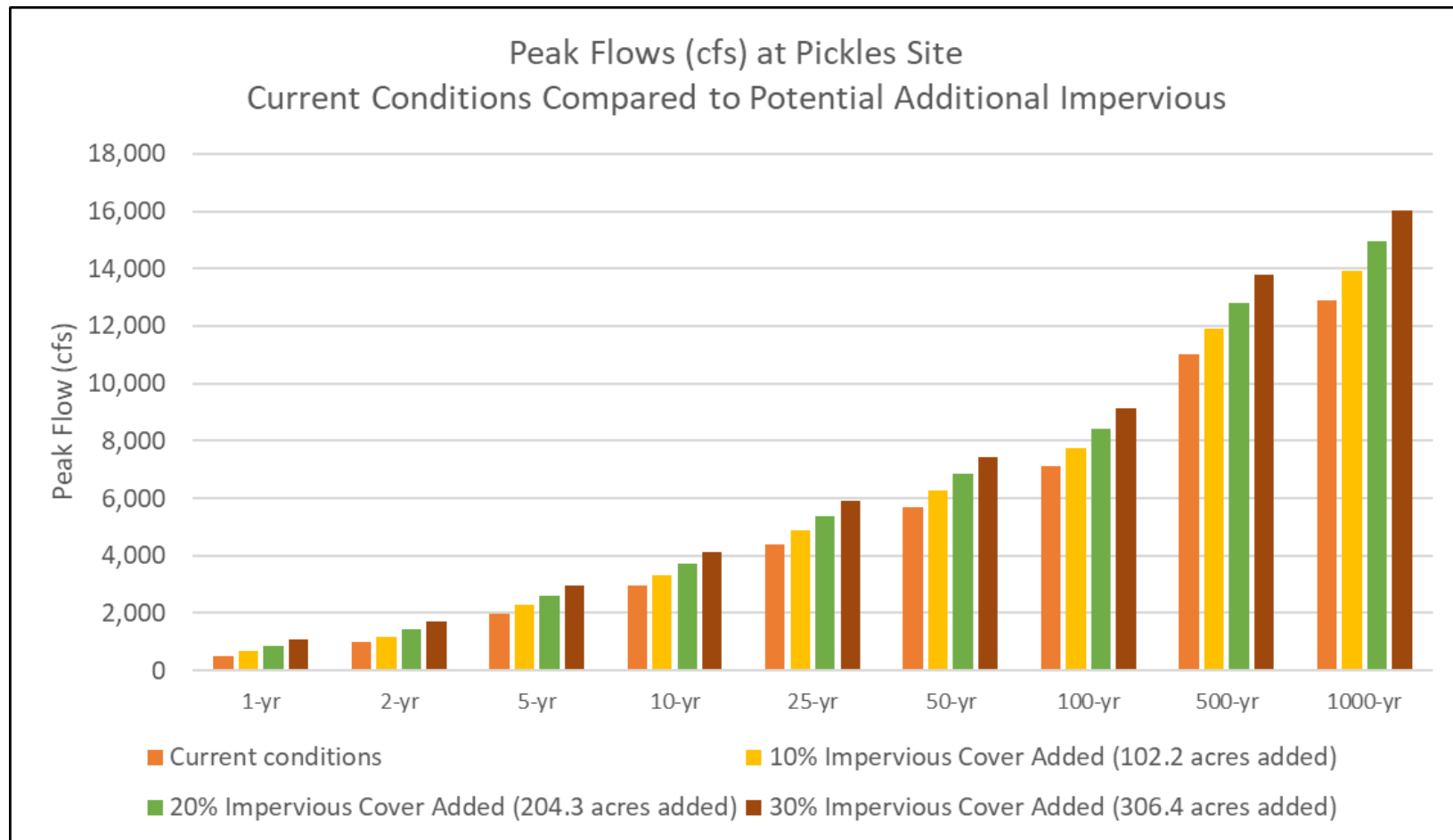


Figure 24. Peak flows during the 1.5-inch storm event are shown for the Pickles site. The left graph shows the flows if no additional basins are constructed (inflow of 63.43 cfs; outflow of 26.35 cfs). The right graph shows the effect of implementation of the 6-4 Ca Carolina basin (inflow of 30.09 cfs and outflow of 8.15 cfs). Also note that the depth of water in the basin is reduced from 3.53 ft (left) to 3.22 ft (right). Note that the y-axis scales are significantly different between the graphs. 30 cfs is highlighted with a red box on the hydrographs to illustrate this difference in scale.



An assessment was completed to determine the impact of additional development within the watershed resulting in the conversion of vegetated (forested) areas to impervious cover. Within the drainage area, forested land cover was reduced proportionally depending on hydrologic soil group and converted to impervious. The existing condition (50.62 acres impervious) were compared to scenarios where impervious is increased by 10% (total of 152.8 acres impervious), 20% (total of 254.9 acres impervious), and 30% (total of 357 acres impervious). Peak flows for these scenarios are shown in Figure 25. Modeled peak flows increase significantly with the addition of this impervious cover within the drainage area.



**Figure 25. Peak flows (cfs) in the Pickles drainage area are compared with varying levels of additional impervious cover.**



With a 10%, 20%, or 30% increase in impervious, on average, peak flows increased an average of 14%, 29%, and 46% respectively. The largest percent increase was observed in the smaller storm events (1- year and 2-year). Table 10 below summarizes these percent increases. In smaller storm events, the percentage increase in peak flows exceeds the percent increase in impervious, further highlighting the need to adequately manage any additional development within the watershed.

**Table 10. Percent increase in peak flows with the inclusion of 10%, 20%, and 30% more impervious than current conditions.**

| Condition                                      | Percent Increase |       |       |       |       |       |        |        |         |              |
|--|------------------|-------|-------|-------|-------|-------|--------|--------|---------|--------------|
|  | 1-yr             | 2-yr  | 5-yr  | 10-yr | 25-yr | 50-yr | 100-yr | 500-yr | 1000-yr | Mean         |
| 10% Impervious Cover Added (102.2 acres added) | 31.59            | 21.69 | 14.86 | 12.45 | 10.56 | 9.69  | 9.04   | 8.07   | 7.80    | <b>13.97</b> |
| 20% Impervious Cover Added (204.3 acres added) | 67.17            | 45.89 | 31.32 | 26.06 | 21.98 | 19.96 | 18.51  | 16.36  | 15.77   | <b>29.22</b> |
| 30% Impervious Cover Added (306.4 acres added) | 107.31           | 72.81 | 49.22 | 40.74 | 34.06 | 30.80 | 28.46  | 24.97  | 24.01   | <b>45.82</b> |

The recommended interventions for this site include (see Figure 26):

1. Restore flow and functionality to the wetland area along the gut by removing key obstructions and allowing water to spill out of the gut and into this area in storm events. This will improve water quality by filtration, restore a previous wetland's hydrologic function and connectivity, and provide significant flood storage.
2. Design and install elevation boardwalks throughout the wetland area.
3. Design and install educational signage along boardwalks to educate visitors. Potential topics include the functionality of wetlands, water quality, flood protection, native flora and fauna, gut health and connectivity, and the importance of protecting greenspace from development in key areas.
4. Provide a parking area so that visitors can access this recreational and educational amenity.
5. Remove invasive species to allow native wetland species to revegetate the area.

A large-scale plan showing these proposed improvements is provided in [Appendix G](#). Note that the wetland restoration area shown on this plan is larger than the basin that was previously modeled. As such, this area would likely be able to provide additional flood storage and water quality benefits beyond those described above.



