Report for **Trinidad ASBS Stormwater Project**

Groundwater Model Technical Report

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1. Introduction

1.1 Background

The City of Trinidad ("City") is undertaking the Trinidad ASBS Stormwater Improvement Project ("Project") to make improvements to the municipal stormwater drainage system. The City's existing stormwater system was constructed in the early 1970's. The system discharges to a single 32-inch stormwater outfall (State Board identification: TRI032), which discharges just south of the boat launch at Trinidad Head to Trinidad Bay, as shown on Figure A-1, in Appendix A. The current system is designed to capture and convey runoff to the outfall and does not incorporate modern retention, treatment, or infiltration features.

Trinidad Bay is designated as an Area of Special Biological Significance (ASBS). It is one of 34 ASBS ocean areas monitored and maintained for water quality by the State Water Resources Control Board. ASBS designated areas cover much of the length of California's coastal waters. They support an unusual variety of aquatic life and often host unique individual species. Trinidad Bay was designated as an ASBS in part because of the fluctuating presence of bull kelp (Nereocystis luetkeana), which are considered biologically significant in providing an ecological base for fish and invertebrate habitats by supplying food and shelter. All ASBS designated areas may be adversely affected by polluted stormwater discharges, which could damage their unique ecosystems.

The long term goal of the City in implementing the Project is to help protect the ASBS by making improvements to the stormwater drainage system including implementation of Low Impact Development Best Management Practices (LID/BMPs) to capture, treat, and infiltrate stormwater runoff from rainfall events. This Report presents results of the development and calibration of a hydrologic model and groundwater model to evaluate the effects of different infiltration scenarios on the local geology including groundwater, local bluffs, and streams. This Report builds on the work, *Geotechnical Analysis* (GHD 2012), completed as part of the City's ASBS Stormwater Improvement Project.

1.2 Project Area

The Project is generally located within the City limits of Trinidad, Humboldt County, California and is shown on Figure A-1 in Appendix A. The City is located in rural northern California, approximately 25 miles from the county seat of Eureka and 300 miles from San Francisco. The community has a population of approximately 1,000 people with approximately 350 living within the City limits.

Much of the urban area overlies a fairly uniform fine sand aquifer, which in turn overlies low permeability Franciscan melange (bedrock). The Project area is bounded by Mill Creek in the North, Parker Creek to the East, and Highway 101 to the Northeast. The Project area is also bounded by coastal bluffs and the Pacific Ocean and Trinidad Bay along the west and south. The groundwater model study area covers approximately 228 acres.

The City has a rudimentary and aging stormwater network which discharges stormwater runoff through an outfall pipe to Trinidad Bay and the Pacific Ocean. Water quality within the ASBS could be impacted by pollution from a number of sources, including, urban runoff from City roads, private parcels, and pets, among other sources. As such, the City is moving towards eliminating its direct stormwater discharge into the ASBS through a series of alternative stormwater management practices.

1.3 Project Purpose and Objectives

The purpose of this portion of the Project is to develop a calibrated groundwater model which can be used to assess the effects of stormwater infiltration design alternatives on the groundwater system, with consideration of the local onsite septic systems and adjacent bluffs.

The objective of this portion of the Project is to configure and calibrate a groundwater model which accurately incorporates the local geology and inputs from surface hydrology, septic systems, and other sources based on geologic and groundwater data collected. The calibrated model then provides the ability to assess the groundwater-related effects of stormwater infiltration design alternatives. The groundwater model builds on the findings from the *Geotechnical Analysis* (GHD 2012) and aims to further delineate groundwater flow paths, quantify groundwater flow velocities and directions, and provide the ability to evaluate potential effects of stormwater Best Management Practices on groundwater patterns in the marine terrace aquifer. This Report has been structured to provide sufficient detail on the model set-up and calibration and simulation of the design scenarios to develop the stormwater infiltration alternatives.

2. Geologic Setting

This section presents a review of the key geologic features in the Project area, which were incorporated into the groundwater model.

2.1 Geology

A review of available geological and hydrogeological information documented in the *Geotechnical Analysis* (GHD 2012) was performed with a brief summary of the key features provided below.

The geology of the study area consists of:

- A ‘layercake’ of Pleistocene marine terrace deposits generally composed by medium to well graded silty sands, which is;
- Underlain by Mesozoic Franciscan Complex bedrock, consisting of a melange of sandstones, greywacke, limestone, various igneous and metamorphic units.

For a more complete description of the area refer to the information presented in the *Geotechnical Analysis* (GHD 2012).

2.1.1 Soil Borings

A total of 18 soil borings (identified as SB-1 to SB-18) were drilled across the study area to varying depths to provide an indication of the depth to bedrock and the terrace stratigraphy (see Appendix A, Figure A-2). The depth to bedrock recorded at the soil borings was used to refine the bedrock elevation surface across the study area, developed as part of the *Geotechnical Analysis* (GHD 2012).

The stratigraphy in the upper 3 to 5 feet of the surface is characterized by loose to compacted disturbed and mixed fill materials of imported river gravel, sand, and silt. Underlying the upper fill and silty sand layer, the majority of the subsurface materials encountered were generally dominated by loose, poorly graded, fine and medium-grained sand down to bedrock.

2.1.2 Geophysical Investigations

Geophysical investigations were conducted along 4 linear transects in the project area to further characterize the subsurface, including the location of bedrock surface and thickness of the marine terrace materials. Seismic reflection and electrical resistivity data were collected and analyzed along each transect, where the transect lines are shown on Figure A-2 (see Appendix G of *Geotechnical Analysis* (GHD 2012) for further detail). The paleochannel features identified along the transects in the geophysical investigations were used in conjunction with the interpreted bedrock elevation surface to infer the presence of:

- Channel features within the bedrock surface; and
- Coarser-grained facies, channel deposits, within the marine terrace deposits.

2.2 Hydrogeology

An understanding of the hydrogeology of the area is required to conceptualize and configure any groundwater model and support the predictive design scenarios. A review of available geological and hydrogeological information documented in *Geotechnical Analysis* (GHD 2012) was conducted to develop an understanding of the local subsurface system. A brief summary of the key hydrogeological features used to develop the groundwater model is provided below. Refer to *Geotechnical Analysis* (GHD 2012) for a full description of the hydrogeology of the study area.

2.2.1 Hydrogeological Setting

The hydrogeology of the study area consists of an unconfined sandy marine terrace aquifer generally composed of medium to well graded silty sands, underlain by Franciscan Complex bedrock.

The sand aquifer is not currently used for extraction purposes due to its low overall storage capacity, relatively shallow depth and proximity to the residential septic systems. Depth to water table ranges from approximately 15 to 55 feet below ground surface (BGS) across the study area and is primarily controlled by the depth to bedrock.

Eighteen soil borings (identified as SB-1 to SB-18) were completed around the City. Soil samples from these bores were analyzed using a mechanical sieve analysis, which indicated that the majority of the soil samples were dominated by fine to medium grained sand.

Further analyses of the soil samples suggest that the vertical hydraulic conductivity through the shallowest or near-surface deposits (down 3 to 10 feet BGS) is approximately 1 to 2 orders of magnitude lower than for the lower portion of the marine terrace (e.g., 1 to 2 orders of magnitude lower than the 38 to 86 feet/day recorded for the sand aquifer due to the higher silt content observed in undisturbed areas and the compaction of imported fill materials to build houses and roads in the disturbed areas).

2.2.2 Mapping of Springs and Seeps

Seeps and springs are generally located at sharp breaks in slope (coastal bluffs), often where the bedrock outcrops along the coastal bluffs within the Project area, and are more widespread on the low point of bedrock cliff slopes, corresponding with paleochannels, pervasive jointing, and sheared bedrock. Seep and spring mapping investigations were conducted as part of the *Geotechnical Analysis* (GHD 2012). In addition, large clusters of springs and seeps were observed on the beachfront bluffs in the northwest and southeast regions of the study area (see Figure A-4 of the *Geotechnical Analysis* (GHD 2012). The observed seeps range from a trickle of water flow (i.e., less than ¼-gallon per minute) around the north and west boundaries of the project area, up to or perhaps greater than 5 gallons per minute (gpm) on the southern boundary bluffs. No estimate has been made of the total spring flow from various areas or around the City as a whole.

2.3 Groundwater Monitoring

Continuous groundwater monitoring (recorded at 15 minute intervals) has been conducted at 8 of the 9 shallow monitoring wells across the study area from November 2012 to May 2013 to provide an indication of the current groundwater levels and the response to rainfall events. The preliminary review of the continuous groundwater level readings indicates that underlying soils have a quick hydraulic response to rainfall events, as indicated by the hydrographs of the groundwater level and rainfall, as shown in Appendix B.

Table 1 provides a summary of the average groundwater level as well as the minimum and maximum groundwater level range recorded over the monitoring period. Monitoring well MW-3 has not been fitted with a logger, and has been dipped only twice during the investigation period. Therefore, data for monitoring well MW-3 is not included in Table 1.

