Sam Day Hill Road
Hydrology & Hydraulics Study

Town of Phippsburg, Maine

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Town of Phippsburg
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Submitted by:
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Project No. 2306025

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Table of Contents

List of Tables

List of Figures

Figures

Appendices

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Acronyms and Abbreviations

2D	2-Dimensional
3D	3-Dimensional
BFE	Base Flood Elevation
CN	Curve Number (method)
DEM	Digital Elevation Model
DSS	Data Storage System
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
GEI	GEI Consultants, Inc.
GOPIF	Governor’s Office of Policy Innovation and the Future
H&H	Hydrologic and Hydraulic
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HSG	Hydrologic Soil Group
IEM	Iowa Environmental Mesonet (Iowa State University)
KELT	Kennebec Estuary Land Trust
LiDAR	Light Detection and Ranging
MHHW	Mean Higher High Water
MRMS	Multi-Radar Multi-Sensor
NAVD88	North American Vertical Datum of 1988
NEH	National Engineering Handbook
NEXRAD	Next Generation Weather Radar
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCC	Northeast Regional Climate Center
NRCS	Natural Resources Conservation Service
NSSL	National Severe Storms Laboratory
QPE	Quantitative Precipitation Estimation (Multi-Sensor)
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey

Executive Summary

The Town of Phippsburg retained GEI Consultants, Inc. to assist with a hydrologic and hydraulic (H&H) study to assess the flood risk for the eastern-most 2,300 feet section of Sam Day Hill Road, a 1.2-mile critical route that becomes inaccessible during severe weather events. Funded by a Community Resilience Partnership grant under the Maine Governor's Office of Policy Innovation and the Future (GOPIF), the study aimed to evaluate existing flood conditions and inform future infrastructure improvements.

As part of the study, GEI developed a 2-dimensional (2D) rain-on-grid hydraulic model of the Parker Head Creek watershed to simulate precipitation and flood scenarios for the 24-hour, 10-, 25-, 50-, and 100-year annual recurrence interval precipitation events (design storms). The analysis was conducted using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, version 6.4.1 (USACE, 2023) and integrated field data collected by Sackett and Brake Survey, Inc. (2024) and Kennebec Estuary Land Trust (KELT).

Key findings indicated that the low-lying section of Sam Day Hill Road is highly susceptible to flooding. The model results indicated that the 10-year storm would produce significant flooding with water depths at the road of up to 3 feet. The duration of road inundation would exceed 17 hours. The severity of road overtopping increased with more remote storm events with the 100-year storm resulting in water depths of up to 5.7 feet. Duration of inundation for the 100-year storm would be about 23 hours.

The model showed no significant difference between peak flood levels when storm events were modeled with normal tides versus extreme tide cycles as indicated by level logger data used for this study. These findings indicated that the model was influenced more by the volume of precipitation and stormwater rather than being influenced by tidal conditions, especially for the 100-year event. Model results and actual observations of flooding at Sam Day Hill Road suggest that flooding issues may be caused by the low elevation of the road as well as issues related to undersized culverts at both Sam Day Hill Road and Parker Hill Road that inhibit stormwater and tidal conveyance.

For many residents, Sam Day Hill Road is the most effective and efficient way to access Route 209, a MaineDOT evacuation route, making Sam Day Hill Road an important connection for residents and first responders. Historic observations confirm that the road has flooded during large precipitation, extreme high tides, and/or storm surge events underscoring the need for action to mitigate flooding and ensure the road's accessibility during emergencies. The findings of this study will serve as a critical baseline for planning future road and culvert enhancements to improve the Town's resilience to flooding.

1. Introduction

The purpose of GEI Consultants Inc.'s hydrologic and hydraulic (H&H) study was to provide the Town of Phippsburg with flood risk information for the eastern end of Sam Day Hill Road – a section that floods during large precipitation and storm surge events. The study was funded by a Community Resilience Partnership grant, administered by the Maine Governor's Office of Policy Innovation and the Future (GOPIF). The Town became a partner in 2023, enabling them to access funds to evaluate the flood risk on Sam Day Hill Road.

This study included the development of a 2-dimensional (2D) rain-on-grid hydraulic model of the Parker Head Creek watershed to simulate the 24-hour 10-, 25-, 50-, and 100-year annual recurrence interval storm events (i.e., design storms). The model was used to estimate flood inundation extents, depths, and durations, peak water surface elevations, flows, and velocities along the lower portion of the Parker Head Creek adjacent to Sam Day Hill Road. GEI performed this evaluation using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, version 6.4.1 (USACE, 2023). GEI partnered with the Kennebec Estuary Land Trust (KELT), which had several water level sensors deployed in the area from November 2, 2023 through December 21, 2023 to capture changes in water surface elevations during tide cycles and precipitation events. The water level data were used to set downstream (tidal) boundary conditions in the hydraulic model and the data were also used for model calibration.

Critical to model development was the compilation of terrain data to represent topographic features of the watershed. The model terrain was compiled from a 1-meter resolution Digital Elevation Model (DEM) developed by USGS (2020). GEI also subcontracted Sackett and Brake Survey, Inc. to collect elevation data along Sam Day Hill Road and at water conveyance structures (i.e., culverts) along Parker Head Creek.

The North American Vertical Datum of 1988 (NAVD88) is the reference datum for elevations in this report and the hydraulic model.

GEI completed the analysis for the Town of Phippsburg in accordance with GEI's Proposal dated December 15, 2023. The following GEI personnel were primarily responsible for performing the hydraulic analysis for this report:

- Project Manager: Alex Gray
- Quality Assurance/Control: Marc Chmura, P.E. (ME)
- In-House Reviewer: Lissa Robinson, P.E. (ME)

2. Background

Sam Day Hill Road is a 1.2-mile-long road that connects Maine State Route 209 (Main Road) with Parker Head Road in the Town of Phippsburg, Sagadahoc County, Maine (Figure 1). Sam Hill Day Road has a history of flooding. The Town's transfer station is located on the north side of Sam Day Hill Road just after the junction with Route 209. For many residents who live on Parker Head Road, Sam Day Hill Road serves as the most effective and efficient way to access Route 209. Route 209 is also listed by MaineDOT as an evacuation route, making Sam Day Hill Road an important connection for residents and first responders during emergencies. However, the road can be inaccessible during large precipitation, extreme high tides, and/or storm surge events.

The most recent Federal Emergency Management Agency (FEMA) Flood Insurance Study (2015) shows that the low-lying area of Sam Day Hill Road, just before the intersection with Parker Head Road, would be inundated by the FEMA's model of the 1-percent annual chance (coastal) storm (Figure 2). The USGS (2020) DEM and a recent topographic survey by Sackett and Brake Survey, Inc. (2024) (Figure 3) confirmed the road's elevation in this area to be as low as 7 feet. FEMA's inundation mapping estimates that the flood elevation in this area would be at elevation 9 feet, meaning that sections of Sam Dam Hill Road would be inundated by up to 2 feet during a 100-year annual recurrence interval flood event.

In addition to tidal impacts, it is also important to identify which types of precipitation events would inundate Sam Day Hill Road – and by how much – before improvements to the road and hydraulic structures can be developed. Furthermore, it is important to look at tidal and precipitation events together to understand the influence of joint coincidence (i.e., extreme precipitation and high coastal water surface elevations). This H&H study evaluates existing conditions, observed precipitation and tidal events, and hypothetical design events to help establish a baseline from which to plan future road or culvert improvements.

3. Sam Day Hill Road

Sam Day Hill Road is paved heading east from the intersection with Route 209 until a location about 3,492 feet to the east where it transitions into a dirt road. About 190 feet further east Parker Head Creek passes underneath Sam Day Hill Road via a small 22-foot-wide open span crossing. Parker Head Creek continues adjacent to Sam Hill Day Road – on the northern side - where it passes under a private driveway via two 48-inch-diameter plastic culverts. Parker Head Creek then passes through a 72-inch-diameter concrete culvert underneath Sam Day Hill Road and enters a ponded area. Parker Head Creek passes underneath Sam Day Hill Road again via four 30-inch-diameter corrugated metal pipes, discharging to another ponded area. The two ponds are situated upstream and downstream of Sam Day Hill Road at the lowest lying section of Sam Day Hill Road. Parker Head Creek continues downstream underneath Parker Head Road to the east, where it discharges into the Mill Pond area of the Kennebec River. Sacket and Brake Survey, Inc., under contract to GEI, collected culvert dimensions, invert elevations, and road surface elevations for the nine hydraulic structures listed above as well as sections of Sam Day Hill Road and Parker Head Road. These features and areas are shown in Figure 3.

4. Hydraulic Model Setup

To perform the H&H analysis, GEI developed a 2-dimensional (2D) rain-on-grid HEC-RAS model of the Parker Head Creek watershed. GEI developed this model using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – River Analysis System (HEC-RAS) software, Version 6.4.1 (USACE, 2023).