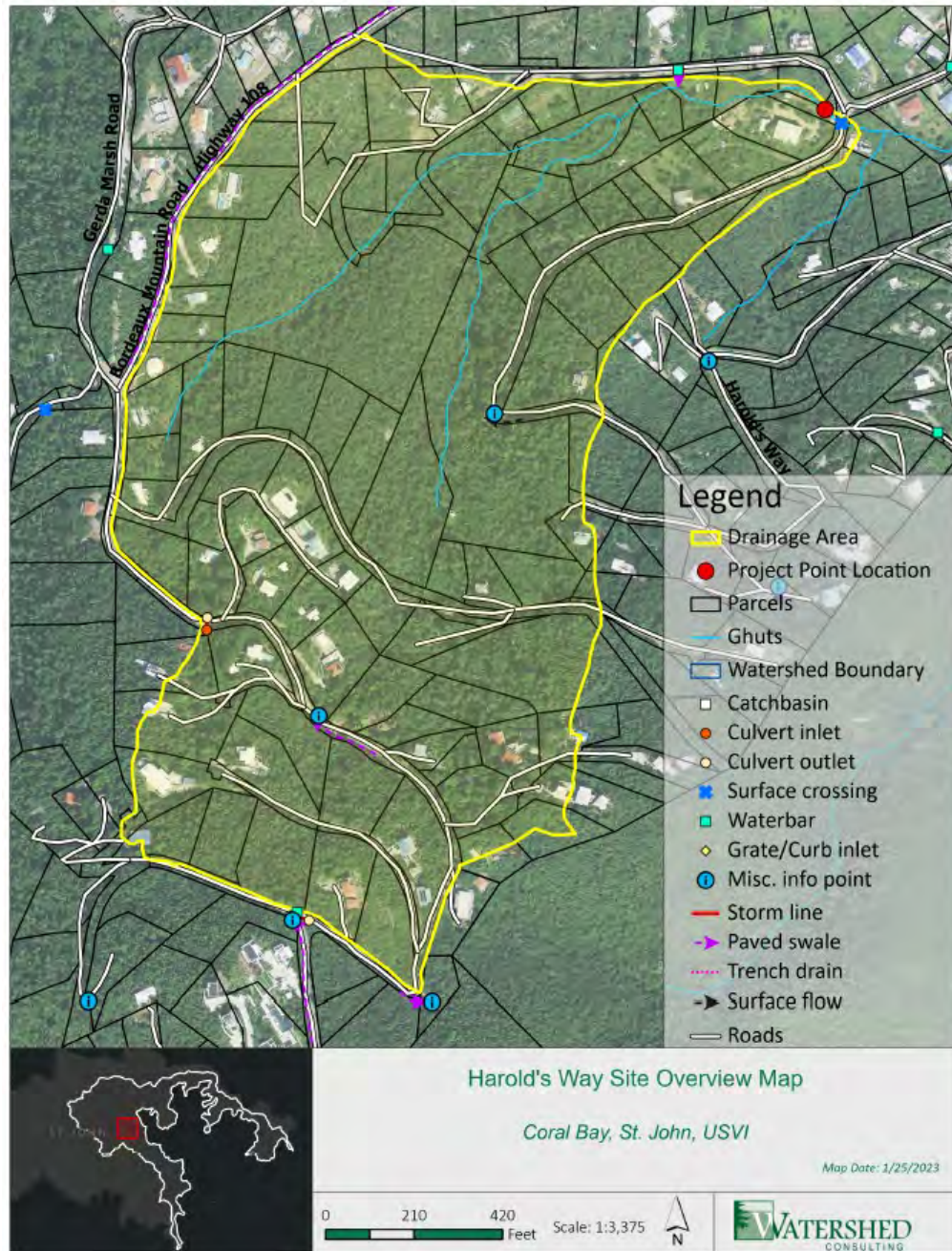




### **11.3.     *Spring Garden***

The Spring Garden site was selected as a high priority area for several reasons. This site includes several key areas including the upper Harold's Way road right-of-way and the guts that run along Joan Krigger Ln and Calvert C Marsh Road. In general, stormwater has been diverted from natural guts as a result of development that was not planned with stormwater management and gut flows in mind. As such, roads, driveways, and structures have been built in areas that are threatened by stormwater flows, both from flooding and from undermining the stability of these structures. Stormwater flows are only predicted to increase in intensity due to climate change and these extreme and intense storm events further threaten property, access to emergency services, and safety.





**Figure 27. The contributing drainage area to the northwest bioretention basin at the Spring Garden site is shown with a yellow polygon. The site location is shown with a red circle.**

The largest of the proposed bioretentions basins for this area was modeled, which included a drainage area of 50.5 acres of primarily residential development (Figure 27). The site is located on relatively level ground. NRCS mapping indicates the soils are non-hydric (CbB - Cinnamon Bay loam 0-5% slopes). NWI mapping does not show any wetlands in the vicinity of the project and no potential wetland areas were noted at or adjacent to the site during the site review. See [Appendix E](#) for a map of the NWI for Coral Bay. A site survey was completed to define existing conditions including culvert inverts and drainage patterns. The contributing drainage area was also verified at this time. The existing condition survey can be found in [Appendix F](#).



In this area, there are many mostly small (<0.75 acre) parcels that are currently undeveloped. If these properties were to be developed into residential or commercial properties, this would further exacerbate the issues in this watershed. Conservatively, there are at least 49 of parcels covering nearly 30 acres that have the potential for development within this watershed, which could increase the impervious cover within this drainage area significantly. If just 30% of the area of these parcels were converted to buildings, driveways, roads, or parking lots, that would result in 9 additional acres of impervious cover.

A HydroCAD model was developed to determine peak flows, assess flows through this area, conceptually design a stormwater basin, assess peak flow reductions as a result of the proposed basin, and assess increases in peak flows as a result of conversion of 9 acres of currently vegetated areas to impervious cover. Modeled peak flows for a range of storm events for the existing conditions as well as the conversion of 9 acres of pervious land cover to impervious cover can be found below in Table 11.

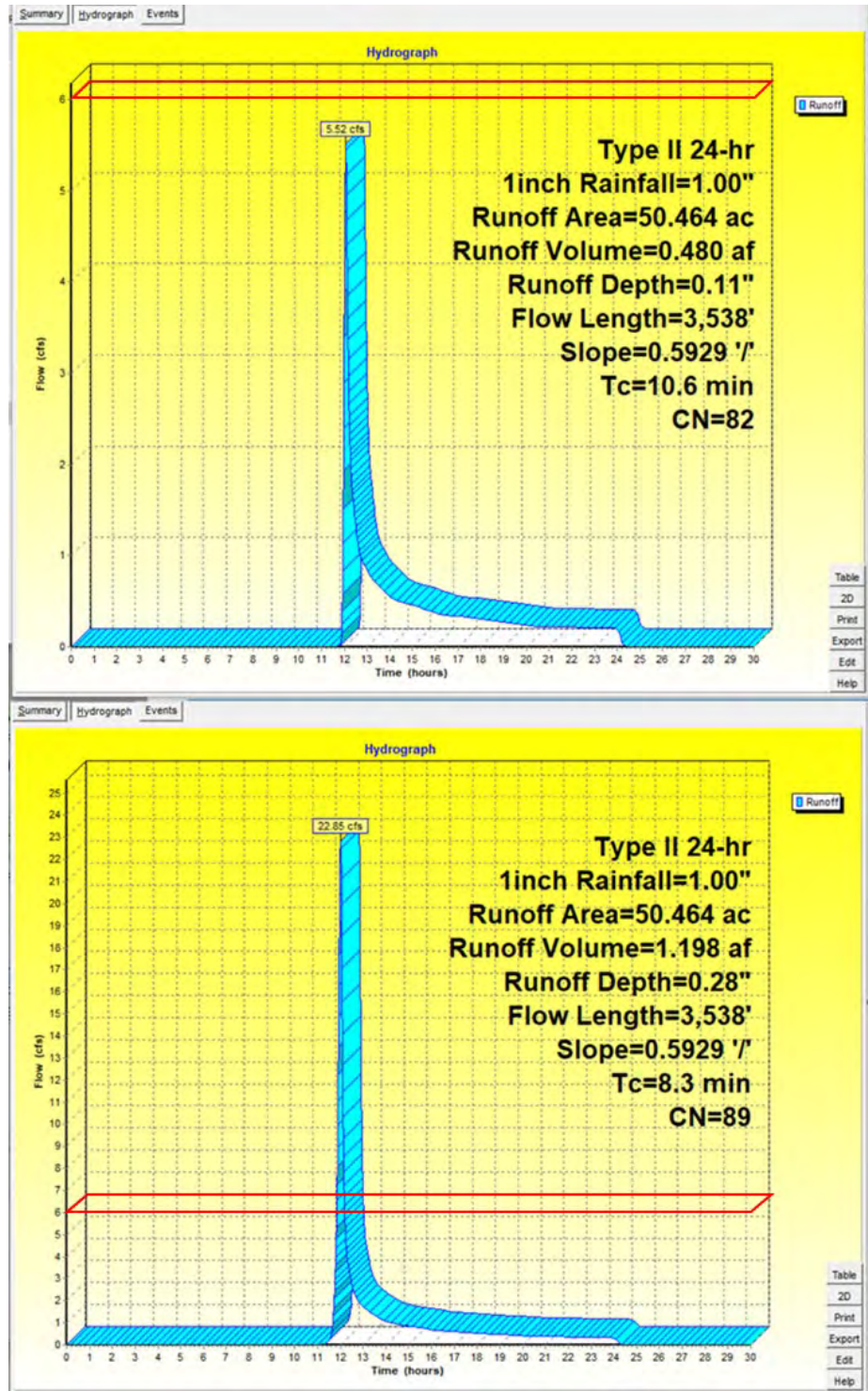
**Table 11. Spring Garden HydroCAD peak flow summary table in existing conditions and with conversion of 9 acres to impervious cover.**

| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) | Existing Conditions Peak Flow (cfs) | Peak Flow (cfs) with Conversion of 9 Acres to Impervious Cover |
|------------------------------------|---------------------------|-------------------------------------|--|
| WQv                                | 1                         | 5.52                                | 22.85  |
| 1-yr                               | 3.11                      | 60.34                               | 87.53  |
| 2-yr                               | 4.23                      | 110.86                              | 143.67   |
| 5-yr                               | 6.37                      | 220.67                              | 261.64   |
| 10-yr                              | 8.19                      | 320.75                              | 367.56   |
| 25-yr                              | 10.9                      | 474.9                               | 529.7  |
| 50-yr                              | 13.2                      | 607.67                              | 669.01   |
| 100-yr                             | 15.7                      | 752.56                              | 820.94   |
| 200-yr                             | 18.4                      | 909.07                              | 985.59   |
| 500-yr                             | 22.5                      | 1,146.18                            | 1,234.61   |
| 1000-yr                            | 25.8                      | 1,336.41                            | 1,434.57   |





The peak flow increase can be seen visually on the hydrograph produced in HydroCAD in Figure 28. Note that the runoff volume in this storm event increases significantly from 0.48 acre-feet to 1.2 acre-feet with conversion of these 9 acres to impervious cover as less stormwater is being intercepted and infiltrated by pervious vegetated surfaces. While this increase in stormwater peak flow and volume is conceptual at this time, it strongly supports the need to limit development in this area and, if development does occur, ensure that it is well planned out with proper stormwater controls.