Table 1 Groundwater Level Summary Data

Well ID	Ground Surface Elevation (ft MSL)	Average Groundwater Level (ft MSL)	Groundwater Level Range (ft MSL)
MW-1	29	11	9 - 14
MW-2	94	65	58 - 66
MW-4	171	136	134 - 138
MW-5	172	133	131 - 134
MW-6	153	135	133 - 136
MW-7	176	131	121 - 135
MW-8	162	133	131 - 134
MW-9	166	118	116 - 119

2.4 Wastewater Management

The City does not have a centralized wastewater system, and all residences and businesses use on-site septic systems. The septic tanks are buried at a depth of approximately 1 to 3 feet BGS depending on installation date, with newer septic system installed 2 to 3 feet BGS. Leach lines are typically set between 3 to 5 feet BGS in a gravel filled trench. The effluent infiltrates into the subsurface under a gravity system allowing for biological treatment and breakdown of the organic matter prior to reaching groundwater. The volume of water introduced to the subsurface is referred to as the septic loading rate.

The average septic loading rate into the marine terrace aquifer across the study area was estimated as the septic systems are a large component of groundwater recharge, especially in the summer months. Water use information from the City was analyzed over a one-year period (September 2011 to August 2012) in conjunction with rainfall data from the Woodley Island Rain Gauge to identify representative months for water use that exclude land application for irrigation. The months January through March were selected as representative months as they received the greatest amount of rainfall, as shown in Table 2. Therefore, landscape watering was assumed to be at a minimum.

Table 2 Rainfall for one calendar year shows that the period from January through March most likely reduced the need for landscape irrigation.

	Sep-2011	Oct-2011	Nov-2011	Dec-2011	Jan-2012	Feb-2012	Mar-2012	Apr-2012	May-2012	Jun-2012	Jul-2012	Aug-2012
Rainfall (Inches)	0.37	4.21	3.86	2.22	7.76	2.63	12.02	4.76	0.77	2.00	0.67	0.07

Variations in water use at each connection were noted from January through March 2012. These variations are believed to be due to holidays, vacations, tourism and meter reading dates. An average water use for each connection during this three month period was used to normalize household and business water use. The average water use was then applied as a septic loading rate for each parcel as described further in Section 4 of this Report.

3. Hydrologic Analysis

This section presents the development and calibration of a USACE Hydrologic Engineering Center's Hydrologic Modeling System software (HEC-HMS) model to simulate precipitation and runoff in the Project area and estimate existing infiltration rates.

3.1 HEC-HMS Model Development

HEC-HMS version 3.3 was utilized to compute peak flows at specific locations within the City limits. HEC-HMS simulates precipitation-runoff and routing processes and allows the generation of storm hydrographs. The procedures outlined in the HEC-HMS Technical Reference and User Manuals were followed for developing, simulating, and interpreting results from the HEC-HMS model. The discussion below follows the sequential steps in developing the HEC-HMS model specific to stormwater evaluation in the City.

3.1.1 Watershed Delineation

Stormwater originating within the City discharges to three distinct watersheds; Mill Creek, the City of Trinidad, and Parker Creek, characteristics of which are summarized in Table 3. The Mill Creek watershed area is approximately 897 acres and ranges in elevation from 0 to 405 feet (NAVD88). The upper portion of the watershed is predominately comprised of second and third growth redwood and fir forest, whereas the mid-portion consists of rural residential areas. The lower portion of the watershed is comprised of a mix of residential and state park land uses. The City watershed area is approximately 40.3 acres and ranges in elevation from 0 to 40.3 feet (NAVD88). The watershed is predominately comprised of residential single family and commercial areas. The Parker Creek watershed area is approximately 243 acres and ranges in elevation from 0 to 243 feet (NAVD88). The upper portion of the watershed is

predominately comprised of second and third growth redwood and fir forest, whereas the mid-portion consists of rural residential areas. The lower portion of the watershed is comprised of a mix of residential and state park land uses.

Table 3 Physical Characteristics of Watersheds Impacted by Stormwater from the City

Watershed	Area (acres)	Top Elevation (ft)	Bottom Elevation (ft)
Mill Creek	897	405	0
City	40.3	54	0
Parker Creek	243	206	0

The first step in developing the HEC-HMS model was to divide the three watersheds into sub-drainages, referred to in HEC-HMS and hereinafter as *sub-basins*. Field reconnaissance was conducted during multiple site visits to determine flow path direction for each street and city block within the three watersheds and related sub-basins. Watershed characteristics such as locations of day-lighted underground storm drains, land use cover, topography and the need to examine runoff hydrographs at specific locations, all factored into how the sub-basins were defined. The physical drainage system for the three watersheds is comprised of 18 Mill Creek sub-basins, 8 Parker Creek sub-basins, and 9 City sub-basins (see Figures A-3, A-4, and A-5, Appendix A).

3.1.2 Watershed Characteristics

A sub-basin element in the HEC-HMS model represents a complete watershed that is governed by three distinct processes: infiltration, runoff, and groundwater baseflow contributions and were estimated by the following:

1. The quantity of rainfall that falls and infiltrates was estimated though a loss rate method;
2. The excess rainfall which does not infiltrate and becomes runoff was estimated through a transform method; and
3. Groundwater contributions to channel flow rates were estimated through a baseflow method.

The specific methodologies used for this Project are presented in the following Sections.

3.1.2.1 Loss Rate Methodology

The HEC-HMS model offers various methods for assigning abstractions of precipitation to account for the depth of rainfall that either infiltrates into the soil horizon or is captured in depressional storage sinks, and does not contribute to runoff. For the purpose of this Project the commonly used Soil Conservation Service (SCS) empirical curve number method was utilized in HEC-HMS to estimate total excess precipitation. The curve number (CN) method determines runoff using the amount of precipitation and the infiltration parameters associated with soil type, soil moisture, preceding rainfall, and surface retention. The amount of rainfall is converted to runoff using the CN. The curve number is based on the antecedent

moisture condition of the soil type, land cover, interception, and surface storage. The CN ranges from 0 to 100, where a value of 100 represents zero losses or an impermeable surface (USDA 1986).

Soils are classified into four hydrologic soil groups (A, B, C, and D) according to their minimum infiltration rate. The soils in the three Project watersheds were delineated from a combination of the 1965 soil survey report, current draft soil survey mapping provided by the USDA-NRCS, and information from the soil borings conducted as part of the *Geotechnical Analysis* (GHD 2012). Antecedent moisture conditions are classified as either low (AMC I), average (AMC II), or high (AMC III). For the purpose of this study, it was assumed that AMC II curve numbers be applied. AMC II assumes that 0.5 to 1.1 inches of rain had fallen in the watershed of interest over the course of 5 days prior to the initiation of the design storm. Curve numbers developed for AMC II are the most widely used in hydrologic analyses when utilizing the SCS method and are considered appropriate for this project.

The diverse land coverage within the project watersheds was divided into 10 discrete land covers representing existing land use conditions: forest, grassland, impervious, gravel, residential estates (1/2 acre minimum), residential single family (10,000 ft^2 minimum), residential single family (6,000 ft^2 minimum), multi-family residential (6,000 ft^2 minimum), industrial, and commercial. Representative CN's were developed for each combination of land use and hydrologic soil groups, as shown in Table 4. Because most sub-basins within the three watersheds consist of several soil types and land covers, an area weighted composite CN was calculated for each sub-basin. The tabulation and final curve number for each sub-basin are shown in Appendix C (see Tables C-1, C-2, and C-3).

Table 4 Land Use and Curve Numbers (CN) based on Hydrologic Soil Group

Land Use	Curve number (CN)[1]			
	Hydrologic Soil Group			
	A	B	C	D
Forest	30	55	70	77
Grassland	39	61	74	80
Impervious	98	98	98	98
Gravel	76	85	89	91
Residential Estates (1/2 acre minimum)	54	70	80	85
Residential Single Family (10,000 ft^2 minimum)	57	72	81	86
Residential Single Family (6,000 ft^2 minimum)	61	75	83	87
Multi-Family Residential, Res. (6,000 ft^2 minimum)	77	85	90	92
Industrial	81	88	91	93
Commercial	89	92	94	95

[1] Curve Numbers (CN) reported are for Antecedent Moisture Condition II (AMC II)

3.1.2.2 Transform Methodology

The SCS Unit Hydrograph (UH) method was used in HEC-HMS as the direct-runoff transform method. The model is based upon averages of the UH derived from gaged rainfall and runoff for a large number of small agricultural watersheds throughout the United States. The SCS UH model uses a dimensionless, single-peaked unit hydrograph. Utilizing the UH method in HEC-HMS requires the lag time for each sub-basin to be defined. The lag time represents the difference in time between the center of mass of effective rainfall and the center of mass of runoff produced (Viessman 1995). The flow path for each sub-basin was initially determined through analysis of the watershed topography and verified through field reconnaissance. The flow paths were then digitized using the California Coastal Conservancy Coastal LiDAR Project digital elevation model (2009-2011) (1-meter grid) for the coastal elevations west of Highway 101, and the NOAA Coastal Service Center digital surface model (5-meter grid) for inland elevations east of Highway 101. The flow paths were digitized in ESRI ArcGIS and elevations required to determine sub-basin slopes were also obtained from the elevation models discussed above. Principles outlined in USDA Technical Release 55 (USDA 1986) were utilized to calculate the lag time based on sheet, shallow concentrated, and channel flow through each sub-basin. The lag time used for each sub-basin in the model calculated from the information above is presented in Appendix C, Table C-4.