The model was used to simulate watershed conditions for the 24-hour 10-, 25-, 50-, and 100-year annual recurrence interval design storm events. The model extended into the Kennebeck River in order to capture possible tidal influence on modeled culverts.

Water level sensors were deployed and data compiled by KELT across the period from November 2, 2023 through December 21, 2023. The data were used to develop the model's downstream boundary conditions. Each design storm was run once under normal tide conditions and once using the highest tide cycle recorded during KELT's observation period. Refer to section 4.5 for further discussion on boundary condition set up.

The focus of this study was to evaluate the depth of the inundation along the low-lying section of Sam Day Hill Road from the different design storm events and downstream tidal boundary conditions.

The model was developed to represent existing conditions in the watershed. Modifications may be made to the model to facilitate design and analysis of future road or culvert modification projects.

4.1. Terrain

A terrain model is a 3-dimensional (3D) representation of the watershed's topography that influences the movement of water through the floodplain among other factors like land cover and soil type. The terrain was developed from 1-meter resolution DEMs based on Light Detection and Ranging (LiDAR) surveys available from USGS (2020). Improvements to the terrain were made by incorporating surveyed elevations along the lower portion of Parker Head Creek and the low-lying section of Sam Day Hill Road. A map of the terrain for the watershed is provided in Figure 4. Since LiDAR picks up the surface of the water rather than the pond bottom, we also modified the terrain so culverts were not submerged or filled (like they were at the time of the LiDAR survey).

4.2. 2D Flow Area

Using the HEC-RAS 2D flow area editor, GEI generated a computational mesh to represent the perimeter of the 2.5- square-mile watershed. A cell size of 50 feet by 50 feet was selected as the default cell size. Smaller cell sizes were input for model stability and additional detail along the main channel and at key geometric features such as culverts. Breaklines were added to the 2D flow area mesh to reduce cell size, reorient the cells to align with geometric features and the primary direction of flow, and to capture “high” features in the terrain.

4.3. Land Cover and Manning’s n-value

Land cover data for the watershed was obtained from the National Land Cover Dataset (USGS, 2021). This dataset is a 30-meter by 30-meter representation of land cover types within the watershed. The National Oceanic and Atmospheric Administration (NOAA) is currently updating land cover in Maine with higher resolution data. At the time of this project only areas representing water and impervious surfaces (NOAA, 2021) had been completed. The NOAA datasets have a resolution of 1 meter by 1 meter and were mosaicked with the NLCD (USGS, 2021) dataset to provide higher resolution land cover where possible. A map of the land cover for the watershed is provided in Figure 5. The distribution of land cover as a percent of the total watershed area is presented in Table 4-1.

Table 4-1. Parker Head Creek Watershed Land Cover

Land Cover	Area (Square Miles)	Area Percentage
Deciduous Forest	0.26	10.5%
Developed, Low Intensity	0.03	1.1%
Developed, Medium Intensity	0.01	0.4%
Developed, Open Space	0.07	2.6%
Emergent Herbaceous Wetlands	0.02	0.7%
Evergreen Forest	0.65	25.8%
Hay/Pasture	0.01	0.6%
Impervious	0.03	1.2%
Mixed Forest	0.85	33.8%
Open Water	0.02	0.6%
Shrub/Scrub	0.01	0.2%
Woody Wetlands	0.56	22.4%

Within the HEC-RAS program, each land cover classification is assigned a Manning’s n roughness coefficient. The lower a Manning’s n value, the less resistance to flow. Manning’s n values were assigned based on values rerecommended in the HEC-RAS 2D User Manual (USACE, 2024b) for “appreciable depths of flow.”

4.4. Infiltration

The Curve Number (CN) method was used to model precipitation loss due to soil infiltration. CN estimates were based on guidance published in Chapter 9 of the Natural Resources Conservation Service (NRCS) National Engineering Handbook (NEH) Part 630 Hydrology (NRCS, 2004a). The CN method estimates infiltration as a function of cumulative precipitation, soil characteristics, land cover, and antecedent soil moisture conditions.

We used the NRCS Web Soil Survey tool to obtain information on hydrologic soil groups and soil characteristics in the watershed (NRCS, 2023). NRCS defines four hydrologic soil groups (HSG): A, B, C, or D. In general, soils with HSG classification of A consist of deep sandy soils and have the lowest runoff potential and the highest infiltration rates. Soils with HSG classification of D generally consist of clay and silt and have the highest runoff potential and lowest infiltration rates. The CN rating systems assigns each HSG-Land Cover parring a value between 0 and 99. High CNs indicate low infiltration rates, and therefore, greater runoff.

The percent distribution of hydrologic soil groups across the Parker Head Creek watershed are shown in Table 4-2. Note, no soils within the watershed were classified as HSG B. A map of the watershed hydrologic soil groups is provided in Figure 6. GEI used engineering judgement to select an appropriate HSG in areas that were assigned dual classifications (A/D, C/D, etc.).

Table 4-2. Parker Head Creek Watershed Hydrologic Soil Groups

Land Cover	Area (Square Miles)	Area Percentage
A	0.02	0.9%
B	0.00	0.0%
C	0.45	17.9%
D	2.04	81.2%

Most of the watershed (81.2%) was estimated to fall under HSG D, indicating the watershed consists mostly of soils with low infiltration rates.

Initial abstraction was calculated using the estimated CN and equations 10-10 and 10-12 published in the Chapter 10 of the NRCS NEH Part 630 Hydrology (NRCS, 2004b). Initial abstraction represents precipitation loss due to interception, infiltration during early parts of the storm, and surface depression storage. CNs and initial abstraction estimates are provided in Appendix A.

Table 4-3. Land Cover Curve Number by Hydrologic Soil Group

Land Cover	Curve Number for Hydrologic Soil Group		
	A	C	D
Deciduous Forest	30	70	77
Developed, Low Intensity	54	80	85
Developed, Medium Intensity	61	83	87
Developed, Open Space	39	74	80
Emergent Herbaceous Wetlands	80	80	80
Evergreen Forest	30	70	77
Hay/Pasture	30	65	73
Mixed Forest	30	70	77
Open Water	98	98	98
Road (Dirt)	72	87	89

Land Cover	Curve Number for Hydrologic Soil Group		
	A	C	D
Road (Paved)	74	90	92
Shrub/Scrub	30	65	73
Woody Wetlands	86	86	86

Table 4-4. Land Cover Abstraction Ratio by Hydrologic Soil Group

Land Cover	Abstraction Ratio		
	A	C	D
Deciduous Forest	4.67	0.86	0.60
Developed, Low Intensity	1.70	0.50	0.35
Developed, Medium Intensity	1.28	0.41	0.30
Developed, Open Space	3.13	0.70	0.50
Emergent Herbaceous Wetlands	0.50	0.50	0.50
Evergreen Forest	4.67	0.86	0.60
Hay/Pasture	4.67	0.82	0.56
Mixed Forest	4.67	0.86	0.60
Open Water	0.04	0.04	0.04
Road (Dirt)	0.78	0.30	0.25
Road (Paved)	0.70	0.22	0.17
Shrub/Scrub	4.67	1.08	0.74
Woody Wetlands	0.33	0.33	0.33

4.5. Boundary Conditions

The downstream boundary condition was set using a stage hydrograph to represent tidal fluctuations in the Mill Pond area of the Kennebec River. KELT provided data to GEI from a water level logger deployed on the ocean side of Parker Head Road to collect water elevations every 6 minutes over a 49-day period. We selected two different boundary conditions to use with the model's design storm events. One boundary condition represented a tide cycle where the highest tide elevation matched that of the area's MHHW elevation (4.52 feet). We used NOAA's VDatum tool to identify the MHHW elevation in the NAVD88 vertical datum. The elevation within KELT's dataset that most closely matched that of VDatum's MHHW value was 4.55 feet. The second boundary condition (referred to in this study as the "extreme tide") represented the tide cycle with the highest elevation present in the 49-day dataset (7.40 feet). Both boundary conditions (MHHW and extreme tide) were input as a time series that spanned a 36.6-hour tide cycle. The peak water surface of the two boundary conditions differed by 2.85 feet. Using two different tidal events allowed us to evaluate how tide cycles and tidal elevations influenced the inundation duration and peak water surface elevations at Sam Day Hill Road for the range of rain events.

Precipitation was applied across the entire 2D flow area of the 2.5-square-mile watershed. The total precipitation estimates over a 24-hour period for the 10-, 25-, 50-, and 100-year annual recurrence intervals were obtained from the Northeast Regional Climate Center (NRCC) website using the low-point of Sam Day Hill Road as the point of interest (NRCC, 2024). Table 4-5 shows the precipitation estimates for each recurrence interval used in the model.