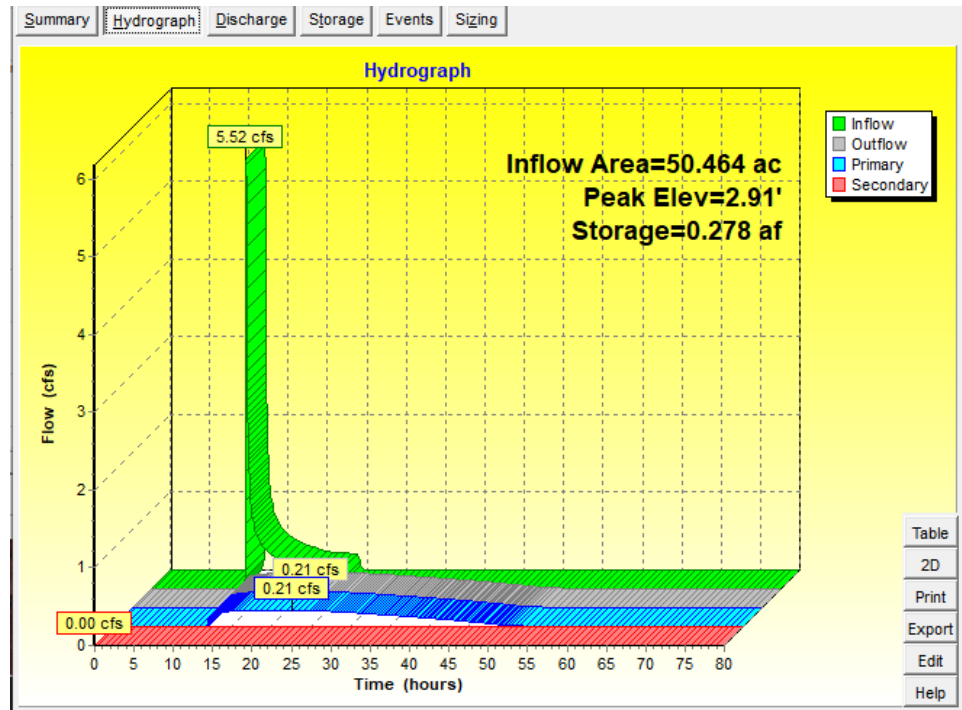


**Figure 28. Peak flows during the water quality storm event (1-inch of rainfall in a 24-hour period) with existing conditions (upper) and with conversion of 9 acres of pervious cover to impervious (lower). Note that the y-axis scales are significantly different between the graphs. Six cfs is highlighted with a red box on the hydrographs to illustrate this difference in scale.**

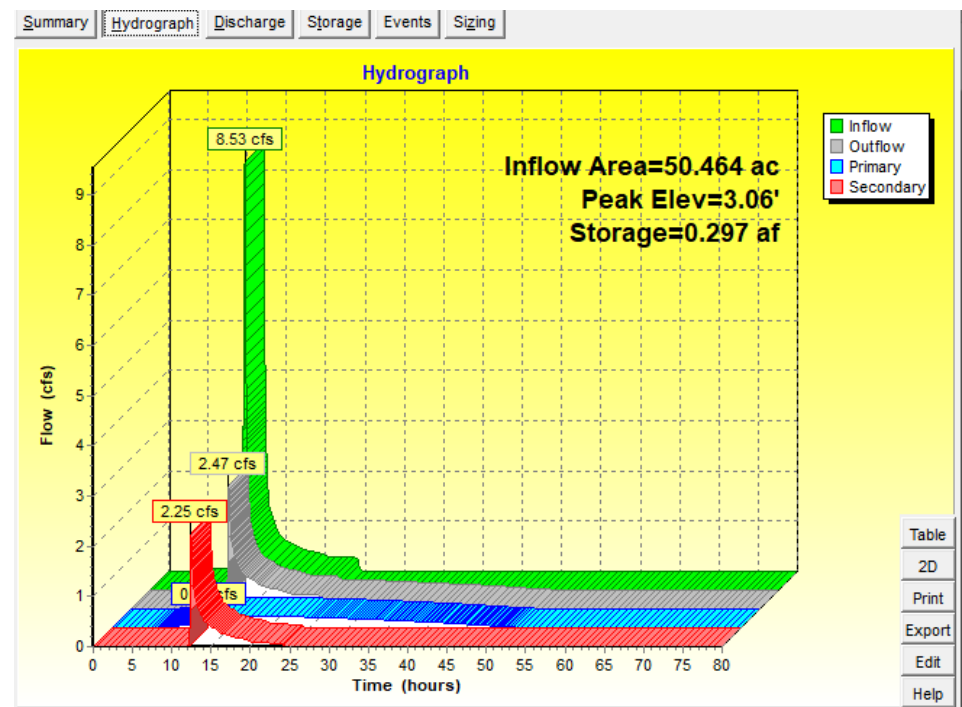


The HydroCAD model was also utilized to identify and size a stormwater basin to manage the drainage at this location and provide water quality and flood reduction benefits. This basin was sized to manage the water quality storm event or the first one inch of rainfall, which includes the majority of pollutants that are washed off of the land surface (known as non-point source pollution or land-based sources of pollution). This basin is approximately 20ft wide, 130ft long, and 5ft deep. In the one-inch storm event, the peak flow from the contributing drainage area is 5.52 cfs. With the addition of this conceptual basin, that peak flow is reduced significantly to 0.21 cfs and the timespan of this flow is extended as flow is slowed down in the basin (Figure 29). This not only allows pollutants to settle out of suspension, but it also reduces the erosive potential of the stormwater flows.

The 1.5-inch storm event was also assessed in HydroCAD to determine reductions in peak flows. In the HydroCAD model, the peak flows and length of time the water is stored are still significantly reduced (8.53 cfs to 2.47 cfs; Figure 30). While reductions in peak flow are not as significant in



**Figure 29. Peak flows are reduced from 5.52 cfs (green line) to 0.21 cfs (gray line) with the addition of a stormwater basin during the one-inch storm event.**



**Figure 30. In the 1.5-inch storm event, peak flows decrease from 8.53 cfs (green line) to 2.47 cfs (gray line). The peak flow from the primary outlet (blue line) was 0.22 cfs.**





larger storm events due to the small size of the basin and limited land available for flood storage, this highlights the need for additional practices distributed throughout the drainage area to further reduce and manage these flows before they reach this location. Several of the previously mentioned undeveloped parcels present opportunities for additional management in this area.

A HEC-RAS model was also completed to assess the extent and depth flooding in the existing conditions at this site. The model shows that during the 1.5-inch event the existing gut does have capacity to convey this runoff without overtopping its banks along the exiting road (Figure 31). The proposed stormwater basin reduces the depth of water within the gut and limits the flooding close to where the gut discharges to the bay (Figure 32).

The model shows that the existing gut begins to overtop its banks starting at the 2-inch storm event with shallow flooding depths (Figure 33). The 2.5-inch storm event shows an average 0.2-ft depth of runoff along the road (Figure 34). The extent and depth of flooding increases in larger storm events. In the 1-year storm event (3.11-inches), flooding becomes evident in the developed areas close to the bay (Figure 35). In the 2-year storm even (4.23-inches), the extent and depth of this flooding increases and the road has an average flood depth of 0.5 ft. It is expected that in larger events, this flooding depth and extent will increase even further.

As discussed above, this modeling further reinforces the recommendation that the undeveloped parcels within this drainage area be utilized for additional stormwater controls, protected from development to the extent possible, and, when development does occur, ensure that development is well planned and stormwater flows and the impacts of additional impervious cover and altered drainages are taken into account prior to construction. Additional stormwater management practices are recommended for the development that has already occurred to manage larger stormwater volumes, which is critical during storms greater than the 1.5-inch event or storms that have the equivalent stormwater volume and intensity.