3.1.2.3 Baseflow Methodology

Baseflow accounts for the quantity of flow contributed from groundwater and not direct precipitation-runoff. For modeling design storms, each sub-basin requires an initial baseflow. For the HEC-HMS model, the baseflow for each sub-basin was assumed to be zero. This is reasonable given the high infiltration rates though the subsurface sands in the project area which result in limited contribution to baseflow, over the time scale at which the hydrologic model is run. For this analysis the hydrologic model is also being used in conjunction with the groundwater model, which accounts for contributions from groundwater to baseflows.

3.1.3 Channel Routing Reaches

Although HEC-HMS is considered to be strictly a hydrologic model, it still offers the capabilities of routing hydrographs from one sub-basin through another. Contributing runoff from a sub-basin into a defined stream channel is modeled in HEC-HMS using open channel flow principles and referred to as a *reach* element. The attenuation characteristics and travel time of water flowing through a reach is dependent on length, slope, friction, flow depth, and channel storage. Several modeling methods for routing water through channel reaches are offered within the program. Because of HEC-HMS's inability to perform step-backwater calculations, the model only analyzes channel reach hydraulics using one representative cross-section flowing at normal depth. Factors associated with channel slope and floodplain interaction govern which method is appropriate for a particular reach. The Standard Muskingum Cunge routing method was used to model the hydrograph routing within each reach. This is an industry standard method used for routing hydrographs and is appropriate for this project. The length, slope, and typical channel cross-sectional shape for each reach inputted to the HEC-HMS model were developed using digital elevation models discussed in 3.1.2.2 in addition to field observations.

Due to the simplistic nature of the hydraulic routing methods employed by HEC-HMS, backwater effects created from flow constrictions are not accounted for. This is acceptable due to the steep sloped nature of the watersheds in the project area, which results in overflows to existing drainages or sheet flow at constriction points. These constrictions could potentially increase peak routing time during larger flow events, which may influence the magnitude and timing of observed peak flows compared to those predicted by the model. However, the overall volume of runoff will not change.

Both the Mill Creek and Parker Creek watersheds contain complex culvert and drainage inlet configurations which may have an impact on the timing of observed peak flows. More complex modeling techniques for reaches would be needed to account for complex drainage channel structures. The City watershed consists of mainly sheet flow into street gutters which discharge to drainage inlets. The drainage inlets within the City have a range of efficiencies for capturing street flow which may have an impact on stormwater routing. A more sophisticated numerical approach would be needed to capture the effects of reduced inflow to storm inlets. Overall, the impact to the project is anticipated to be minor as the change in the efficiency of runoff capture would result in moving water between sub-basins. While this alters the peak flow of the sub-basin hydrographs, the overall volume of water to be infiltrated is not affected.

The hydraulic routing time used in this preliminary study assumed velocities for full flowing pipes. This is a reasonable assumption as the project is focused on large storm events.

3.1.4 Precipitation Events

The HEC-HMS model offers various methods for assigning and modeling precipitation events. For the purpose of simulating design precipitation events, the 24-hour Frequency Storm method was utilized in HEC-HMS. This method requires the total point-precipitation depths for selected exceedance probability durations. The method also requires the determination of a rainfall distribution. For the purpose of this study, 24-hour rainfall depths were obtained from NOAA Atlas II for the 2, 10, 25, 50, and 100-year recurrence as shown in Figure 1.

Precipitation data was obtained from the NOAA Precipitation Frequency Data Server for the City, which reflects an interpolation of NOAA gages in the area. The Point Precipitation Frequency is estimated from the Woodley Island gage which is located in Eureka, California at an elevation of approximately 10 feet above mean sea level (MSL). The City watershed ranges in elevation from 0 to 54 feet above MSL.

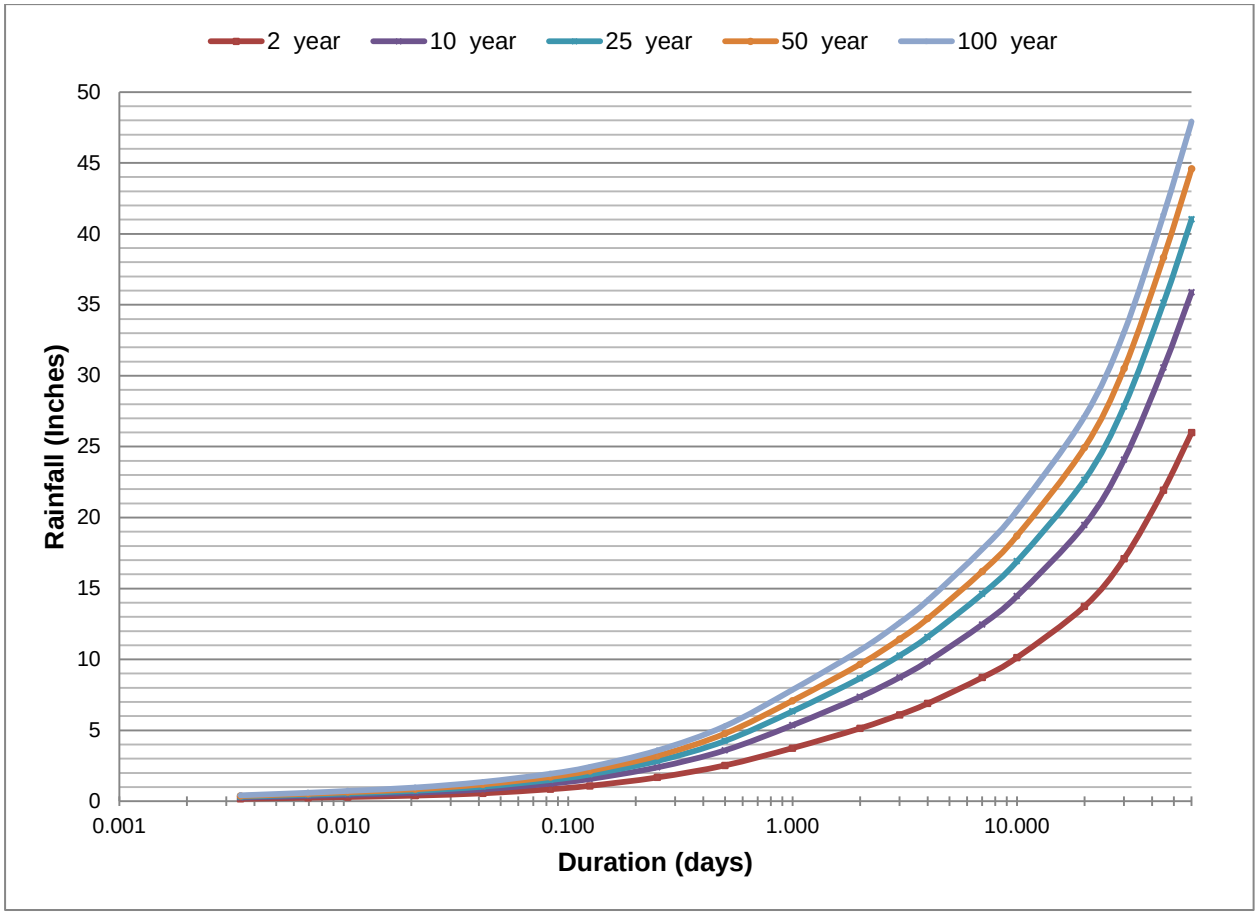


Figure 1 Partial Duration Series (PDS) Based Precipitation Frequency Estimates (NOAA, 2013)

3.2 HEC-HMS Model Results

Utilizing the HEC-HMS model input data for CN, lag time data presented in Appendix C, and precipitation data discussed above, hydrographs were developed for each sub-basin and routed through each reach. The discharge hydrograph for the 24-hour storm event for each of the three watersheds is shown in Appendix D (see Figures D1, D2, and D3).

Table 5 summarizes the peak flows for the 2, 25, 50, and 100-year, 24-hour storm events for all three watersheds. The peak discharges were measured at the ocean discharge location for each watershed. As expected, Mill Creek experiences the highest peak flow events, which corresponds with the largest watershed area. The peak discharges and discharge hydrographs presented in this Section and in Appendix D show the results of the non-calibrated hydrologic models.

Table 5 Peak Discharge for Parker Creek, City and Mill Creek Watersheds

Watershed	Peak Discharge (cfs)			
	2-year, 24-hour	25-year, 24-hour	50-year, 24-hour	100-year, 24-hour
Parker Creek	51.8	125.2	151.5	180.4
City	14.2	35.7	43.8	52.5
Mill Creek	235.5	613.5	743.8	887

3.3 Calibration of HEC-HMS Model

The purpose of model calibration is to confirm model accuracy using actual measured flow data and adjust the model parameters to match measured data to model results. In the absence of calibration, model results can vary from actual conditions. The calibration of the HEC-HMS model required two pieces of information, flow data and precipitation data. The sections below discuss the storm drain flow data collected by the City and the precipitation data used in the model calibration. There is currently very limited stream flow monitoring data for Mill and Parker Creeks, preventing the full calibration of the hydrologic models. However, some spot data was obtained from a previous analysis on Mill Creek (Madrone 2011) and was qualitatively used to check the hydrograph outputs at the culvert along Patrick's Point Drive. The focus of the Project is on the City watershed. Therefore, the lack of data to calibrate the Mill and Parker Creek watershed hydrographs was not a concern and should not impact the final project. The ability to evaluate relative impacts to these watersheds can still be evaluated with the use of the groundwater model. The following sections discuss the calibration process that was completed for the City watershed.