Table 4-5. Estimates for 24-hour Precipitation Events

Recurrence Interval	Precipitation Estimate (Inches)
10-year	4.59
25-year	5.67
50-year	6.67
100-year	7.85

The values in Table 4-5 were then applied to the NRCC dimensionless distribution curves to calculate the rainfall in 6-minute increments.

4.6. Culvert Crossings

Structures were built within the model to represent the geometry of culverts and conveyance openings of other stream crossings. Culvert invert elevations recorded during the survey were directly input into the model. Other culvert parameters included culvert length, material, slope, Manning’s n-value, and entrance and exit loss coefficients.

5. HEC-RAS Model Calibration

Model calibration was performed to demonstrate the model can reasonably replicate observed stream and pond conditions. The process involved comparing simulated model results with observed conditions and assessing what, if any, model input(s) warranted refining to more accurately align with observed conditions.

5.1. Selection of Calibration Storm

To select a candidate storm for calibration, we reviewed precipitation data for the watershed from Weather Underground (https://www.wunderground.com/) – a website containing meteorological data from a network of weather stations maintained by members with personal weather stations (WU, 2024). We reviewed and selected the largest precipitation event recorded during the period of deployment of KELT's water level loggers. Data from multiple weather stations were cross referenced to eliminate outliers and ensure that the precipitation event affected the whole watershed. The storm between December 10 and December 12, 2023 was selected for model calibration. Precipitation depths for this event totaled about 1.9 in.

5.2. Precipitation Data

To accurately model an observed storm event, it is critical to have reliable, high resolution precipitation data. During a storm event, precipitation intensity and duration can vary significantly from one end of a watershed to the other. GEI elected to use gridded rainfall data to simulate the recorded storm event of interest in the HEC-RAS Model. The gridded data can capture temporal and spatial variability of observed storms allowing for more accurate results compared to average basin methods where precipitation would typically be averaged across the entire watershed.

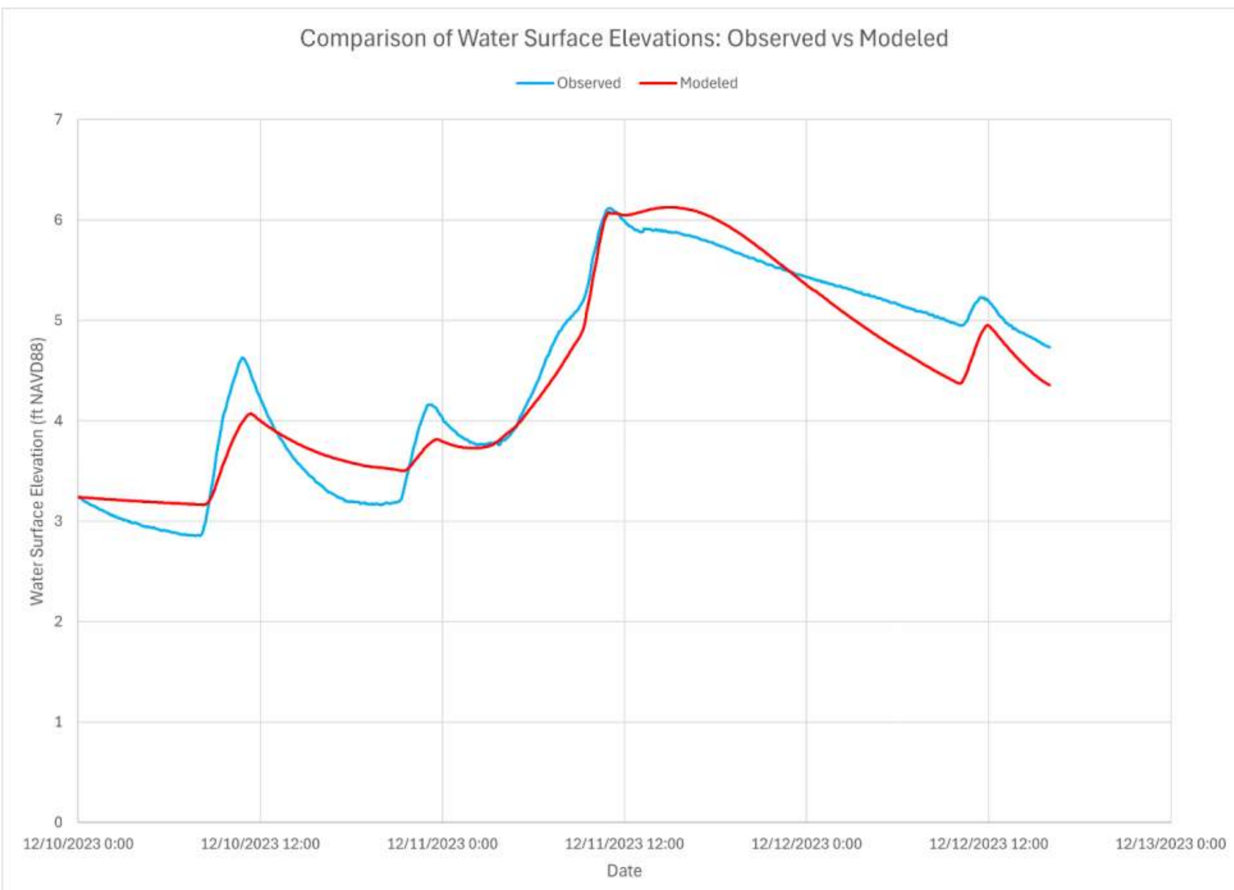
Multi-Radar Multi-Sensor (MRMS) – a system originally developed by NOAA's National Severe Storms Laboratory (NSSL) – produces gridded precipitation data as a time series. The automated system compiles data from Next Generation Weather Radar (NEXRAD) stations, satellite observations, and numerical weather prediction models to generate gridded data records for the United States.

The MRMS data for this project was downloaded from Iowa State University's Iowa Environmental Mesonet (IEM) as Multi-Sensor Quantitative Precipitation Estimation (QPE) Pass 2 data (NOAA NSSL, 2023). The dataset was downloaded in GRIB file format and represented 1-hour precipitation estimates at an approximate 1100x900-meter grid resolution. GEI used U.S. Army Corps of Engineers HEC Hydrologic Modeling System (HEC-HMS) version 4.12 (USACE, 2024a) to convert the raw gridded precipitation data into a Data Storage System (DSS) file for input to HEC-RAS. The precipitation files were projected to align with the hydraulic model's coordinate system and time zone and were clipped to the Parker Head Creek watershed boundary.

5.3. Model Calibration Results

Rainfall runoff modeling can be considered reliable if the model can reasonably replicate observed stream and pond conditions. As mentioned in Section 5.1, we simulated a storm that took place between December 10 and December 12, 2023 and compared model results with readings from the water logger just upstream of Parker Head Road. Figure 5-1 shows a graph comparing the water surface elevations of the observed conditions (water logger) and the model. The calibration model used the MRMS rainfall data applied as a spatial time series over the watershed and the time series of the water surface elevations from the water logger data downstream of Parker Head Road as the downstream boundary condition. Overall, the general shape of the water surface elevations of the observed and modeled conditions are similar. The model appears to pick up the influence of the tides until flows from the precipitation event exceed the influence of the tides for the peak runoff at about 12:00 on December 11. The peak water surface elevations compared very well with both the observed and simulated reaching a peak water surface at elevation 6.1 feet.

Figure 5-1. Graph Comparing Observed and Modeled Water Surface Elevations



6. Results

The HEC-RAS model results were extracted from RAS Mapper (the HEC-RAS model viewer). For inundation results at Sam Day Hill Road, we selected the low point on the road (i.e., where the road surface was at elevation 7 feet) and compared the road surface elevation with the maximum water surface elevation during each of the model scenarios to calculate the maximum inundation depth. The maximum water surface was also used to develop a maximum inundation extent (i.e., in plan view). We used this maximum extent to calculate the maximum length of road inundated from each scenario. We then reviewed the duration of flooding and determined the maximum amount of time the road was inundated during the 36.6-hour tide cycle of each model scenario.

6.1. MHHW and Extreme Tide Downstream Boundary Conditions

The scenarios in the model included the 10-, 25-, 50-, and 100-year precipitation events for two downstream boundary conditions: normal tide cycle and extreme tide cycle. We initially expected that the inundation results (maximum water surface elevation, maximum inundation extent, and duration of inundation) would differ based on the downstream boundary conditions. For example, we anticipated the 10-year precipitation event during the normal tide cycle would produce lower water surface elevations than the 10-year precipitation event during the extreme tide cycle. However, the downstream boundary condition did not impact the overall inundation results for the rain scenarios evaluated. This topic is further discussed in Section 7.