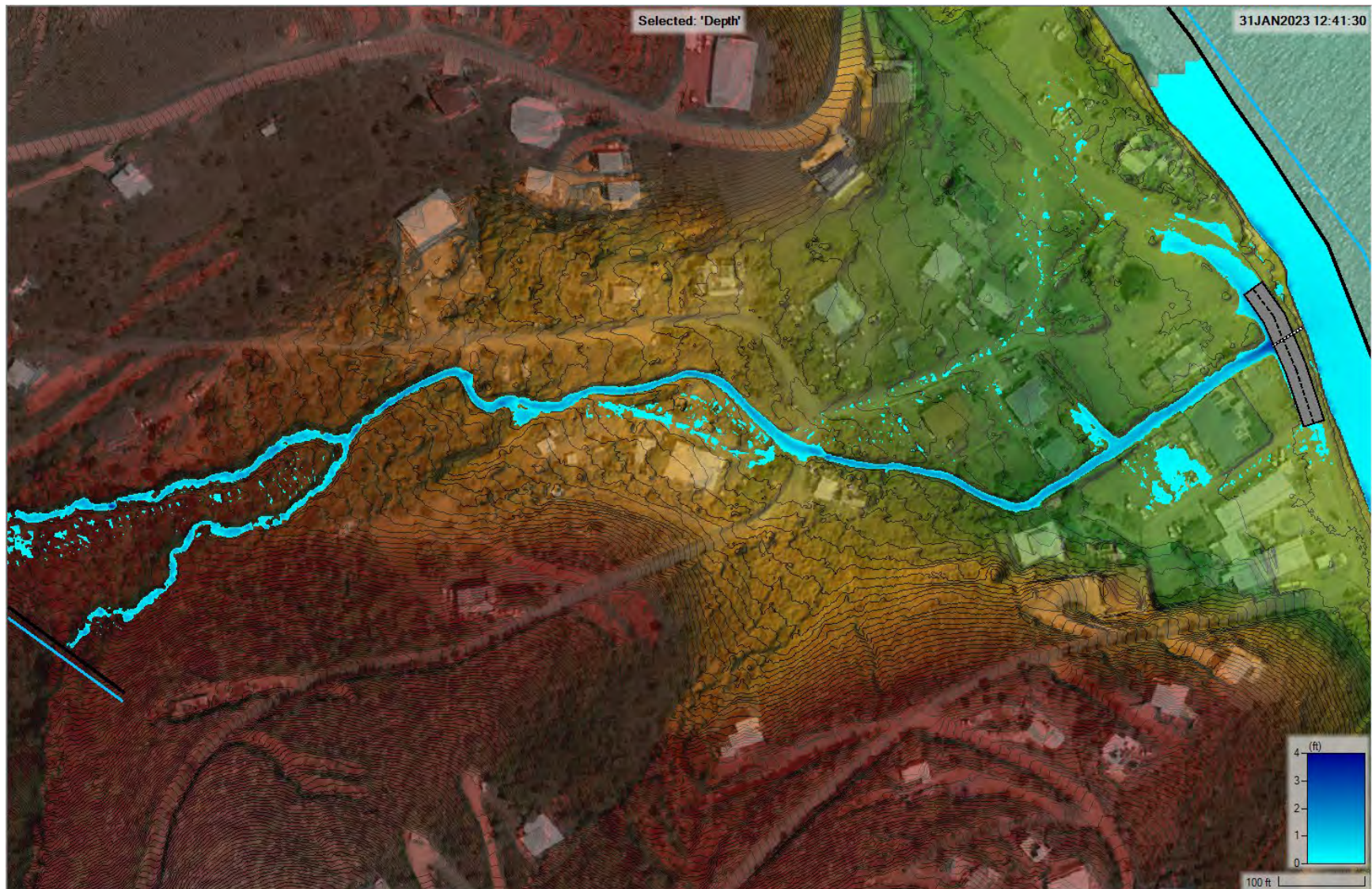
**Figure 31. Flood depth during a 1.5-inch storm event at the Spring Garden site. Depth is indicated by blue shading with deeper water depths shown in darker blue.**





Figure 32. Flood depth during a 1.5-inch storm event at the Spring Garden site with the proposed stormwater basin in place. Depth is indicated by blue shading with deeper water depths shown in darker blue.





**Figure 33. Flood depth during a 2-inch storm event at the Spring Garden site. Depth is indicated by blue shading with deeper flooding depths shown in darker blue.**



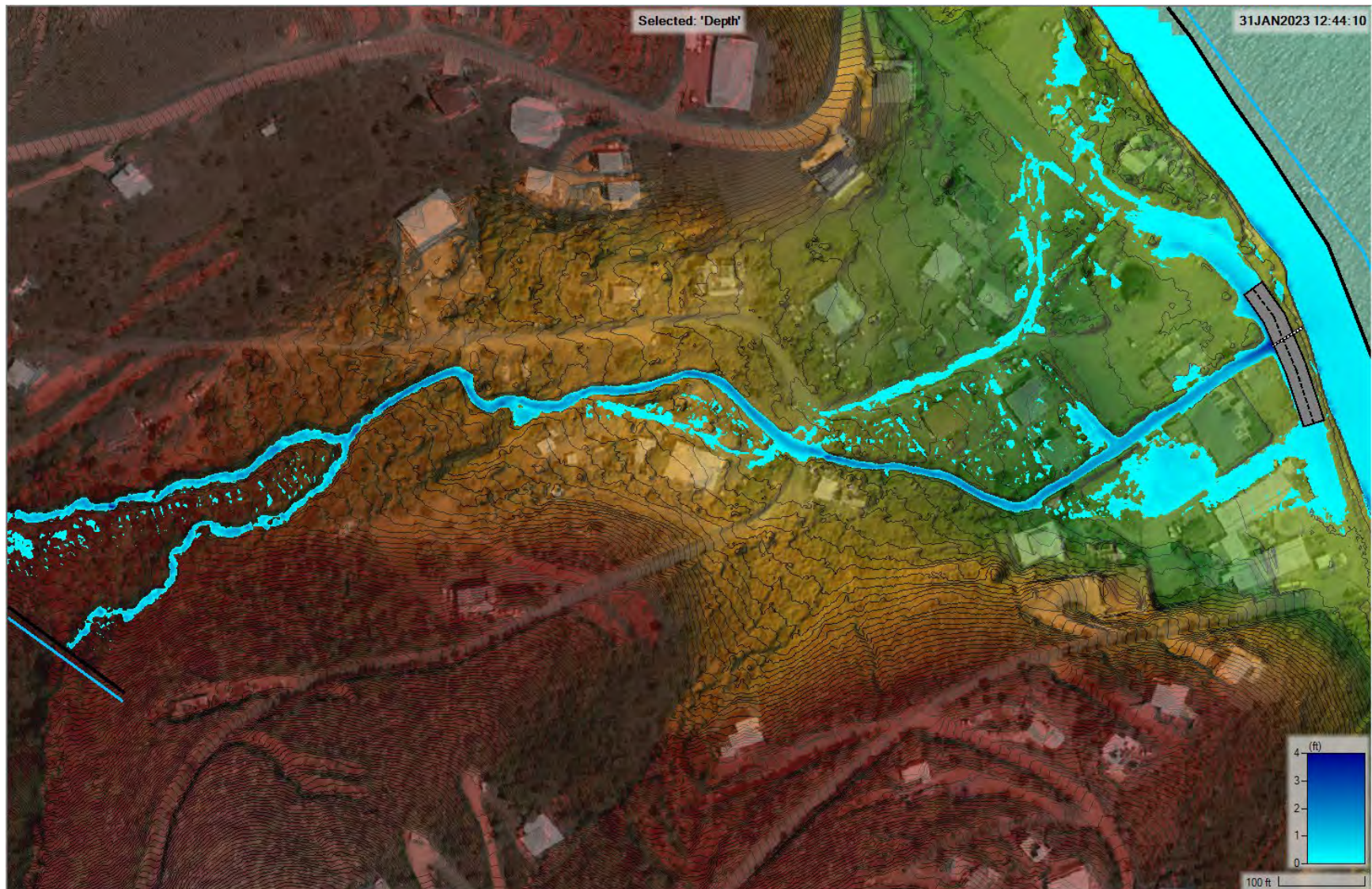


Figure 34. Flood depth during a 2.5-inch storm event at the Spring Garden site. Depth is indicated by blue shading with deeper flooding depths shown in darker blue.