3.3.1 Storm Drain Monitoring

Storm drain flow monitoring was conducted on the City's storm drain system at the inlet located at the corner of Galindo and Van Wycke Avenues between the months of October 2011 through August 2012. This storm drain is the last access point before the final discharge to the ASBS. All stormwater flows collected by the City's storm drain system exit past this point. The period of limited record hydrograph is presented below in Figure 2. The peak flow event for the period of record occurred on Feb 28, 2012 at 7:30 PM, with a corresponding flowrate of 6.13 cfs. The monitoring data was utilized to calibrate and validate the HEC-HMS model.

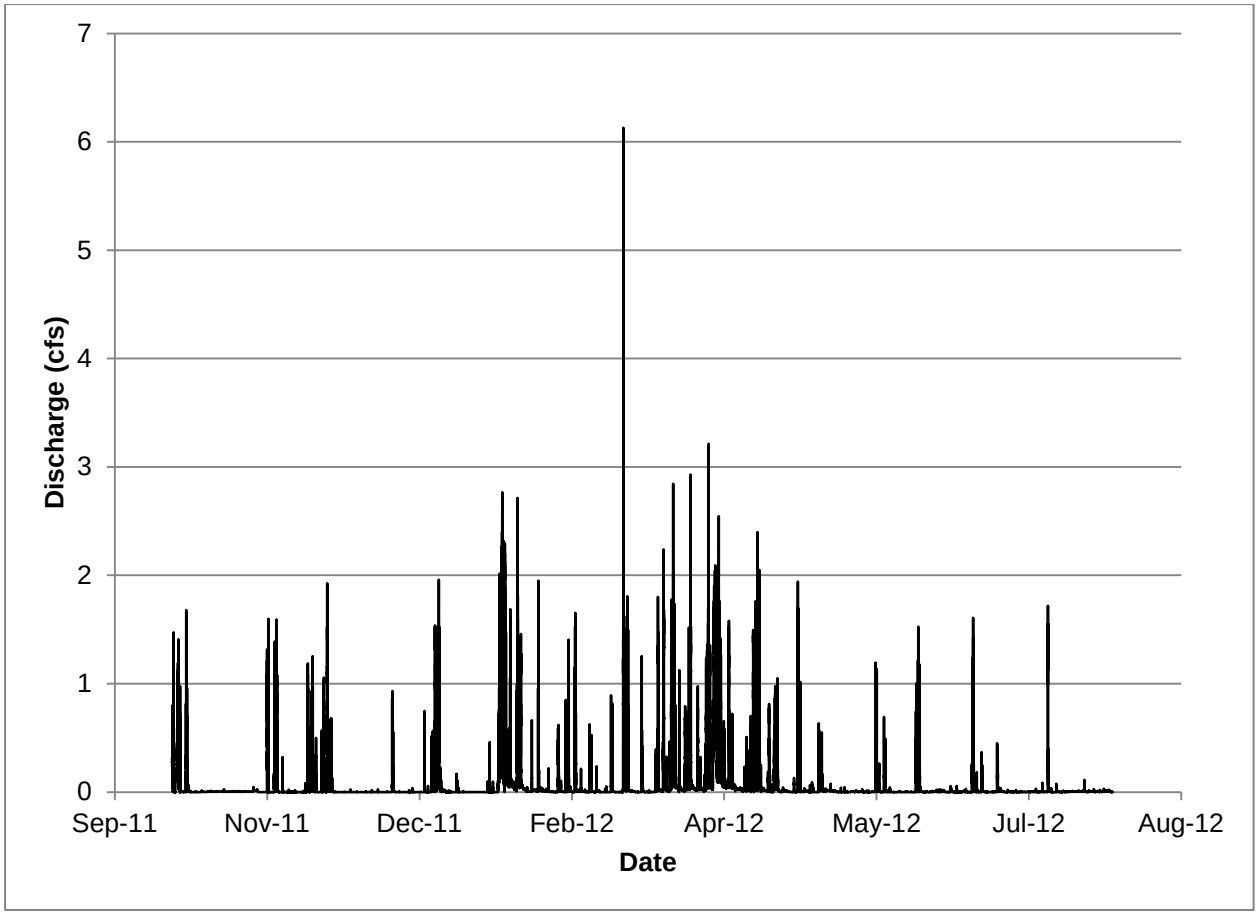


Figure 2 City's Storm Drain Discharge Monitoring Hydrograph at the Corner of Galindo and Van Wycke Avenues for the Period of October 2011 to August 2012

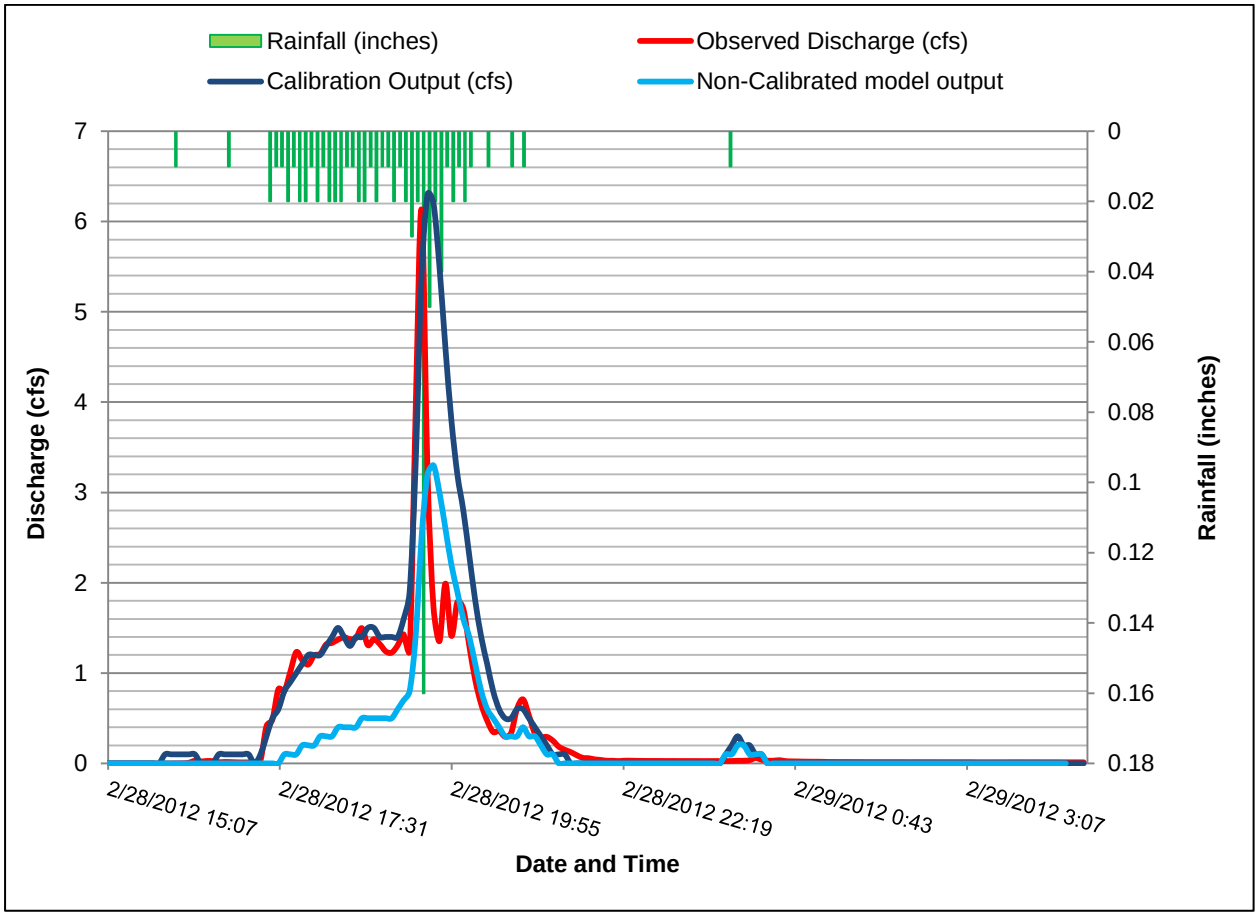
3.4 HEC-HMS Calibration

The available storm drain flow and rainfall data was used to calibrate the HEC-HMS hydrologic model for the City watershed. As discussed previously, the precipitation data was provided by the NOAA Precipitation Frequency Data Server. The advantage of using storm drain flow monitoring data for the calibration of a hydrologic model is that the calibration method adjusts the runoff characteristics of the sub-basins to result in a total storm drain flow rate that matches the recorded historical storm flow rates. This allows the model to more accurately reflect existing infiltration characteristics, and therefore produce more realistic storm drain flow hydrographs for the Project reach.

Because of the limited nature of the HEC-HMS model, it was important to choose a distinct storm event for the calibration process. The storm of February 28, 2012, provided a measured distinct storm drain flow and could be modeled accurately by HEC-HMS. Figure 3 shows the measured storm event hydrograph,

the original HEC-HMS output, and the calibrated HEC-HMS output at the storm drain flow measuring location.