6.2. Inundation Results

Table 6-1 and Figure 7 show the inundation results for the model scenarios. The extreme tide alone (no precipitation) resulted in Sam Day Hill Road not being inundated. However, even during the smallest storm modeled (10-year), Sam Day Hill Road was inundated by approximately 2.9 feet at the lowest section of the road. The low-lying section of the road was inundated along a length of about 600 feet (i.e., flood depths greater than 0 feet). The lowest part of the road was inundated for about 17 hours and 18 minutes.

The largest storm modeled (100-year) resulted in a maximum depth of 5.7 feet, a maximum inundation length of approximately 730 feet, and an inundation duration of 22 hours and 42 minutes at the lowest part of Sam Hill Dam Road. As mentioned in Section 6.1, the peak water surface elevations at Sam Hill Day Road were similar regardless of the tidal scenario (i.e., MHHW or extreme tide).

In addition, Parker Head Road was overtopped in the 25-, 50-, and 100-year scenarios by depths of 1.3, 1.7, and 2.0 feet, respectively.

Table 6-1. Inundation Results for Model Scenarios

Scenario	Maximum Inundation Depth (ft)	Maximum Inundation Length (ft)	Inundation Duration (hh:mm)
Extreme Tide Alone	0	0	00:00
10-Yr	2.9	600	17:18
25-Yr	4.8	700	20:12
50-Yr	5.3	715	21:24
100-Yr	5.7	730	22:42

6.3. Velocity Results

High flow velocities, especially adjacent to earthen embankments, have the potential to cause significant erosion. One area along Sam Day Hill Road exhibits this issue. Figure 6-1 shows two corrugated high-density polyethylene (HDPE, or plastic) culverts that run underneath the driveway of a private residence just uphill of the low-lying section of Sam Day Hill Road. Water that passes through these culverts then channels downhill and alongside Sam Day Hill Road, as shown in Figure 6-2.

This study was not intended to fully evaluate velocity, erosion, and/or scour. We recommend additional work and modeling be performed to evaluate these conditions since sometimes lower rainfall events without coincident peak tidal water surface elevations can sometimes cause the worst erosion.

Figure 6-1. Photo of Culverts Under Driveway

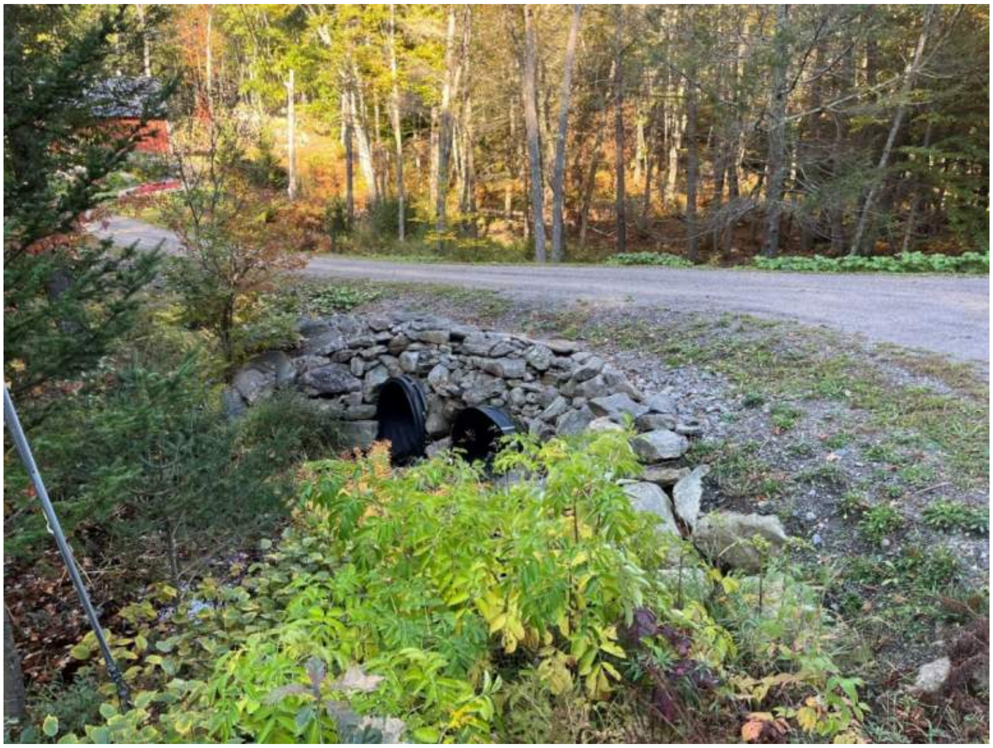


Figure 6-2. Photo of Channel Downstream of Driveway Culverts

Figure 6-2 is the location where the flow velocities were the highest in the model. Table 6-2 below provides the maximum velocity for each model scenario. The visual representation of these results is in Figure 8.

Table 6-2. Velocity Results for Model Scenarios

Scenario	Maximum Velocity (ft3/s)
Extreme Tide Alone	NA
10-Yr	11.4
25-Yr	12.1
50-Yr	12.6
100-Yr	13.5

7. Discussion

Sam Day Hill Road has a history of flooding. The road is adjacent to Parker Head Creek and the road surface at its low-lying section is roughly at elevation 7 feet, 2 feet lower than the Base Flood Elevation (BFE) (1% annual chance storm) mapped by FEMA. FEMA's mapping represents coastal analysis and does not include the addition of riverine flooding from Parker Head Creek. The results of the scenarios in GEI's H&H model show the road is likely more prone to flooding from precipitation events than what is indicated by FEMA maps, which were developed from coastal analysis.

As mentioned in Section 6.1, there was no significant difference between peak water surface elevations along Sam Day Hill Road when the downstream boundary condition was input as the MHHW tide cycle or the extreme tide cycle. At the time of this study, the culvert under Parker Head Road was a 72-inch-diameter corrugated metal pipe. Our analysis indicated that this culvert is limiting conveyance of both sea water and stormwater and may be exacerbating conditions at Sam Hill Day Road.

The timing of the peak precipitation relative to the tide cycle also had no difference in peak water surface elevations along Sam Day Hill Road. We ran models with the peak flow occurring at the same time as the peak tide, as well as peak flow occurring at the low end of the tide cycle. In both scenarios the culvert underneath Parker Head Road, serving as the only outlet, was quickly overwhelmed and required multiple tide cycles to fully drain the ponded flood waters. Therefore, the tide cycles did not appear to adversely influence the peak water surface elevations at Sam Day Hill Road.

The inundation results from the 24-hour, 10-, 25-, 50-, and 100-year annual recurrence interval storm scenarios represented a useful suite of existing conditions on which road and/or culvert modifications can be evaluated. These rainfall events are commonly used to evaluate culverts and bridges. Some combination of road elevation and culvert modification would likely improve the vulnerability of Sam Day Hill Road. GEI evaluated one conceptual culvert replacement scenario in the following section. Culvert and bridge sizing also evaluate the flood of record and the 500-year event. While the scenarios evaluated for this study are sufficient for the purpose, more detailed design evaluations will also warrant consideration of flows for the flood of record and 500-year event when evaluating potential road overtopping and sizing conveyance structures.

7.1. Culvert Replacement Modification

To understand the impact modifying culverts might have on flooding at Sam Day Hill Road, GEI developed a model for "proposed conditions" that maintained Sam Day Hill Road at its current elevation but replaced the culverts on Parker Head Creek with concrete box culverts as shown in Table 7-1 below.

Table 7-1. Box Culvert Replacement Configurations

Current Culvert(s) Configuration	Replaced Box Span (ft)	Replaced Box Rise (ft)
Two 48 in HDPE culverts (driveway)	16	6
One 72 in concrete culvert (Sam Day Hill Road)	20	7
Four 30 in corrugated metal culvert (Sam Day Hill Road)	20	4.25
One 72 in corrugated metal culvert (Parker Head Road)	20	7

It is important to note that the box culvert configurations in the model were used to maximize hydraulic connectivity. In some instances, the top of the box culvert was close to the road surface elevation and may not be appropriate. The culvert modifications were merely an experiment to understand their impact on inundation results, shown in Table 7-2 below.

Table 7-2. Sam Hill Day Road Inundation Results for Model Scenarios with Box Culvert Replacements

Scenario	Maximum Inundation Depth (ft)	Maximum Inundation Length (ft)	Inundation Duration (hh:mm)
10-Yr	0.6	415	02:06
25-Yr	0.8	500	03:18
50-Yr	1.0	545	07:18
100-Yr	1.5	675	10:24

The results in Table 7-2 show that the maximum inundation depth, maximum inundation length, and inundation duration were all reduced for each scenario when the current culverts were replaced by box culverts. For example, the maximum inundation depth for the 100-year scenario was less than 2 feet, while the same scenario with current culvert configuration was 5.7 feet and almost 3 feet for the 10-year scenario and current culvert configuration. In addition, Parker Head Road was not overtopped in any of the scenarios. A visual representation of the results is in Figure 9. These results provide some initial helpful considerations for future modeling of potential road and culvert improvements.