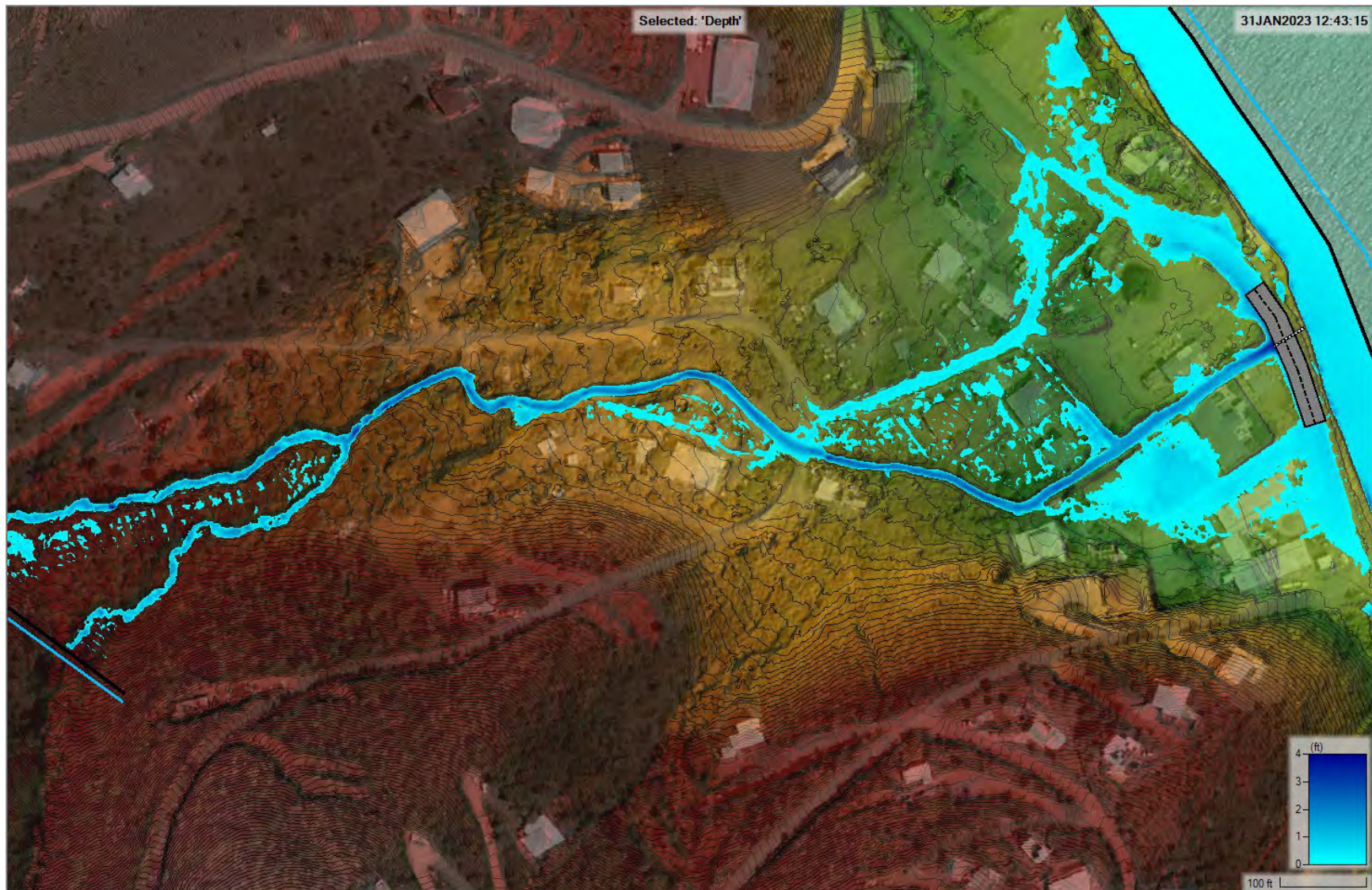


Figure 35. Flood depth during a 1-year (3.11-inch) storm event at the Spring Garden site. Depth is indicated by blue shading with deeper flooding depths shown in darker blue.



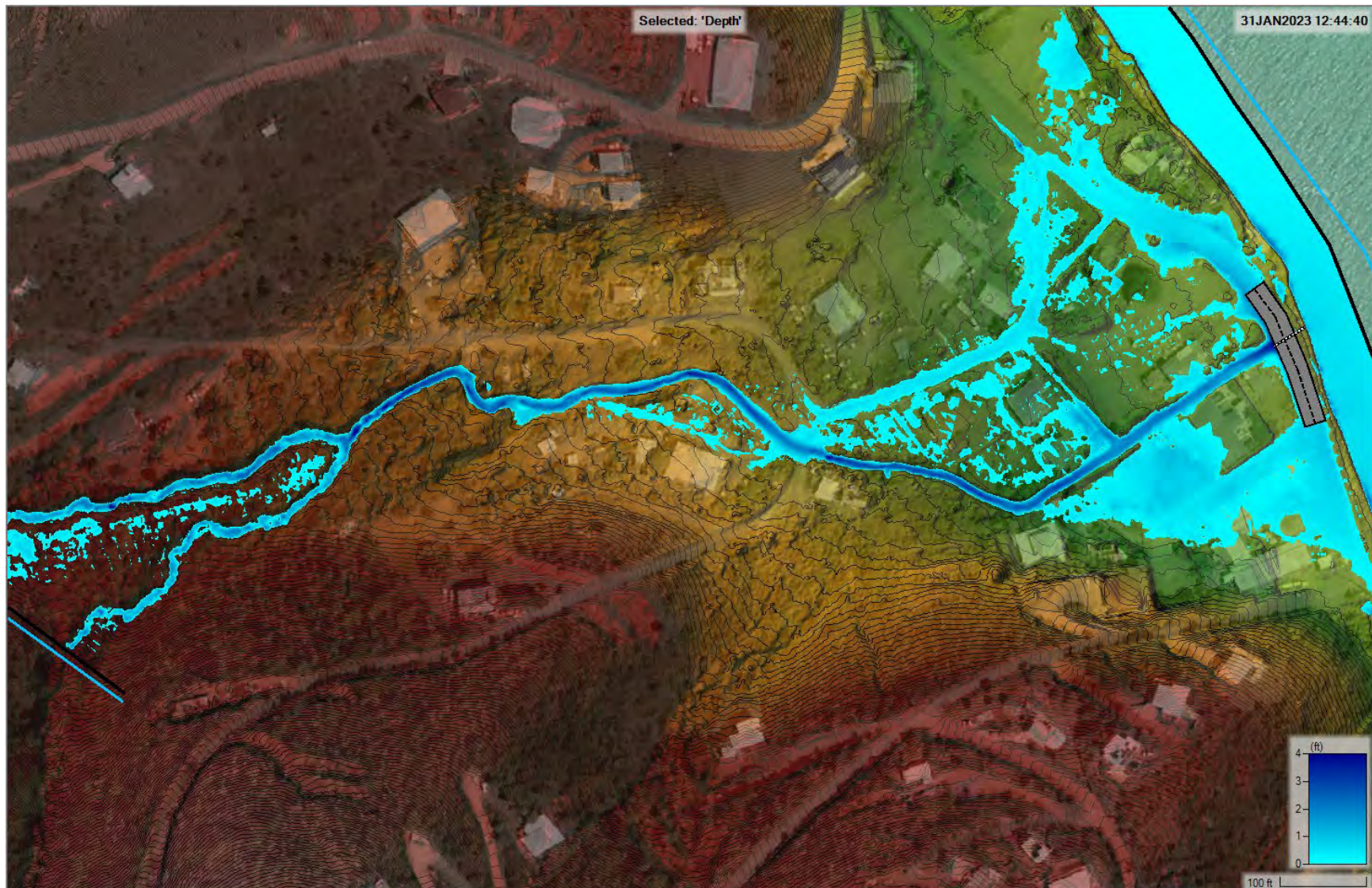


Figure 36. Flood depth during a 2-year (4.23-inch) storm event at the Spring Garden site. Depth is indicated by blue shading with deeper flooding depths shown in darker blue.





There are several other components to the proposed retrofit of this site. The first is to ensure that water that runs down Calvert C Marsh Road to the east is redirected to the gut south of the road via paved water bars or a similar diversion. This will reduce the amount of sediment and other pollutants that are mobilized by this water, reduce the erosion along the road, and restore hydrologic connectivity to the gut.

The other components of the proposed retrofits for this site focus on the gut that runs through the eastern section of the valley. Currently, a road right-of-way has been cleared at the top of Harold's Way. The right-of-way includes a steep slope that funnels stormwater onto and down Harold's Way instead of to the stable gut channel (Figure 37).



**Figure 37. The cleared road right-of-way (right of photo) funnels turbid water across and down Harold's Way in storm events (Photo by CBCC).**

The recommended interventions for this site include (see Figure 38):

1. Create a bioretention basin along the northwestern gut flows from the gut, provide water quality benefits, and reduce peak discharge and downstream flooding. This would require excavation of the raised benches along the gut.
2. Redirect stormwater flows that currently run down Calvert C. Marsh Road back into the stable gut with two paved water bars.
3. Redirect water back into the gut at the top of cleared right-of-way that drains towards Harold's Way.



4. Install a series of four gabion dams along this cleared right-of-way to slow these erosive flows as they run down this steep slope.
5. Install a surface crossing at the bottom of the cleared right-of-way to direct water across Harold's Way and to the gut.
6. Stabilize the slope at the outlet of this surface crossing to prevent erosion due to stormwater flows.
7. Install a second bioretention basin further down this gut where the slope of the land becomes less steep to slow and filter stormwater.

A large-scale plan showing these proposed improvements is provided in [Appendix G](#). Note that the bioretention basin shown on this plan is larger than the basin that was previously modeled. As such, this basin would be able to provide additional flood storage and water quality benefits beyond those described above.







#### 11.4. Lala Land

The Lala Land site was selected as a priority as this chronic problem area is the only access road to many homes (approximately 20-30). The drainage area to this priority location includes 36.3 acres (Figure 39). It is located just downstream from the Ironwood Rd culvert project (the Ironwood Rd culvert drainage area is contained by this project's drainage area). The drainage area is also a part of the drainage areas for both