Figure 3 Comparison of observed discharge from February storm event and the output hydrographs from the calibrated and non-calibrated HEC-HMS models for the City watershed



The original HEC-HMS results produced a peak event that was reduced and less responsive to early rainfall than the observed storm event (see Figure 3 and Table 6). The shortened attenuation and reduced peak of the non-calibrated HEC-HMS hydrograph produced a total storm volume less than the observed storm volume (e.g., 0.26 ac-ft. to 0.43 ac-ft.). In order to increase the peak of the HEC-HMS hydrograph, the percent impervious areas for each sub-basin were increased (for a discussion of the HEC-HMS model inputs and methodology, see Section 3). The total storm volumes of the calibrated HEC-HMS model and the observed storm event were within 27% of each other (0.59 ac-ft. and 0.43 ac-ft., respectively), while the peak flows were within 3% of each other as presented in Table 6. The difference in total storm volume is reflected in the attenuated HEC-HMS hydrograph which may reflect the underestimation of the rate at which water drains from the storm drain system. The calibrated hydrograph

is somewhat conservative for use in project design as it slightly overestimates the total runoff volume to be addressed by the project but accurately captures the peak runoff.

Table 6 Comparison of the City watershed observed storm drain flow to calibrated and non-Calibrated HEC-HMS model hydrographs at the storm drain flow measuring location (Feb. 28-29, 2012)

Model	Peak Flow (cfs)	Total Storm Volume (Ac-ft)
Observed Storm Event	6.12	0.43
HEC-HMS Non-Calibrated	3.3	0.26
HEC-HMS Calibrated	6.3	0.59

Once the calibrated HEC-HMS model was established, the rainfall depths defined in previous sections of this Report as the 2-year, 25-year, 50-year, and 100-year precipitation events were inserted into the calibrated HEC-HMS model. The resulting storm event flows were calculated and compared to calibrated and non-calibrated HEC-HMS flows, as presented in Table 7.

Table 7 Non-Calibrated and Calibrated HEC-HMS Flows for the City Watershed

Return Period	City Watershed Peak Flow (cfs)	
	HEC-HMS Non Calibrated	HEC-HMS Calibrated
2-year	**14.2**	**15.9**
25-year	**35.7**	**36.3**
50-year	**43.8**	**43.9**
100-year	**52.5**	**52.0**

The calibrated hydrograph for the 2-, 25-, 50-, and 100-year, 24-hour storm for the City watershed is shown in Figure 4.

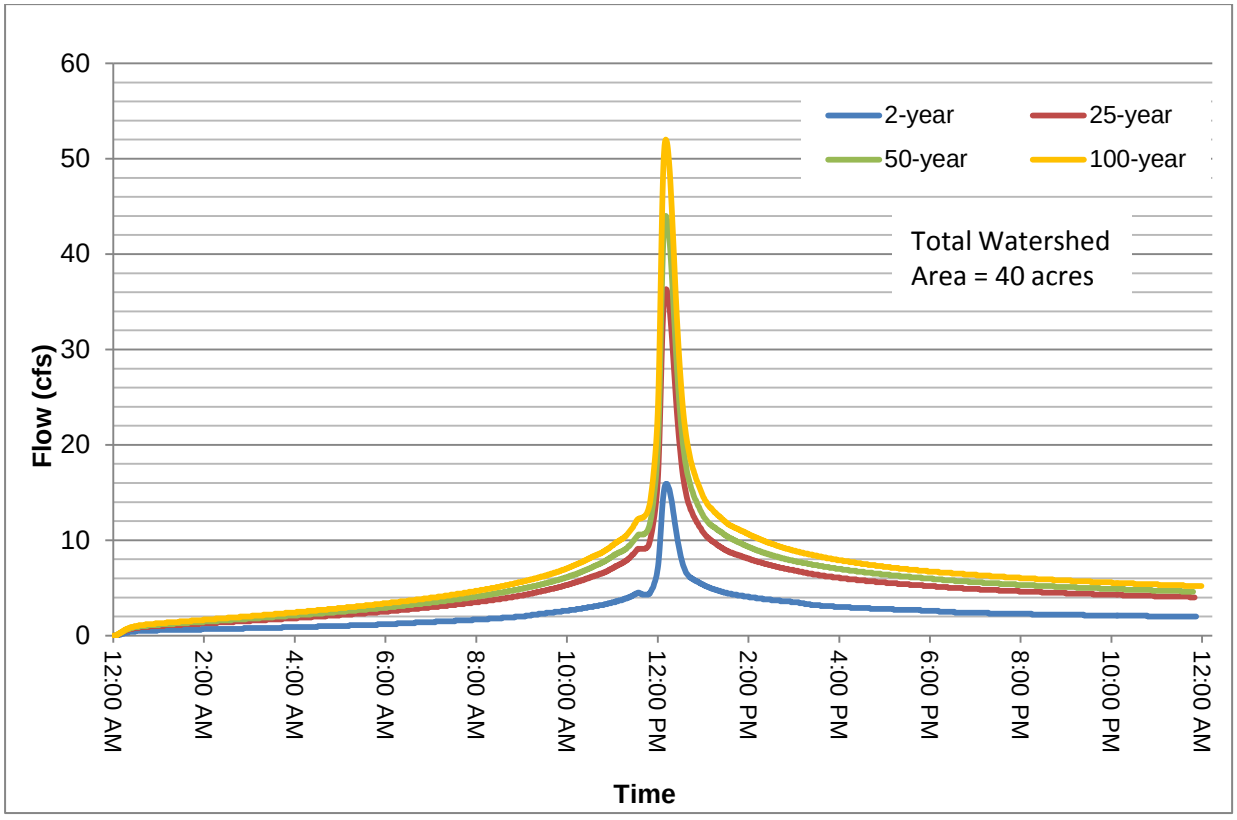


Figure 4 Calibrated discharge hydrographs for the 24-hour storm events for the City Watershed at the discharge location

4. Groundwater Model

This section of the Report covers the development and calibration of the groundwater model.

4.1 Model Code and User Interface

The groundwater model was developed using the Groundwater Vistas (v6) interface and the MODFLOW-SURFACT (v4) application (HydroGeoLogic 1996), which is a modular three-dimensional finite-difference groundwater numerical package. MODFLOW-SURFACT was selected due to:

- The ability to integrate the surface water system; and
- SURFACT's increased stability compared to 'standard' versions of MODFLOW, based on SURFACT's ability to simulate unsaturated conditions and the robust numerical solvers.

The thickness of the unsaturated zone varies from close to (or at) surface at springs and seeps, to more than 40 feet in some areas as is seen at well MW-9.

4.2 Model Location and Geometry

The groundwater model domain covers an area of 9,910,332 ft^2, and is shown in Figure E-1 in Appendix E. It was developed in NAVD88 projection, and the coordinates of the south-west corner are 5968650 feet east, 2275340 feet north. The Coastal LiDAR digital elevation model (DEM) used in the *Geotechnical Analysis* (GHD 2012) was used to generate the groundwater model surface, and re-interpolated to produce a 2 x 2 meter (6.5 x 6.5 feet) gridded surface. The bedrock surface produced as part of the *Geotechnical Analysis* (GHD 2012) was also refined as part of the groundwater modeling study to ensure that the depth to bedrock recorded at the soil borings was accurately represented, and to include the interpreted depth to bedrock from the geophysical Transects 1 and 4 (seismic and resistivity surveys, carried out by Spectrum Geophysics – presented in Appendix G of the *Geotechnical Analysis* (GHD 2012)).

In order to simulate the septic systems and stormwater infiltration design options, the model was separated into five model layers, indicated as:

- Layer 1 was configured with a thickness of 3 feet, which is a fairly typical depth of installed leach lines below the ground surface;
- Layers 2 through 4 have a variable thickness across the model domain and extend from the bottom of Layer 1 to the confining bedrock layer, Layer 5, which functions as an aquitard; and
- Layers 2 through 4 have thicknesses that range from 2 to 145 feet, with an average thickness of 45 feet.

The final model was comprised of 465 rows and 495 columns. The model grid size of 2 x 2 meters was selected to provide adequate resolution to model the septic tanks and the stormwater infiltration design options, while maintaining a suitable model run time. The model was configured to simulate steady state conditions, before moving to calibrate against transient conditions. Figure E-1, in Appendix E shows the modeled bedrock elevation and the sand thickness of the aquifer across the model domain.

4.3 Hydraulic Conductivity and Storage

The model layers were separated into 8 hydraulic conductivity zones across model Layers 1 through 5 (shown in Figures E-2 and E-3 in Appendix E) to represent the different hydraulic properties based on findings from the *Geotechnical Analysis* (GHD 2012). Model Layer 1 consists predominantly of low conductivity upper marine terrace sediments, with coastal bluffs along the west and south coastal regions and in the north along Mill Creek, and lower marine terrace sands along the coastline. The coastal bluff areas were identified from interpretations provided in the *Geotechnical Analysis* (GHD 2012), and from regions where the surface elevation slope was greater than 45 degrees. Model Layers 2 through 4 consist predominantly of lower marine terrace sediments, with larger areas of coastal bluffs along the

west and south coastal regions and in the north along Mill Creek, and high conductivity sediment filled paleochannel zones. The paleochannel zones were assigned based on interpretations from the geophysical investigations (discussed in Section 2.1.2) and the bedrock elevation surface.

Table 8 summarizes the values assigned to the saturated hydraulic conductivity zones in the groundwater model. These estimates were based on the findings reported in the *Geotechnical Analysis* (GHD 2012) and refined during the calibration process. An effort has been made to calibrate the model to observed groundwater levels using hydraulic conductivity values within the range of observed data (i.e. grain size distribution results as presented in the *Geotechnical Analysis* (GHD 2012)).