7.2. Recommendations

Rising sea levels and increases in the intensity and frequency of precipitation events will continue to threaten Sam Day Hill Road. Each time the road floods and flood waters recede, more of the road is washed out into the ponds on either side of the low-lying road section. This not only lowers the road elevation but causes the ponds to fill with material, reducing pond storage. Overtime, the road will continue to become more vulnerable to the next flooding scenario.

GEI recommends the Town further investigate road and culvert improvements that will reduce the vulnerability of Sam Day Hill Road. Costs of replacing the culverts will vary depending on the dimensions and materials. Elevating the road would likely be an expensive measure and could require embankment stabilization to withstand future events. These improvements should be weighed against the threats to achieve long term risk reduction. The Town could then use this information to make an informed decision about mitigation projects that balance costs, benefits, and risk.

Some culvert replacement projects, especially those that seek to address stream discontinuity and watershed improvement, may be applicable for grant-funded assistance. GEI recommends identifying potential funding avenues while improvements are also being explored. The Coastal Communities and GOPIF grants continue to be excellent resources for resiliency-based funding. Given that Sam Day Hill Road is an important local road with implications for delayed emergency services when it is flooded, there may be grant assistance for projects that improve public safety.

While design and construction to improve Sam Day Hill Road may be prevented or delayed by the eventual costs, additional modeling could help identify short duration (more frequent) storms that would likely inundate the road. This information could then be used to post information online (Town website, Facebook, etc.) to warn travelers when a current precipitation event may have the potential to flood Sam Day Hill Road.

8. Limitation of Liability

This report presents analyses and results of a site-specific hydrologic and hydraulic study of the Parker Head Creek watershed. GEI developed a hydrologic and hydraulic model of the Parker Head Creek watershed to evaluate flood conditions during the 24-hour, 10-, 25-, 50-, and 100-year annual recurrence interval storm events. The hydrologic and hydraulic model was created using GEI's engineering judgment. The work aimed to be comprehensive and conservative in the development of infiltration rates, design storm precipitation, and other parameters presented in this study. The assumptions are consistent with standard methods for developing information on design storms.

For modeling of design storms, antecedent moisture conditions were assumed to be fully saturated (i.e. the ground was assumed to be fully wet prior to the storm event). Initial loss, the amount of precipitation lost to ground infiltration at the start of the storm event, was assumed to be 0. This is a conservative assumption that results in greater runoff. If a storm event occurs in the watershed, actual conditions, peak flows, and peak water surface elevations will vary from those presented in this report.

This study included limited hydraulic analysis and does not include an evaluation of the structural integrity of roads, culverts, bridges, and/or other appurtenances. Because the methods, procedures, and assumptions used to develop the analysis are approximate, the results should be used only as guidance.

The HEC-RAS model was developed to provide reasonably accurate results along the lower section of Parker Head Creek. With any complex hydraulic model, a balance must be struck between model stability, accuracy, and run-time speed. GEI structured the model so that flood conditions could be estimated with reasonable accuracy in locations where needed while still maintaining optimal model performance. Use of the model to extrapolate results from locations not prioritized in this study including tributaries and un-surveyed culverts may provide comparatively less accurate results.

The hydraulic model was developed and calibrated to evaluate watershed characteristics for the storm events presented. Assessing Parker Head Creek and its tributaries under low flow conditions, non-coincident precipitation and tidal conditions, or different tidal or sea level scenarios was not the objective of this study. Evaluation of Parker Head Creek under different conditions would require calibration and additional analyses.

Reuse of this report for any other purposes, in part or in whole, is at the sole risk of the user.

9. References

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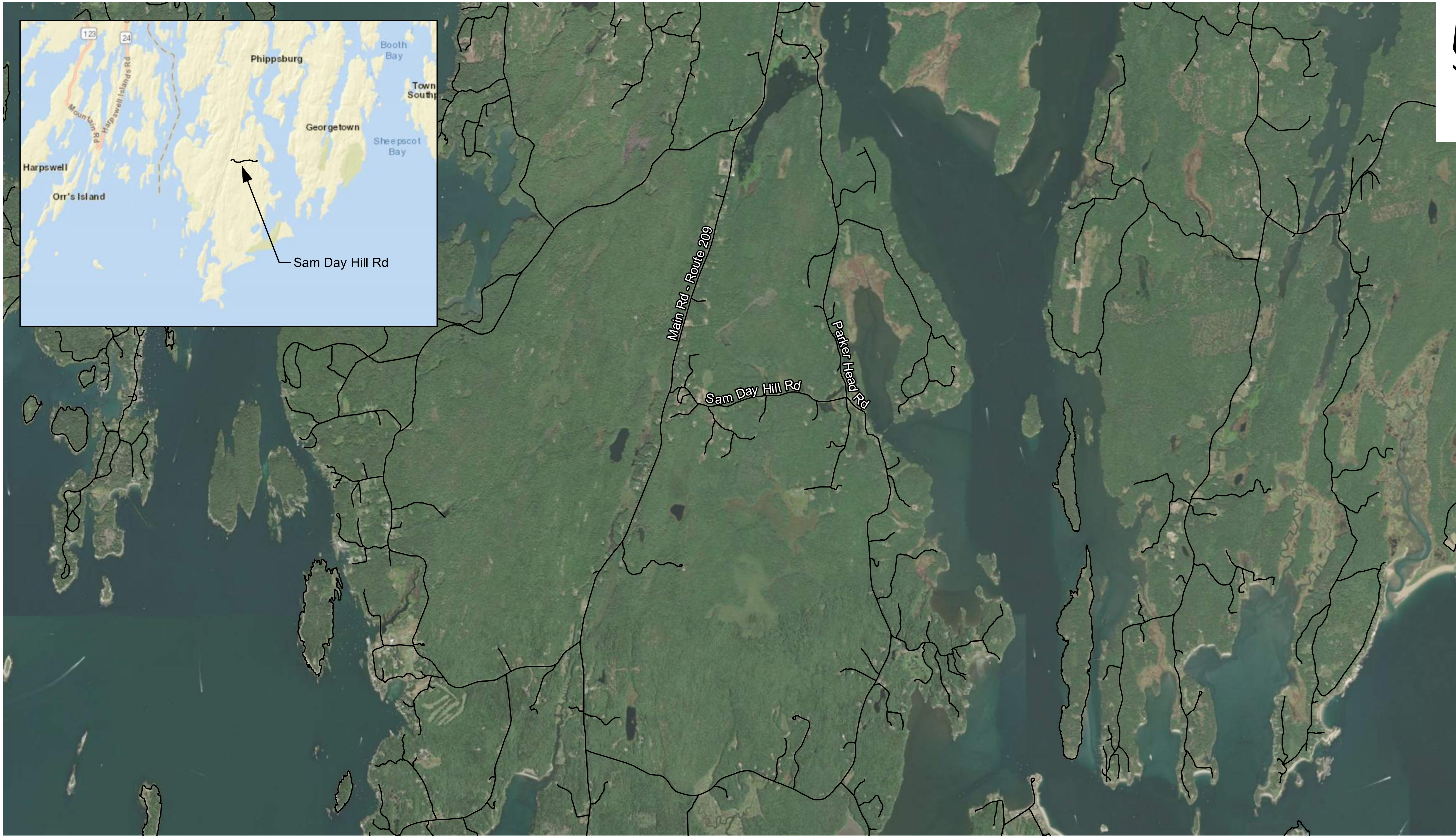
Figures



LEGEND:

—— Road

0 3,000 6,000

Feet

SOURCE:
1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Imagery (ESRI, 2020-2022).