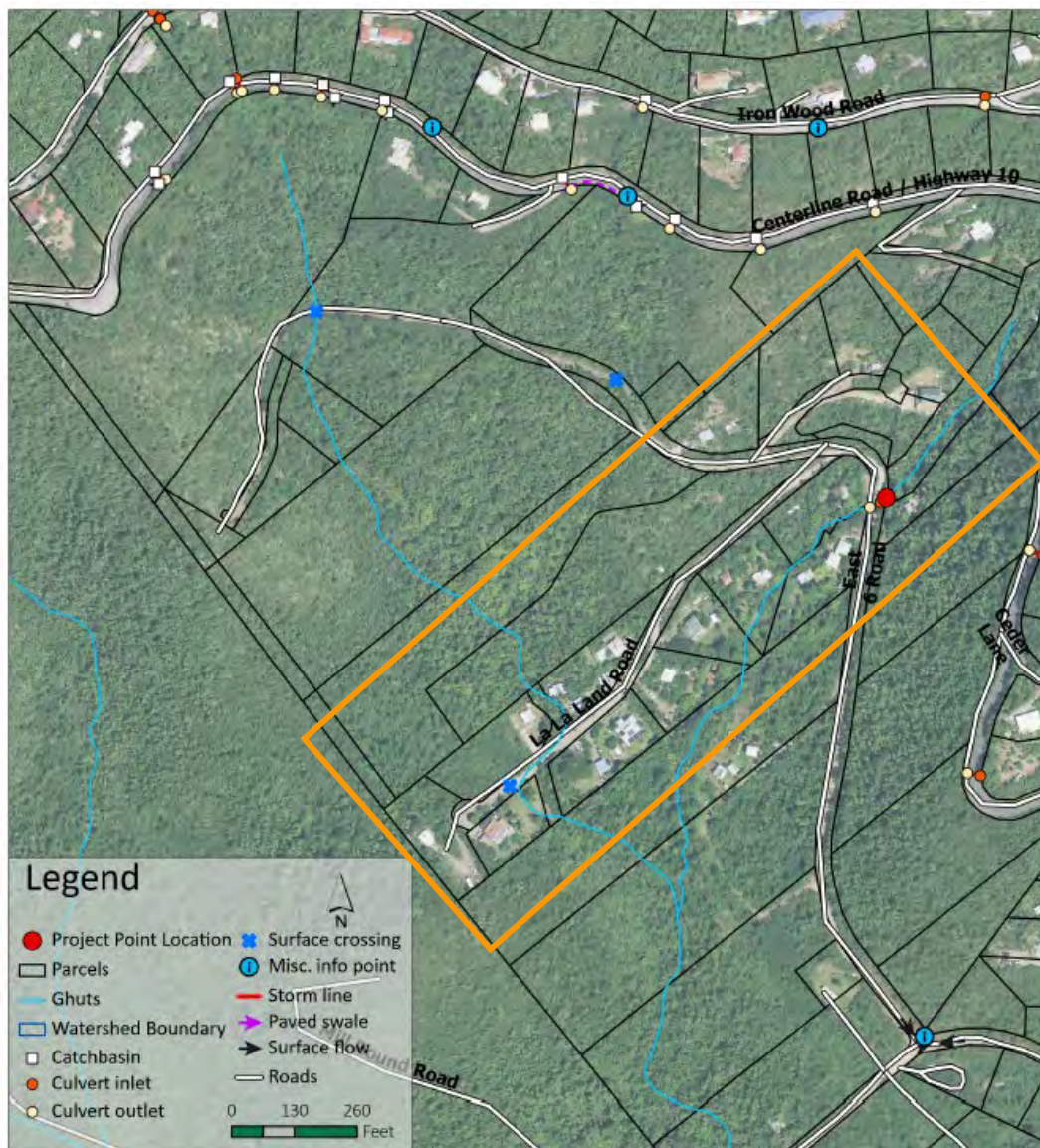
Figure 39. The Lala Land drainage area, highlighted in yellow, includes 36 acres of residential development. The site location is shown with a red circle.





the 6-4 Carolina and the Pickles sites. The problem area centers around a gut crossing with an existing bridge (see the location of the red circle on Figure 39). One issue in this location is that some of the water from Centerline Rd (Route 10) above does not currently enter the gut as it should due to the development patterns and drainage infrastructure that was put into place.

CBCC has documented recurring drainage issues in this area, which increased following road work on Route 10 in 2015. Flows are bypassing the natural stable gut channel and stormwater is flowing overland and then reaching the gut at the road crossing where the bridge is located. Sediment has been deposited on the adjacent roadway, which can make access to and from these homes challenging if not impossible at times. This could isolate these residences in an emergency. These homes can be seen in Figure 40 below with those at-risk residences highlighted with an orange box. There are also several undeveloped parcels that are accessed via this road to the north and west of this area. If these parcels are developed in the future,



**Figure 40. The Lala Land project site includes a bridge gut crossing (location shown with a red circle) can isolate the residences past this area when stormwater overtops the road. This area is shown in an orange box.**



this would increase the number of homes that would be isolated if this area became inaccessible due to drainage issues at the gut crossing.

Following Hurricane Irma in 2017, volunteer property owners along Estate 6 Road and Lala Land Road spent 200 hours repairing the road. They have noted that maintenance is needed frequently and over \$75,000 has been spent on road repairs over the years. Typically, annual costs have been \$2,000-3,000 collectively. One home was destroyed during the 2017 hurricanes due to stormwater overflowing the gut.

This site is located on road cut into a moderately steep hillside. NRCS mapping indicates the soils are non-hydric (VsE - Victory-Southgate - 20-40% slopes). NWI mapping does not show any wetlands in the vicinity of the project and no potential wetland areas were noted at or adjacent to the area during the site review. See [Appendix E](#) for a map of the NWI for Coral Bay. A site survey was completed to define existing conditions including culvert inverts and drainage patterns. The contributing drainage area was also verified at this time. The existing condition survey can be found in [Appendix F](#).

A HydroCAD model was developed to determine peak flows and assess flows through this area. Modeled peak flows for a range of storm events can be found below in Table 12. The high flows modeled at this location are a result of the large drainage area (36.3 acres), steep slopes, and soils that limit infiltration.

**Table 12. Lala Land HydroCAD peak flow summary table.**

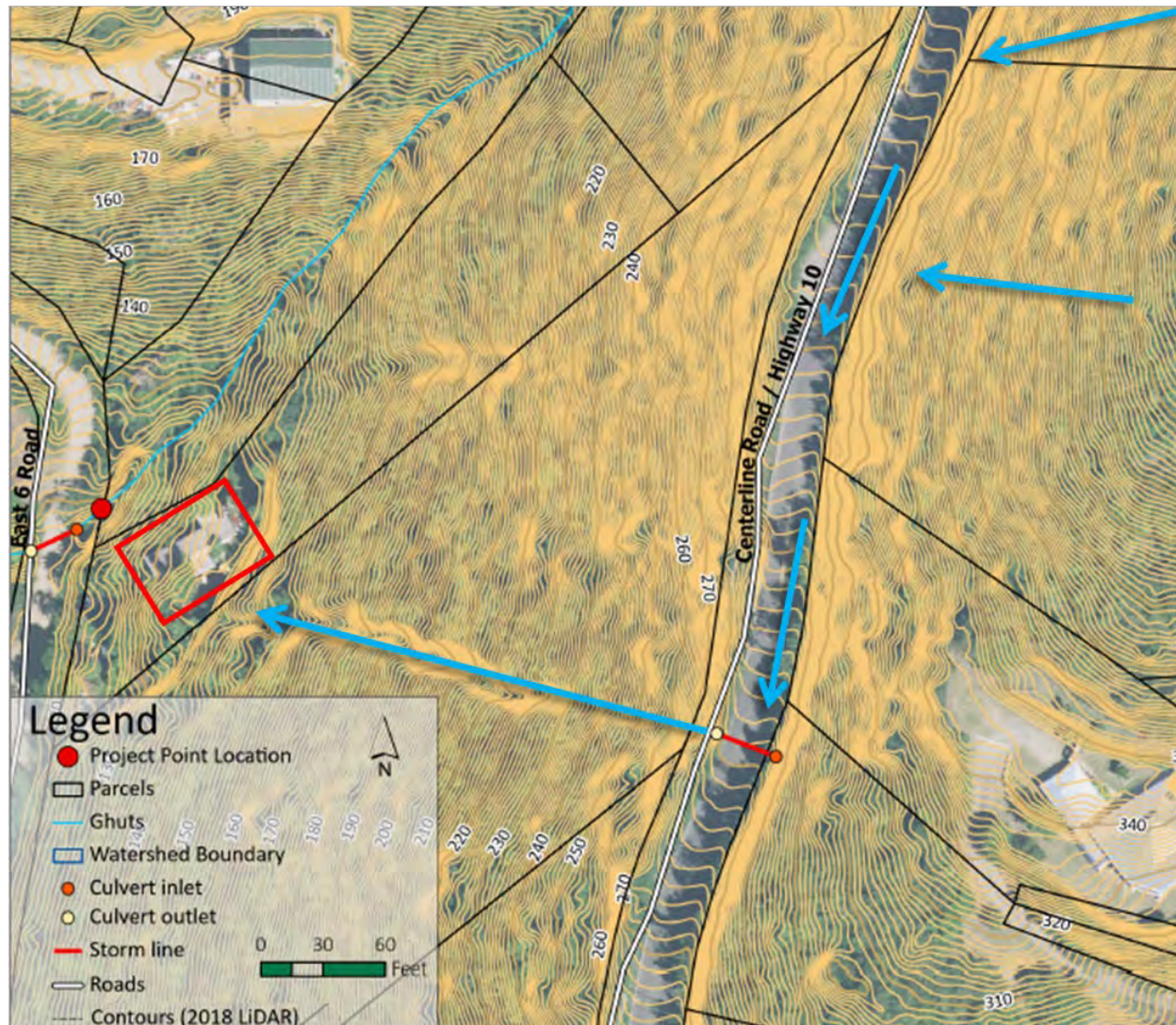
| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) | Peak Flow (cfs) |
|------------------------------------|---------------------------|-----------------|
| WQv                                | 1                         | 11.05           |
| 1-yr                               | 3.11                      | 78.73           |
| 2-yr                               | 4.23                      | 129.28          |
| 5-yr                               | 6.37                      | 232.40          |
| 10-yr                              | 8.19                      | 322.48          |
| 25-yr                              | 10.9                      | 457.32          |
| 50-yr                              | 13.2                      | 571.49          |
| 100-yr                             | 15.7                      | 695.04          |
| 200-yr                             | 18.4                      | 827.82          |
| 500-yr                             | 22.5                      | 1,028.32        |
| 1000-yr                            | 25.8                      | 1,188.92        |