Table 8 Calibrated Model Hydraulic Conductivity

Zone	Description	Horizontal hydraulic conductivity (ft/d)	Vertical hydraulic conductivity (ft/d)
1	Upper marine terrace / soil	2	2
2	Coastal bluffs	0.005	0.0005
3	Lower marine terrace (sands)	1	1
4	Lower marine terrace (sands)	5	5
5	Lower marine terrace (sands)	8	8
6	Interpreted consolidated region	0.8	0.8
7	Unconsolidated beach sands	27	4
8	Confining Franciscan Bedrock	1.0 E-10	1.0 E-11

Unsaturated flow was simulated using the numerical model MODFLOW-SURFACT, which allows for variable saturation using a combination of the Pseudo-Soil Relations moisture-retention function. The model layers were separated into multiple zones corresponding to the upper soils and the lower marine terrace and various regions within the marine terrace. The distinction of the zones was based upon geological field data, geologist interpretation, mapped soil properties, and model calibration.

Storage and porosity parameters were also divided into two zones across Layers 1 through 4, summarized below in Table 9. Model Layer 1 consists of a uniform zone representing the upper marine terrace sediments, and model Layers 2 through 4 consist predominantly of the lower marine terrace, with the upper marine terrace sediments along the western and southern coastline. The storage parameters were based on literature values for sandy soils (Fetter 2001; Freeze & Cherry 1979), and were refined during the calibration process.

Table 9 Calibrated Model Storage Parameters

Zone	Description	Storativity (Ss)	Specific Yield (Sy)	Porosity
1	Upper marine terrace / soil	1.0 E-6	0.12	0.35
2	Lower marine terrace	2.0 E-6	0.2	0.3

4.4 Model boundary conditions

The groundwater model boundary conditions are discussed below and presented in Figure E-4 in Appendix E.

4.4.1 No Flow boundaries

Model cells were inactivated in areas where ground surface elevation was less than 0 feet MLS which represents the areas within the ocean, including areas to the west and south of the City. Model cells to the north of Mill Creek and to the west of Highway 101 and Parker Creek were also inactivated, because these sections are physically separated from our study area by the defining boundary conditions of the creeks and Highway 101. In addition, areas identified where the bedrock surface was at or very near the ground surface were inactivated in model Layers 2 through 4, which conceptually represent just a thin soil profile over the bedrock.

The bedrock (Layer 5) was initially modeled with a low conductivity of 1.0E-10/1.0E-11 feet/day and then changed to a no-flow boundary condition. The modification did not appreciably change the model results and greatly decreased the required computational time.

4.4.2 Constant Head Boundaries

Constant head boundary conditions occur where the hydraulic head of the cell is held constant over time. A constant head boundary was applied to the model boundary cells along the west and south (e.g., coastline) and adjacent to Highway 101. The boundary cells along the coast were assigned a head of 0 feet MSL, with a saturated thickness of 2 feet. While the elevation along the coast will vary with tidal influence, the minor elevation changes are not anticipated to effect results especially since fluctuations at sea level do not impact groundwater flows in the model area. The majority of the coastline boundary cells were assigned to model Layer 1. However, in areas where the elevation of the bottom of model Layer 1 was greater than 0 feet MSL, the constant head boundary cells were assigned to model Layer 2. The boundary cells adjacent to Highway 101 were assigned to the model in Layer 2. These cells were assigned a uniform head of 136 feet MSL (based on the extrapolation of observed groundwater levels), and a variable saturated thickness calculated as the difference between the uniform head (136 feet MSL) and the bottom of Layer 2.

4.4.3 Rivers

River boundary conditions were included in the model to simulate the flow of water into and out of the aquifer from Mill and Parker Creeks (and tributaries). The river bed elevation was assigned as the Layer 2 top elevation minus 0.33 feet. The river bed elevation was set to equal the stage height water elevation in order to prevent leakage from the river boundary to the modeled aquifer. This means that these watercourses are simulated as accepting discharge from the aquifer (base flow) only.

4.4.4 Septic Systems

The septic systems represent a constant flow into the model and do not change over time. The septic systems were incorporated into the groundwater model using the Well package. Injection rather than extraction wells, were used to simulate the flux into the model at the location of each septic system discussed in Section 2.4. The wells were set in Layer 1 (based on the fact that septic system trenches are typically installed around 3 to 4 feet deep BGS), and each cell within a property's septic system was assigned a constant discharge rate for all stress periods, corresponding to the calculated septic loading rate.

The septic loading was applied to each parcel based on the seepage area required for leach lines per typical septic system design standards and the calculated daily flow rate. The seepage area required was determined using an area method, as outlined in Wells and Septic Systems (Alth 1992). The area method predicts a required seepage area per bedroom based on percolation rate. A range of percolation rates from 1.4 to 14.1 inches/hour was determined for silty to clean sand soils in the City (Freeze & Cherry 1979). It was also determined that areas of 325 ft^2 to 140 ft^2 per bedroom are to be used for percolation rates from 1 to over 7 inches/hour, respectively (Alth 1992). A percolation rate of 4 inches/hour and an area of 190 ft^2 were used as a median value.

Structures on each parcel were analyzed using an aerial image and an estimated number of bedrooms were recorded. The standard number of bedrooms estimated for each property was estimated to be 2.5. Additional bedrooms were added for larger houses or parcels containing what appeared to be multiple living units. Smaller houses were assigned no less than 2 bedrooms. Commercial and public properties were assigned a larger number of bedrooms based on the assumption that a larger septic area would be required for increased septic usage on properties such as restaurants and public parks.

The number of bedrooms for each parcel was used to estimate the total seepage area required for each parcel. The model area was approximated by 43 ft^2 (2m x 2m) grid squares. The seepage area required was divided by the grid square area to determine the number of grid squares required for application of septic loading for each parcel. The septic load for each parcel was then equally distributed among the required grid squares and located within the parcel boundaries.

4.5 Recharge

The model domain was divided into five land use zones across model Layer 1 (displayed in Figure E-4 in Appendix E and summarized in Table 10).

The land use zones were based on the watershed land use classifications discussed in Section 3.1.2. Areas within the model domain which were not classified as part of GHD's HEC-HMS modeling, such as along the bluffs which do not drain to the City's existing outfall, were classified based on ocular estimations of aerial imagery.

A transient recharge dataset was generated for the five recharge zones based on water balances developed separately by engineers/hydrogeologists in two separate GHD offices. Respectively, these water balances investigated the February 2012 and September 2012 storm events and the full daily time series of rainfall from 2008 to 2013. The water balance for the groundwater model was used to parameterize recharge, while the HEC-HMS water balance served as a check. For the full time series water balance, it was assumed that:

- No recharge would occur within impervious areas;
- Rainfall-runoff-recharge would be the same in the pervious areas of Parker Creek and Mill Creek watersheds; and
- High relief (high topographic slope) areas would experience only 10% of the rainfall infiltration recharge estimated for Parker Creek and Mill Creek watersheds.

This water balance, specifically the calculation of soil zone evapotranspiration and recharge, was based around the Penman-Grindley method (Sniffer 2003), and calibrated against the observed groundwater level rise in a number of the monitoring wells around the site. Partitioning of rainfall into runoff was based on the calculation of runoff by the separate HEC-HMS model.

The resulting recharge time series were used to populate the transient recharge sequence (summarized in Table 10) and to provide initial estimates of the steady state recharge. The recharge rates used for the steady state calibration were greater than the average recharge rates to more accurately represent conditions during periods of greater rainfall when stormwater infiltration would occur. Recharge Zones are shown in Figure E-4 in Appendix E.

Table 10 Recharge Zones

Zone	Description	Average recharge (ft/d)	Range of recharge (min and max) (ft/d)	Steady state recharge (ft/d)
1	Impervious	0	0	0
2	Pervious - Mill Creek	0.0178	0 – 0.1608	0.012
3	Pervious - Parker Creek	0.0178	0 – 0.1608	0.012
4	Pervious - City	0.0182	0 – 0.1608	0.012
5	High slope (DEM slope > 45°)	0.0018	0 – 0.0161	0.0012

4.6 Groundwater Model Calibration

The groundwater model was calibrated by iteratively adjusting the model parameters to achieve a good match between the computed and observed groundwater levels. The key model inputs which were adjusted during the calibration process were:

- Hydraulic conductivity;
- Zonation of hydraulic conductivity;
- Unsaturated soil parameters;
- Recharge; and
- Bedrock topography.

The model was calibrated in steady-state mode against the groundwater levels observed at the 9 monitoring wells, and against the 'time-of-drilling' groundwater level (where the water table was intersected) documented in the soil lithology log presented in the *Geotechnical Analysis* (GHD 2012) at the seven soil bores which were not subsequently converted to monitoring wells but have a recorded groundwater level. The groundwater monitoring data recorded from November 2012 through May of 2013 in 8 of the 9 monitoring wells are presented in Appendix B. The groundwater elevation data was plotted against daily precipitation. The figures also show the location of the ground surface and bedrock surface. As can be seen from the figures, the groundwater elevation does not vary significantly, even with large precipitation events.

Scatter plots (modeled versus observed groundwater levels) are presented in Figure 5 for the adopted steady-state calibration. It should be noted that spot groundwater levels were recorded at the soil bores in mid-to-late January 2012, whereas the steady-state calibration target for the monitoring wells was based on the first recorded water level in mid-November 2012.