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

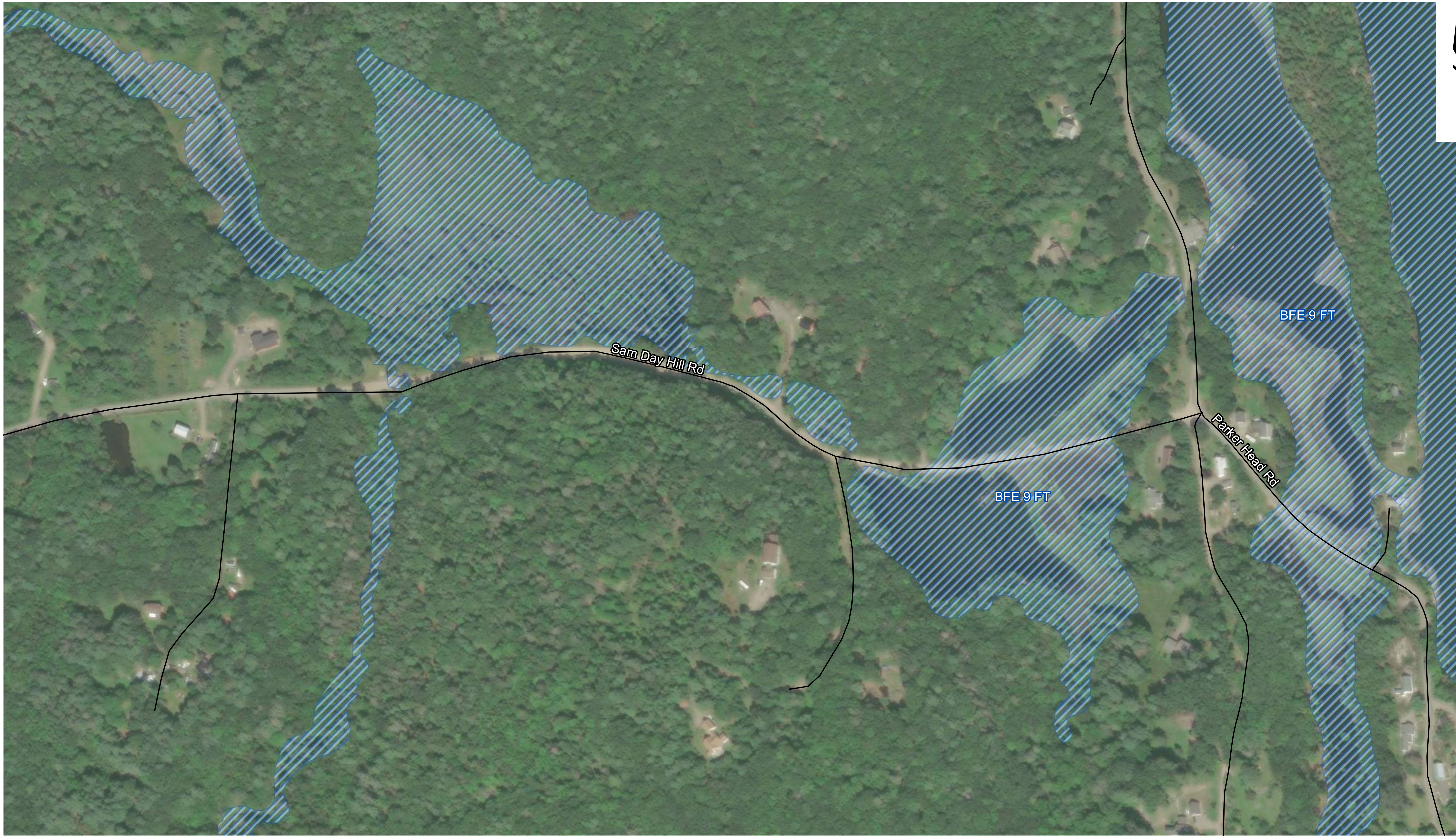
GEI Consultants

PROJECT LOCATION

Project 2306025 | September 2024 | Fig. 1

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Project_Location.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,



LEGEND:

Road

FEMA 1% Annual Chance Storm Inundation

SOURCE:

1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. FEMA layer effective 7/16/2015 and accessed 5/15/2024.
3. Imagery (ESRI, 2020-2022).

0 250 500
Feet

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

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Project 2306025

FEMA 1-PERCENT ANNUAL CHANCE INUNDATION BOUNDARY

September 2024

Fig. 2

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\FEMA_Boundary.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,

LEGEND:

- Surveyed Elevation Location
- Road

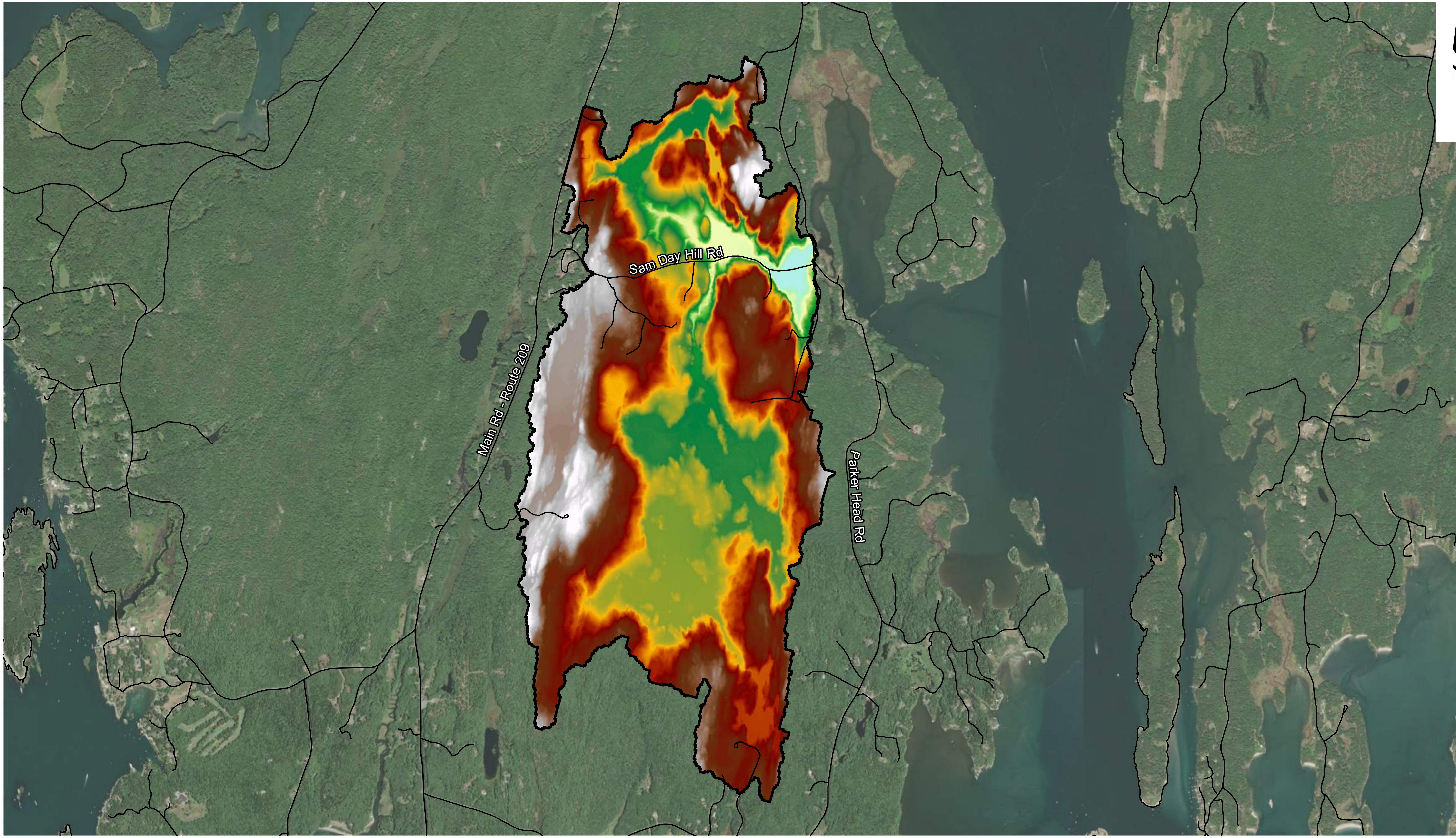
SOURCE:
1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Locations surveyed by Sacket and Brake Survey, Inc. (3/1/2024).
3. Imagery (ESRI, 2020-2022).

0 250 500
Feet

Sam Day Hill Road Hydrology & Hydraulics Study Phippsburg, Maine	GEI Consultants	SURVEYED ELEVATIONS
Town of Phippsburg Phippsburg, Maine	Project 2306025	September 2024 Fig. 3

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Surveyed_Elevations.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,



LEGEND:

Road

Watershed

Digital Elevation Model (DEM)

FT (NAVD88)

High : 160.09

Low : 2.05

SOURCE:

1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Watershed developed using StreamStats (USGS, 2023).
3. Imagery (ESRI, 2020-2022).