One of the issues that contributes to flows overtopping the road and threatening surrounding infrastructure is that there are areas where drainage flows down the steep slopes, concentrated along roads that run perpendicular to these flow paths, and then either discharged via low points in the road shoulder or are collected and discharged via culverts. However, these culverts are often not placed in areas where flows can enter the stable gut. Instead, this concentrated and erosive channel continues flowing down the steep slopes. This stormwater path is often in conflict with existing development. This is particularly notable along Centerline Rd (Route 10) in this area. Figure 41 shows an area where stormwater concentrates from the steep hillside to the east, is intercepted by Centerline Rd, flows down the road, and is then collected and discharged via a culvert to the west. The flow path from this culvert, which can be clearly seen in topographic data (LiDAR-derived contours shown with orange lines in the figure), is directed towards a residence (as highlighted with a red box in Figure 41). The flows are diverted around the home to the southeast (away from the gut to the north of the house), but flowing water resists making sharp





changes in direction and exerts more force on the outside bend of a change in direction, which in this case is directly at the home. Then, the water flows towards the road and must cross the road or make its way along the road to the gut. While additional cross drainage along Centerline Rd is recommended to break up these concentrated flows, planning and engineering must also be completed to ensure that culvert outlets discharge stormwater that is not creating more issues downstream and is instead directed to the stable gut via a defined and stable route or otherwise mitigated using a best management practice.



**Figure 41. The Lala Land bridge and project location is shown with a red circle. Flow direction arrows are shown in blue. The red box outlines a home that is located in the flow path of the discharge from the culvert on Centerline Road.**

For this site, improved drainage from this culvert along Centerline Road via a stabilized channel to the gut is recommended (see Figure 42). It is also recommended that when engineering plans are developed for Centerline Rd by the USVI Department of Public Works (DPW), careful attention is paid to the location and frequency of cross drainage as well as management of stormwater flows from culvert outlets. As this area is very steep, a stormwater basin is not possible. However, it is recommended that flows within surrounding the gut (from concentrated areas such as low points from road drainage and culvert outlets) be stabilized and slowed with gabion dams. These practices will improve drainage conditions and reduce erosion. A large-scale plan showing these proposed improvements is provided in [Appendix G](#).



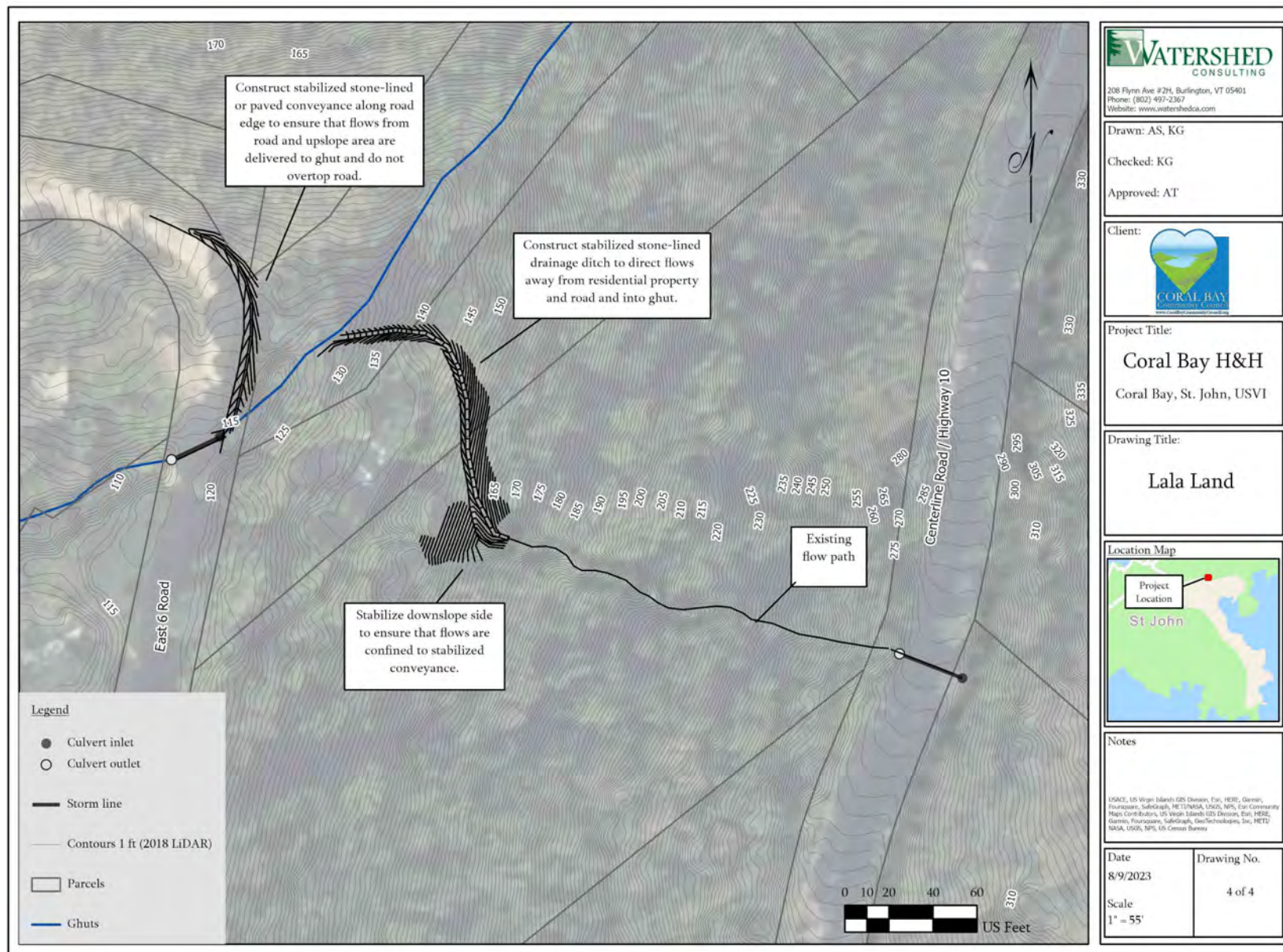


Figure 42. Proposed retrofits for the Lala Land site.



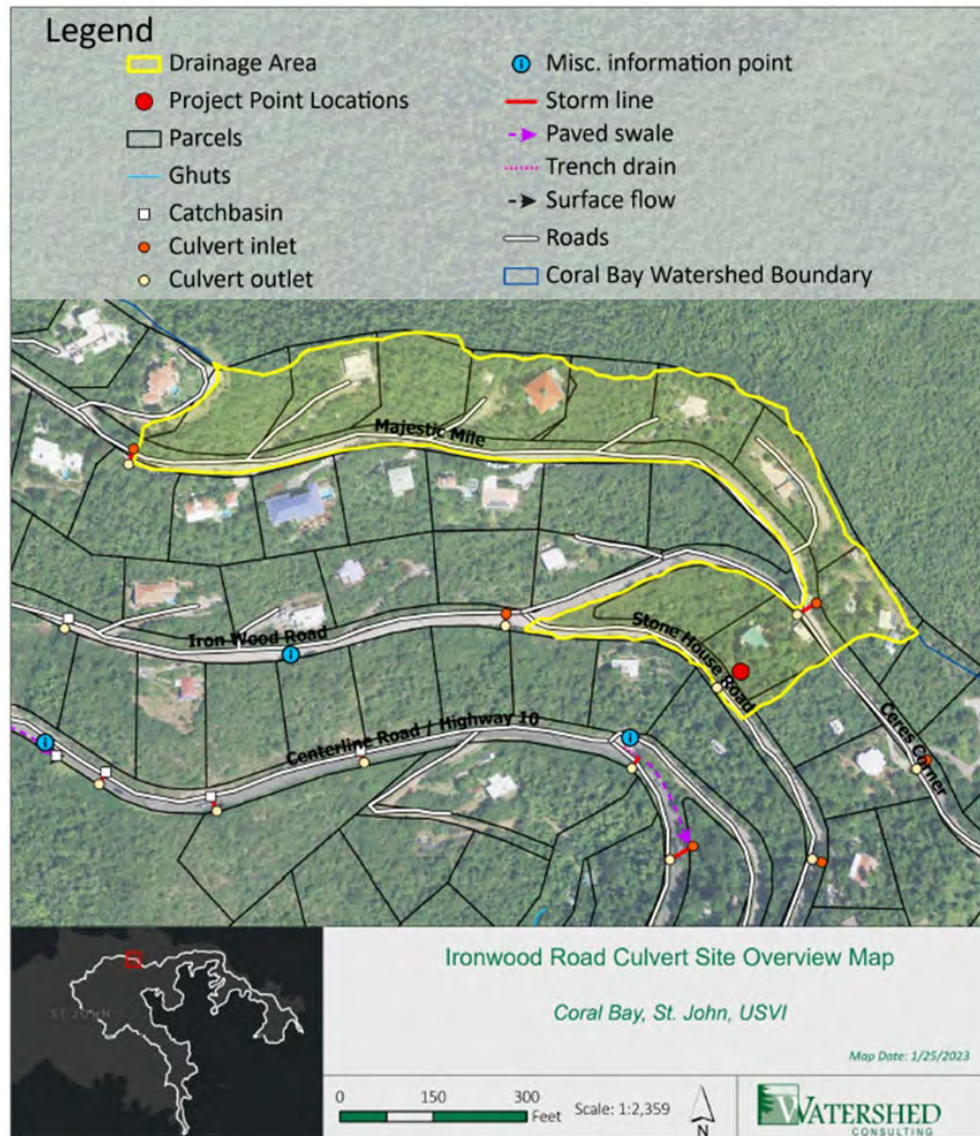


### **11.5.     *Ironwood Road Culvert***

The Ironwood Rd culvert was selected as a priority modeling site. This key location currently has additional design work being completed by an engineering consultant selected by CBCC. CBCC applied for and received grant funding to complete the engineering design to repair this chronic problem area. Modeling results for this project were developed for and tailored to supporting this design work.