The calibration goal was to achieve less than +/- 10% difference (indicated on Figure 5 by the dashed red lines) for the depth to water table. The results indicate that the computed depth to groundwater level is generally within the target range of +/- 10% when compared to the observed recordings.

In terms of a qualitative assessment of the model simulation, the groundwater model adequately captures both the average water levels and the fluctuations in groundwater elevations in response to recharge. Although, the signal or response of individual recharge events are typically more muted in the modeled hydrograph than in the observed data.

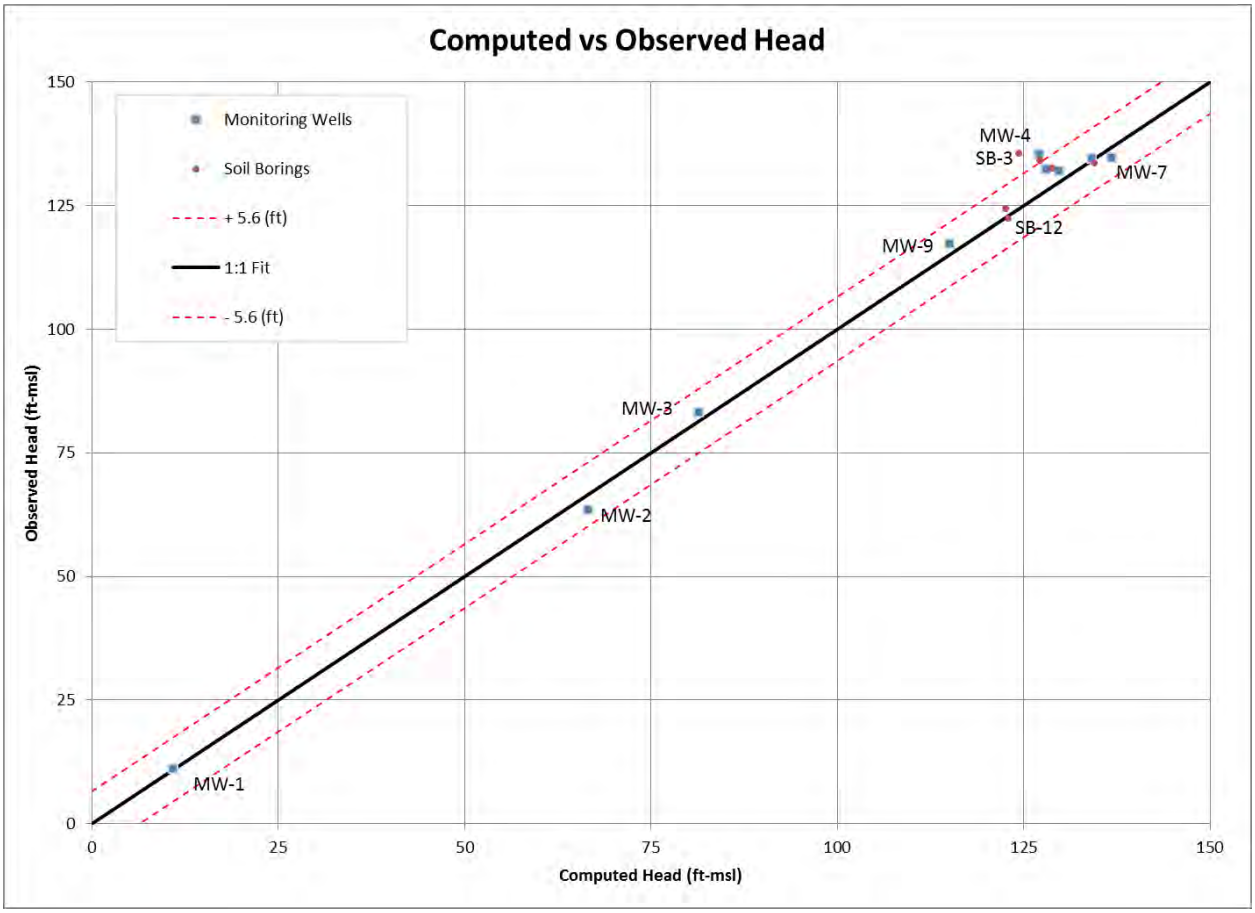


Figure 5 Steady-State Calibration Observed vs. Computed Groundwater Levels

4.7 Assessment of Model Credibility

A third party quality check of the model was completed as part of this project. HydroGeoLogic, Inc. (HGL) a pioneer in the groundwater modeling field since 1987, was hired to complete the review. Several improvements to the model were identified and those changes were incorporated into the model. HGL provided a memo regarding their review which is included in Appendix F.

In response to the comments from the independent model review, by HGL, a sensitivity analysis was performed for both the steady state base condition and transient loading condition. The steady state sensitivity analysis focused on the hydraulic conductivity and recharge rates. The transient model sensitivity was analyzed by varying the specific storage values and calculating the change in predicted groundwater elevations.

The hydraulic conductivity values used in the model were assigned to various zones as shown in Appendix E. The dimensions of the zones were based upon soil sample sieve results and geologic

interpretation of the model domain. The hydraulic conductivity values for each zone were varied by the range of values for the individual zones soil classification. For instance the hydraulic conductivity for dense well graded sand was varied from 0.1 to 50 feet per day. The recharge rate was also varied. The range of infiltration rates was based upon the range of wet weather rainfall from very dry years to above average water years. The recharge rates for the sensitivity analysis were varied from 2 to 20 inches of rainfall per month.

The steady state base conditions model was found to be very sensitive to both of these parameters. The predicted groundwater elevations were increased with greater infiltration rates and lower hydraulic conductivities and decreased with lower infiltration rates and higher hydraulic conductivities. The change in predicted groundwater elevations was as much as 12 feet in some locations for the given parameter values. The hydraulic conductivities used in the model were the result of the calibration process where the difference between the predicted and observed groundwater elevations was minimized using a portion of the actual average rainfall for the observation period. The portion of the rainfall used for infiltration was 4.3 inches per month and was based upon the hydrology model water balance.

The sensitivity analysis for the transient model varied the specific storage of the subsurface soils. The range of specific storage values used in the sensitivity analysis is summarized in Table 11 below.

Table 11 Range of Specific Storage Values[2]

Subsurface soil type	Upper value (ft-1)	Lower value (ft-1)
loose sand	3.05E-04	1.49E-04
dense sand	6.10E-05	3.96E-05
dense sandy gravel	3.05E-05	1.49E-05
rock, fissured jointed	2.10E-05	1.01E-06

[2] Table from Anderson and Woessner (1992)

The modeled response of predicted groundwater elevations with the change in specific storage values varied by location and was greatest in the areas where infiltration galleries and septic leach lines were simulated. The maximum change in predicted groundwater elevation was approximately 4% and decreased with distance away from the infiltration galleries and septic leach lines.

5. Predictive Modeling

As discussed previously, the purpose of the development and calibration of the groundwater model was to have a tool which could be used to evaluate the effects of new stormwater infiltration systems. This section describes how this tool was used for that purpose.

The calibrated groundwater model was first used to calculate a “Base Condition” that represents the subsurface hydrogeologic conditions during a rainy/wet period as the stormwater system exists today. The model was run in a steady state where the input conditions representing a rainy/wet period were held constant.

The “Base Condition” model was then modified to include proposed stormwater infiltration for different design scenarios. Various design scenarios were developed that included diverting portions of stormwater runoff into infiltration areas. The infiltration areas included infiltration chambers, infiltration galleries (a collection of infiltration chambers), swales, and rain gardens. Figure E-6 in Appendix E depicts a typical layout of infiltration areas as they are seen by the model.

The model was then run in a transient mode. The execution of the model in the transient mode allows for multiple time steps with varying input values for each time step. The steady state input conditions representing a rainy/wet period were used for all time steps as the “base” wet period infiltration. Runoff/discharge hydrographs developed with the hydrology model, described in Section 4, were used to estimate infiltration loadings rates for the proposed new infiltration systems. The model then calculates and outputs groundwater levels for each time step.

The infiltration areas are represented in the model using the Well package, similar to the septic system inputs. Injection, rather than extraction wells were used to simulate the stormwater infiltration into the model at the location of each infiltration area. The individual infiltration areas encompass several model nodes and flow to the infiltration area was divided equally and applied to each of the model nodes within the area. The infiltration areas will be sized using the appropriate design methodologies for each infiltration area type and site condition. The model is then executed and the model results evaluated to assess the effects of the proposed infiltration scenario.

The results of the proposed scenario depict the groundwater elevations throughout the site, which may be used to create contours that depict the groundwater flow directions. This information may then be compared with the Base Condition to assess impacts. The groundwater model may also be used to quantify the volume of water exiting at the boundaries of the model. Figure E-7 in Appendix E shows the site with several cross sections depicting the base condition and an example infiltration scenario. The graphs on Figure E-7 show the following:

- Ground surface is represented by green;
- Depth of the septic zone is shown as dotted green line;

- Groundwater elevation for a 50-year event is represented as dark blue with a dotted dark blue line representing the minimum 3-foot separation from septic systems as required by county guidelines;
- Groundwater elevation during a 2-year storm event is shown in light blue; and
- Bedrock surface is shown as red.

This type of graph allows the project designer to easily identify areas of potential impacts to septic systems and geologic features. Overall, the model was used and met its intended purpose as a design tool for the new stormwater infiltration systems.