0 1,000 2,000

Feet

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

GEI Consultants

WATERSHED DIGITAL ELEVATION MODEL (DEM) ELEVATIONS

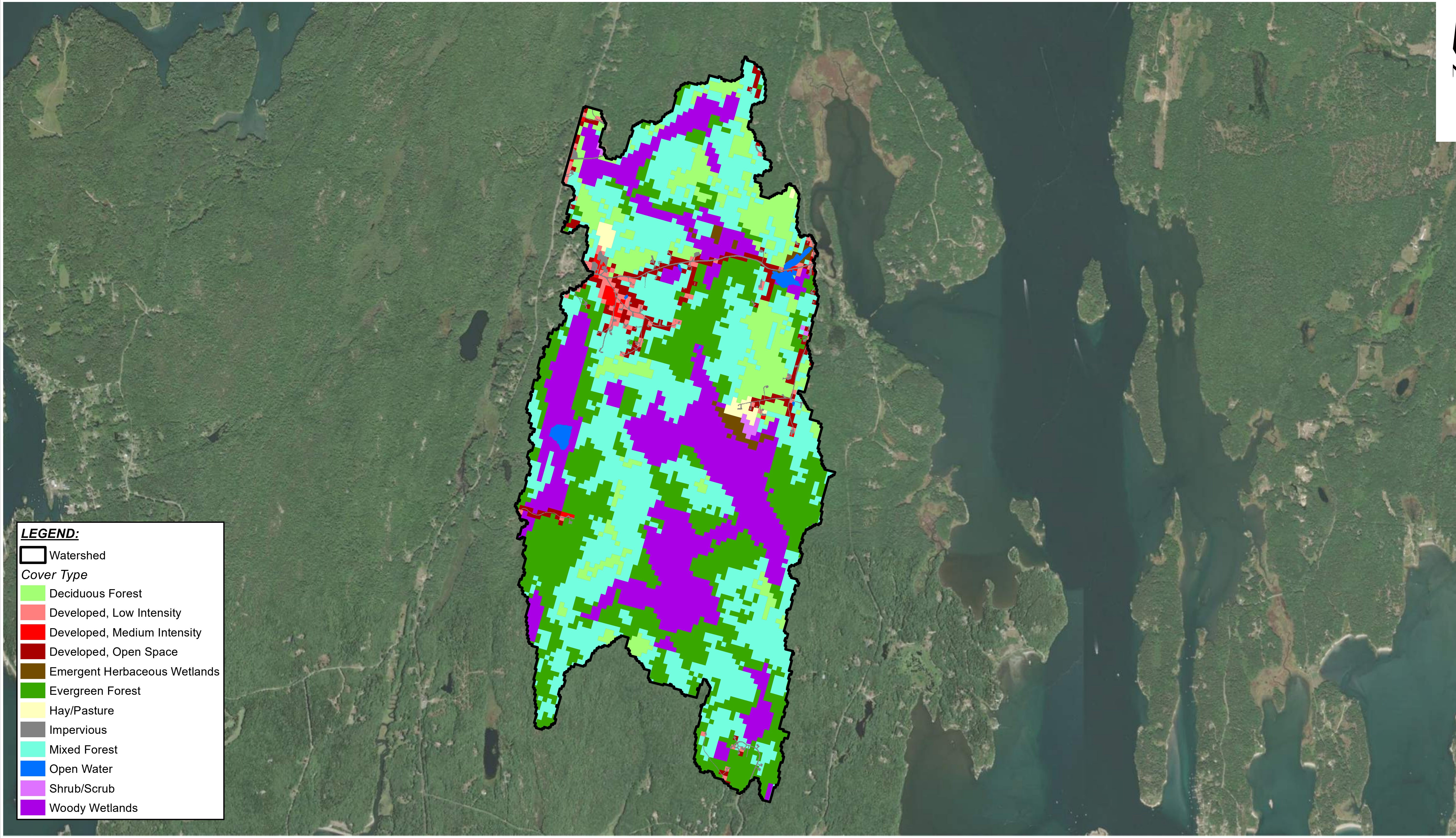
Project 2306025

September 2024

Fig. 4

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Terrain.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,



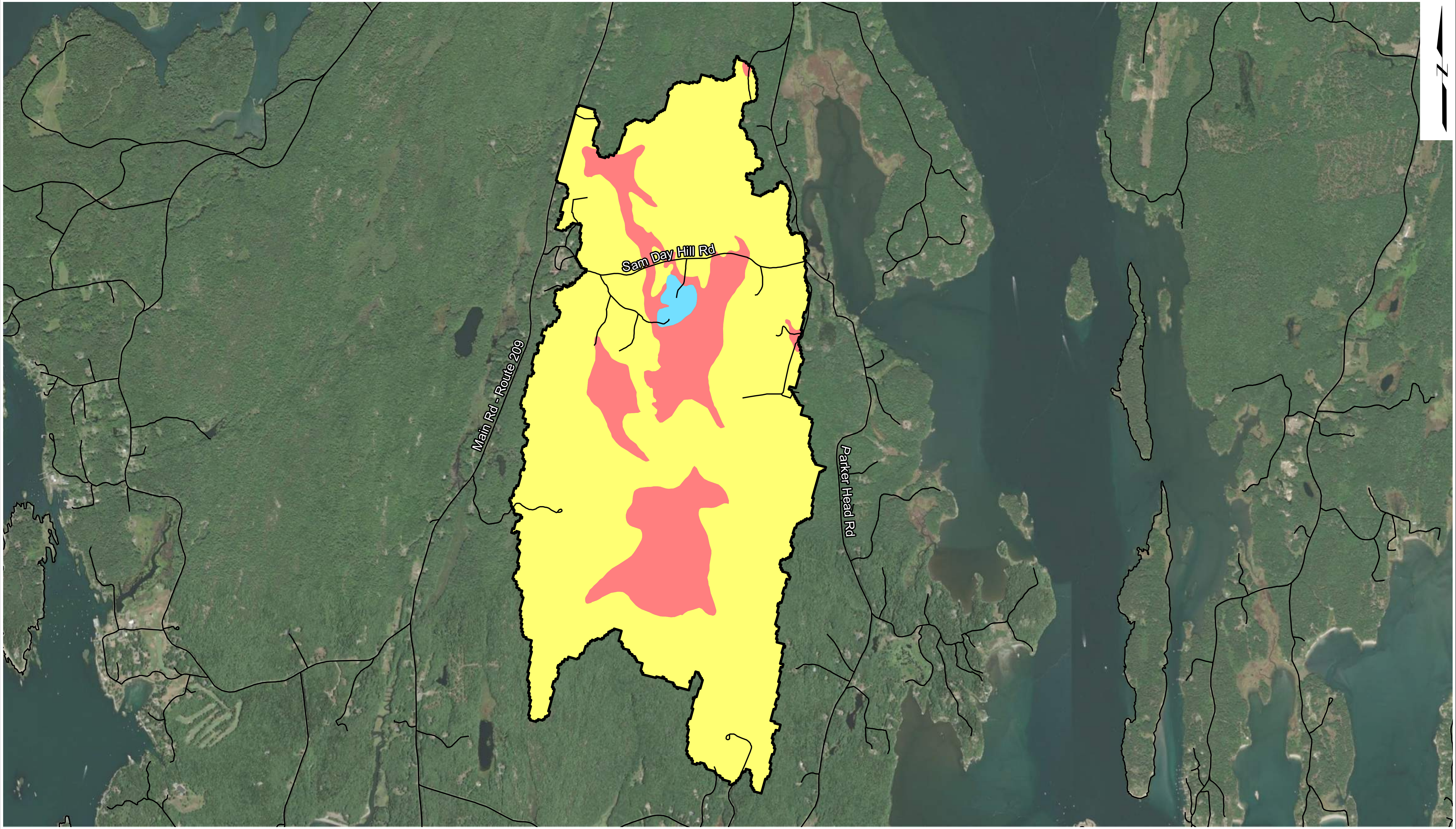
SOURCE:
1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Watershed developed using StreamStats (USGS, 2023).
3. Land Cover (USGS, 2021).
4. Imagery (ESRI, 2020-2022).

0 1,000 2,000
Feet

Sam Day Hill Road Hydrology & Hydraulics Study Phippsburg, Maine	GEI Consultants	WATERSHED LAND COVER
Town of Phippsburg Phippsburg, Maine	Project 2306025	September 2024 Fig. 5

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Land_Cover.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,



LEGEND:

Road

Watershed

Hydrologic Soil Group

A

C

D

SOURCE:

1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Watershed developed using StreamStats (USGS,2023).
3. Soil groups (NRCS, 2023).
4. Imagery (ESRI, 2020-2022).

0 1,000 2,000

Feet

Sam Day Hill Road Hydrology & Hydraulics Study Phippsburg, Maine	GEI Consultants	WATERSHED HYDROLOGIC SOIL GROUP
Town of Phippsburg Phippsburg, Maine	Project 2306025	September 2024 Fig. 6

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Soils.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,

LEGEND:

- Road
- Extreme Tide Alone
- 10-Year
- 25-Year
- 50-Year
- 100-Year

SOURCE:
1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Inundation boundaries based on HEC RAS 2-D model results.
3. Imagery (ESRI, 2020-2022).