The drainage area to this site includes 5.7 acres of primarily residential development on steep slopes (Figure 43). A significant landslide occurred downhill of the culvert during Hurricane Irma in 2017. This event washed soil and large rocks onto the Centerline Road (Route 10) road surface and surrounding area for approximately a month. Heavy equipment was required to keep one lane of the road open to allow traffic to pass. Similar issues at this location have occurred during storm events both prior to and following this extreme event.

A site survey was completed to define existing conditions including culvert inverts and drainage patterns. The contributing drainage area was also verified at this time. The existing condition survey can be found in [Appendix F](#).



**Figure 43. The contributing drainage area to the Ironwood Rd culvert is shown with a yellow polygon. The culvert project location is shown with a red circle.**

A natural resources assessment was completed for this location. The site is located on a road cut into a steep hillside. Natural Resources Conservation Service (NRCS) mapping indicates the soils are non-hydric (SrG - Southgate Rock Outcrop Complex 60-90% slopes). The National Wetlands Inventory (NWI) mapping does not indicate that there are any wetlands in the vicinity of the project and no potential wetland areas were noted at or adjacent to the site during the site review. See [Appendix E](#) for a map of the NWI for Coral Bay.

The developed HydroCAD model was utilized to assess the peak flows from the contributing drainage area to the Ironwood Rd culvert. These flows are summarized in Table 13 below. This information will be critical in completing a culvert improvements and stabilization of the surrounding area. The engineering analysis will determine the best design for a stabilization technique (i.e., retaining wall, riprap, or terracing) to prevent future issues at and downstream from this culvert including landslides, provide safe overflow for larger storms, and stabilize the drainage leaving the Ironwood Rd culvert as it flows down towards





Centerline Road. Modeled peak flows confirm the necessity of this stabilization and drainage improvements in this area, particularly in larger storm events where the existing culvert's capacity is exceeded.

**Table 13. Ironwood Rd Culvert HydroCAD peak flow summary table.**

| Rainfall Event Recurrence Interval | Rainfall Event Depth (in) | Peak Flow (cfs) |
|------------------------------------|---------------------------|-----------------|
| WQv                                | 1                         | 1.91            |
| 1-yr                               | 3.11                      | 14.09           |
| 2-yr                               | 4.23                      | 22.84           |
| 5-yr                               | 6.37                      | 40.58           |
| 10-yr                              | 8.19                      | 56.01           |
| 25-yr                              | 10.9                      | 79.07           |
| 50-yr                              | 13.2                      | 98.57           |
| 100-yr                             | 15.7                      | 119.67          |
| 200-yr                             | 18.4                      | 142.34          |
| 500-yr                             | 22.5                      | 176.57          |
| 1000-yr                            | 25.8                      | 204             |



## 12. Sea Level Rise

Sea level rise associated with climate change was a potential issue of concern that was assessed during this modeling effort. Information provided in the report entitled “Flood Hazard Maps for Flood Drainage Infrastructure Vulnerability Scenarios and Risk Assessment for Earthquake and Tsunami” and the associated data depicting changes in flood inundation in Coral Bay due to sea level rise was reviewed (RMSI, 2021). Probabilistic flood hazard maps are shown in [Appendix I](#) for the 10-, 25-, 50-, 100-, and 500-year return periods with and without predicted sea level rise in Coral Bay.

In general, flood inundation extent was increased only minimally over these return periods (Figure 44). As such, these increases in flood inundation were generally not considered to be impactful for the key areas of interest. While it is recommended that data is reviewed over time to ensure that predictions do not increase, the priority is to reduce flooding and water quality issues driven by precipitation events as these pose the greatest threat to infrastructure, water quality, and resilience.

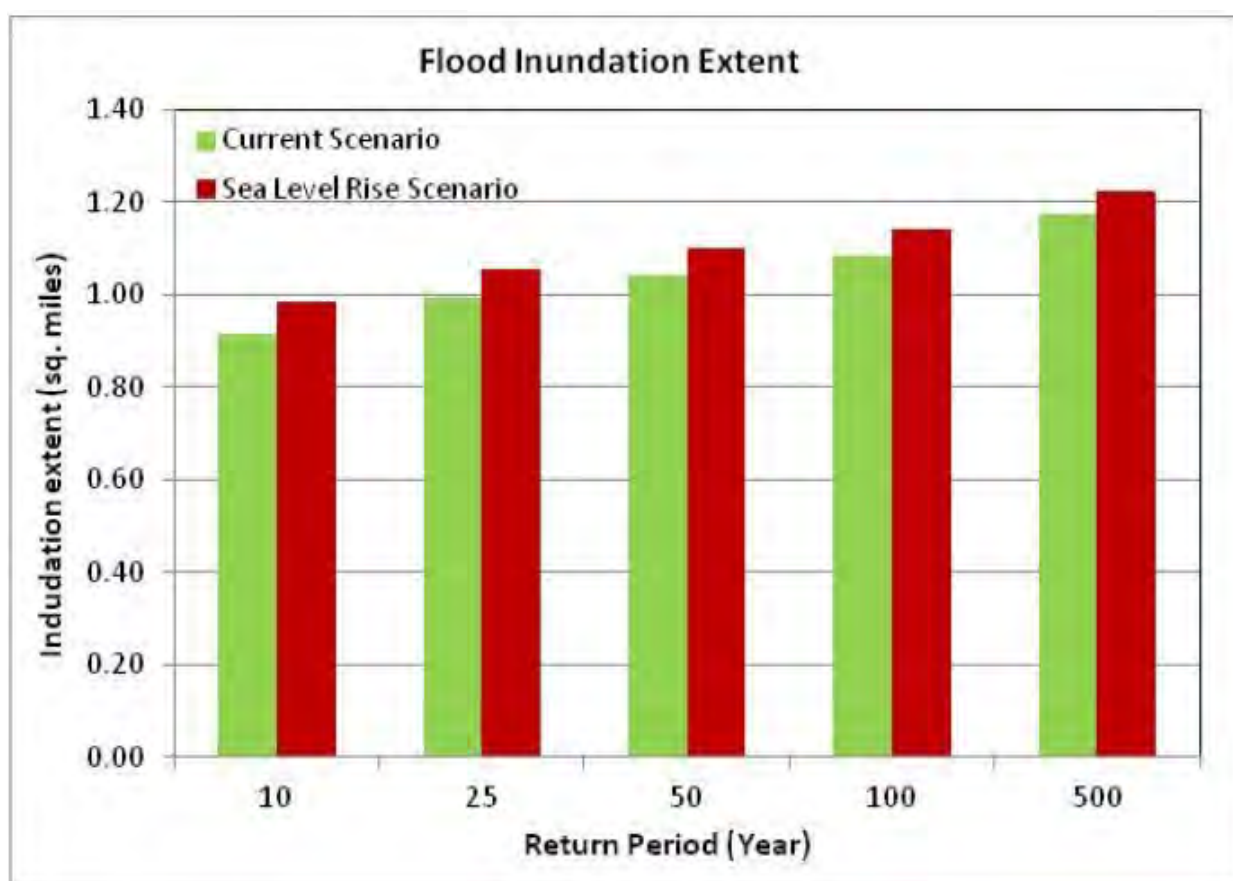


Figure 44. Change in flood inundation area due to sea level rise for the entirety of St. John (figure reproduced from RMSI, 2021).

## 13. Conclusions

The modeling and assessments completed during this project have indicated that distributed practices installed throughout the watershed to improve water quality and reduce flooding are critical. Acquisition and/ or protection of key areas that have not yet been developed is also a very high priority for the watershed. These critical parcels include areas around the guts, particularly in headwater or other





particularly steep areas, areas where BMPs such as bioretention basins could be installed, areas where wetlands could be protected or restored, or areas that are particularly vulnerable to erosion (i.e., erodible soils). An inventory of the watershed is recommended to identify and prioritize these areas.

It is recommended that the conceptual designs developed for the priority areas be further refined and advanced to final design. This will require not only engineering design, but also coordination with key landowners. A focus should also be placed on reducing stormwater peak flows in subwatersheds with particularly high flows.

## 14. References

RMSI (2021). Natural Hazard Risk Analysis: U.S. Virgin Islands: Flood Hazard Maps for Flood Drainage Infrastructure Vulnerability Scenarios and Risk Assessment for Earthquake and Tsunami