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

GEI Consultants

Project 2306025

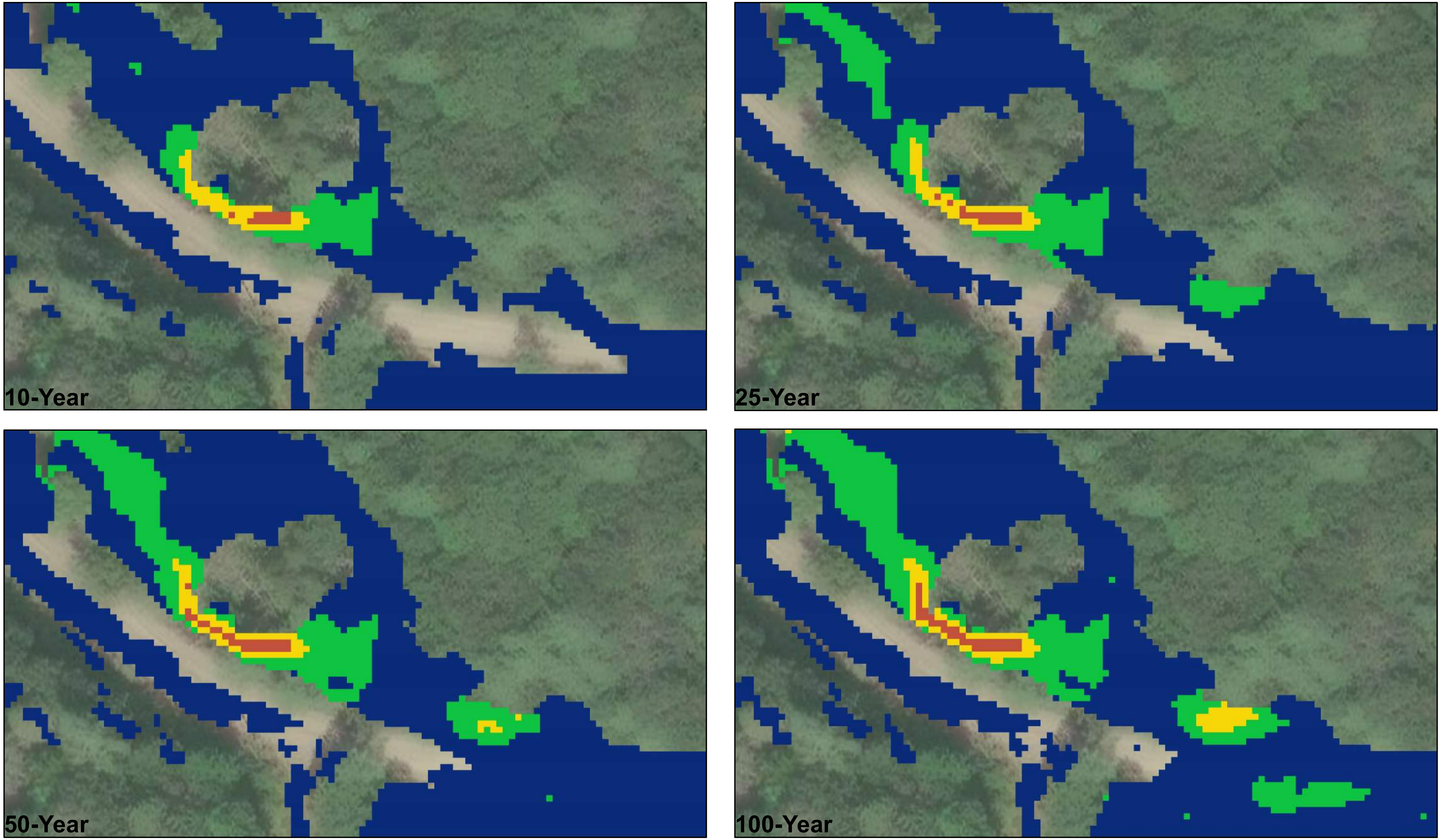
HEC-RAS H&H
2-D MODEL
INUNDATION RESULTS

September 2024

Fig. 7

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Inundation_Results.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,



LEGEND:

Velocity (cf/s)
- 0.1 - 4
- 4 - 8
- 8 - 12
- 12 - 16

0 50 100
Feet

SOURCE:
1. Velocities based on HEC RAS 2-D model results.
2. Imagery (ESRI, 2020-2022).

Sam Day Hill Road Hydrology & Hydraulics Study Phippsburg, Maine	GEI Consultants	HEC-RAS H&H 2-D MODEL VELOCITY RESULTS
Town of Phippsburg Phippsburg, Maine	Project 2306025	September 2024 Fig. 8

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Velocity_Results.mxd

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

LEGEND:

- Road
- 10-Year with Box Culverts
- 25-Year with Box Culverts
- 50-Year with Box Culverts
- 100-Year with Box Culverts

SOURCE:
1. Roads layer accessed via ArcGIS Online (updated 4/24/2024).
2. Inundation boundaries based on HEC RAS 2-D model results.
3. Imagery (ESRI, 2020-2022).

0 150 300
Feet

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

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Project 2306025

HEC-RAS H&H
2-D MODEL (MODIFIED)
INUNDATION RESULTS

September 2024

Fig. 9

B:\Working\PHIPPSBURG, TOWN OF\2306025 Sam Day Hill Rd H_H Study\05_GIS\Inundation_Results_Box_Culverts.mxd

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI,

Appendix A Curve Numbers and Associated Abstraction Ratios

Curve Number

Land Cover Description from GIS	Class Number		Hydrologic Soil Group (HSG)				Other
			A	B	C	D	
NoData	0	NoData					
255	1	255					
0 (2ft depth from run to obtain high res. water areas)	2	0 (2ft depth from run to obtain high res. water areas)	98	98	98	98	98
Dirt (road)	3	Dirt (road)	72	82	87	89	89
Pavement (road)	4	Pavement (road)	74	84	90	92	92
Open Water	11	n/a	98	98	98	98	98
Developed, Open Space	21	Open space, good	39	61	74	80	80
Developed, Low Intensity	22	Residential, 1/2 ac lots	54	70	80	85	85
Developed, Medium Intensity	23	Residential, 1/4 ac lots	61	75	83	87	87
Developed, High Intensity	24	Urban, commercial	89	92	94	95	95
Barren Land Rock-Sand-Clay	31	Open space, poor	68	79	86	89	89
Deciduous Forest	41	Woods, good	30	55	70	77	77
Evergreen Forest	42	Woods, good	30	55	70	77	77
Mixed Forest	43	Woods, good	30	55	70	77	77
Shrub-Scrub	52	Brush, good	30	48	65	73	73
Grassland-Herbaceous	71	Brush, good	30	48	65	73	73
Pasture-Hay	81	Meadow	30	58	71	78	78
Wood Wetlands	90	n/a	86	86	86	86	86
Emergent Hebaceous Wetlands	95	n/a	80	80	80	80	80

Abstraction Ratio

Land Cover Description from GIS	Class Number		Hydrologic Soil Group (HSG)				No Data
			A	B	C	D	
NoData	0	NoData	0.00	0.00	0.00	0.00	0.00
255	1	255	0.00	0.00	0.00	0.00	0.00
0 (2ft depth from run to obtain high res. water areas)	2	0 (2ft depth from run to obtain high res. water areas)	0.04	0.04	0.04	0.04	0.04
Dirt (road)	3	Dirt (road)	0.78	0.44	0.30	0.25	0.25
Pavement (road)	4	Pavement (road)	0.70	0.38	0.22	0.17	0.17
Open Water	11	n/a	0.04	0.04	0.04	0.04	0.04
Developed, Open Space	21	Open space, good	3.13	1.28	0.70	0.50	0.50
Developed, Low Intensity	22	Residential, 1/2 ac lots	1.70	0.86	0.50	0.35	0.35
Developed, Medium Intensity	23	Residential, 1/4 ac lots	1.28	0.67	0.41	0.30	0.30
Developed, High Intensity	24	Urban, commercial	0.25	0.17	0.13	0.11	0.11
Barren Land Rock-Sand-Clay	31	Open space, poor	0.94	0.53	0.33	0.25	0.25
Deciduous Forest	41	Woods, good	4.67	1.64	0.86	0.60	0.60
Evergreen Forest	42	Woods, good	4.67	1.64	0.86	0.60	0.60
Mixed Forest	43	Woods, good	4.67	1.64	0.86	0.60	0.60
Shrub-Scrub	52	Brush, good	4.67	2.17	1.08	0.74	0.74
Grassland-Herbaceous	71	Brush, good	4.67	2.17	1.08	0.74	0.74
Pasture-Hay	81	Meadow	4.67	1.45	0.82	0.56	0.56
Wood Wetlands	90	n/a	0.33	0.33	0.33	0.33	0.33
Emergent Hebaceous Wetlands	95	n/a	0.50	0.50	0.50	0.50	0.50

Sam Day Hill Road
Hydrology & Hydraulics Study
Phippsburg, Maine

Town of Phippsburg
Phippsburg, Maine

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CURVE NUMBERS AND ASSOCIATED ABSTRACTION RATIOS

September 2024