6. Conclusions

This report summarized the development of a combined hydrology and groundwater model of the City. The model was developed with supporting geologic and hydrologic data to better understand the subsurface geologic processes and to create a predictive tool to be used in the design of new proposed stormwater infiltration systems. Emphasis was first placed on collecting needed data and parameters to build a useful model and then collecting data to calibrate the model. The calibrated model provided a useful tool to evaluate the effects of different infiltration options. An iterative approach to infiltration design was carried out allowing for the development of the conceptual design of infiltration strategies for the Project area.

The hydrology assessment developed runoff or discharge hydrographs for the City. The simulations were based upon historical rainfall records, land cover and use, soil type, and ground slope. Discharge hydrographs were generated for 10 individual sub-watersheds that comprise the City watershed. Discharge hydrographs for a 24-hour storm were developed for 2-, 25-, 50-, and 100-year storm events. The combined peak discharges for all City sub-watersheds ranged from 22.9 cfs for the 2-year storm event up to 76.0 cfs for the 100-year storm event. The resulting discharge hydrographs were used to develop stormwater infiltration design alternatives. These alternatives were also simulated in the groundwater model.

The groundwater model was developed using MODFLOW-Surfact, a 3D flow model that combines surface infiltration and interactions with surface waters, such as rivers, lakes, and oceans. The groundwater model was developed using data and analysis presented in “City of Trinidad ASBS Stormwater Improvement Project Geotechnical Analysis”. The Geotechnical analysis included: review of previous studies and data, field mapping, 19 soil borings, 11 monitoring wells, and seismic refraction and electrical resistance tomography. The model depicts the groundwater system under the City as predominantly an uplifted marine terrace aquifer, comprised of consolidated marine sands, which overlays Franciscan bedrock. Groundwater movement through the sandy aquifer is relatively fast with hydraulic conductivities ranging from 1 to 25 feet per day. The groundwater system under the City is largely isolated by Mill Creek to the north, Parks Creek to the east, Trinidad Bay to the south, and the ocean to the west.

The City groundwater system has only minimal connection to up gradient aquifers. Groundwater inflow to the City groundwater basin comes predominantly from surface infiltration of precipitation and leachate from septic systems. Groundwater entering the system infiltrates vertically through the sandy aquifer until it hits the confining layer (Franciscan bedrock) and then flows laterally along bedrock until it mixes with sub surface ocean/bay groundwater, which then flows into Mill or Parks Creek, or exits through seeps and springs.

The steady state groundwater model was calibrated using groundwater elevation data, from 9 monitoring wells throughout the City. The data was continually collected on 15 minute intervals throughout the wet weather period (November through March). After the model was calibrated it was used to assess various stormwater infiltration design scenarios. To perform the assessment the model was run in transient mode to accurately represent the timing of the design runoff events. The model results depict the groundwater elevations at each time step and the maximum groundwater level predicted for all locations in the model. The model results were then used to assess septic and geotechnical impacts.

The construction, calibration and performance of the model were independently reviewed by HydroGeologic Inc. to confirm that the model was appropriately constructed and executed for this application.

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Appendices

Appendix A

Figures

A-1 Vicinity Map City of Trinidad

A-2 Site Map, Geophysical Transect, Boring, and Monitoring Well Locations

A-3 Mill Creek Watershed Sub-Basins

A-4 City Watershed Sub-Basins

A-5 Parker Creek Watershed Sub-Basins

Phase 1
Phase 2
Area of Special Biological Significance (ASBS)
Project Area
Trinidad City Limits
Humboldt County
Counties

Paper Size ANSI A
0 200 400 600 800
Feet
Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

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City of Trinidad
Trinidad ASBS Stormwater Project
Initial Study and Mitigated Negative Declaration

Job Number	0106311005
Revision	1
Date	15 Oct 2013

Vicinity Map

Figure A-1

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\Figures\FA-1_Vicinity.mxd

718 Third Street Eureka, CA 95501 USA T 707 443 8326 F 707 444 8330 E eureka@ghd.com W www.ghd.com

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Data source: StreetMapUSA, Roads, Boundaries, 2010. Bing Aerials, Aerial Imagery, 2012. City of Trinidad, Area of Special Biological Significance, 2011. Humboldt County, Watersheds, 2011. Created by:amshows

Paper Size 11" x 17" (ANSI B)

0 100 200 300 400 500 600

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Soil Boring

Monitoring Well

Preexisting Monitoring Well

Project Area Boundary

Geophysical Transect
(Seismic Reflection & Electrical Resistivity)

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Site Map, Geophysical Transect, Boring, and Monitoring Well Locations

Figure A-2

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\Figures\FA-2_Site_Map.mxd

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Data source: Bing, Aerial Maps, 2012. GHD Inc., Field Points, 2012. Created by:amshows

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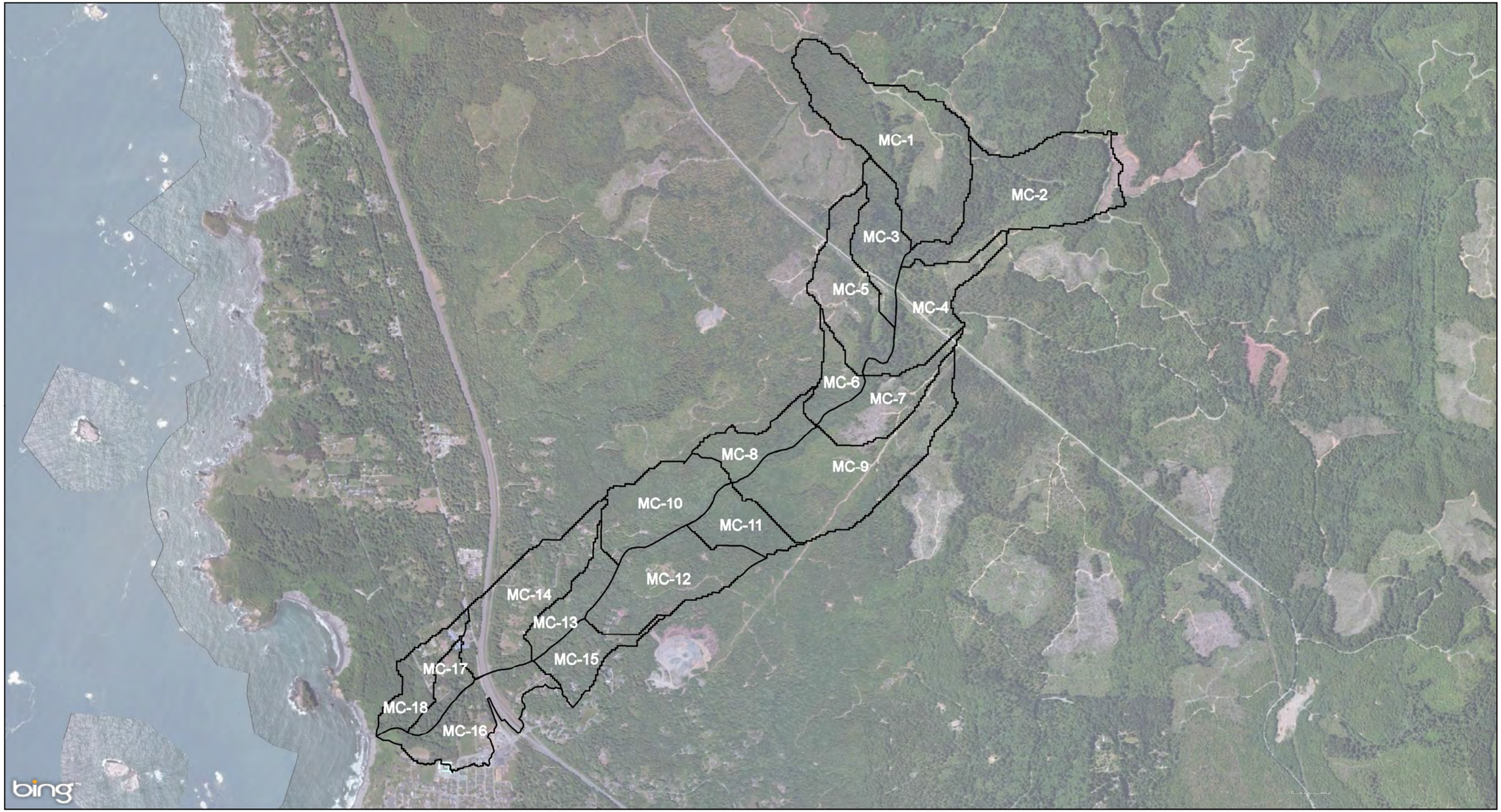

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Mill Creek Sub-Basins

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Mill Creek Watershed Sub-Basins

Figure A-3

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\Figures\FA-3 Mill Creek WS.mxd

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Data source: NOAA, CA Coastal Conservancy Coastal Lidar Project, 2012. GHD Inc., Field Points, 2012. Created by:amshows

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Paper Size 11" x 17" (ANSI B)

0 100 200 300 400 500

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

City Sub-Basins

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

City Watershed Sub-Basins

Figure A-4

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\Figures\FA-4 City Watersheds.mxd

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Data source: NOAA, CA Coastal Conservancy Coastal Lidar Project, 2012. GHD Inc., Field Points, 2012. Created by:amshows

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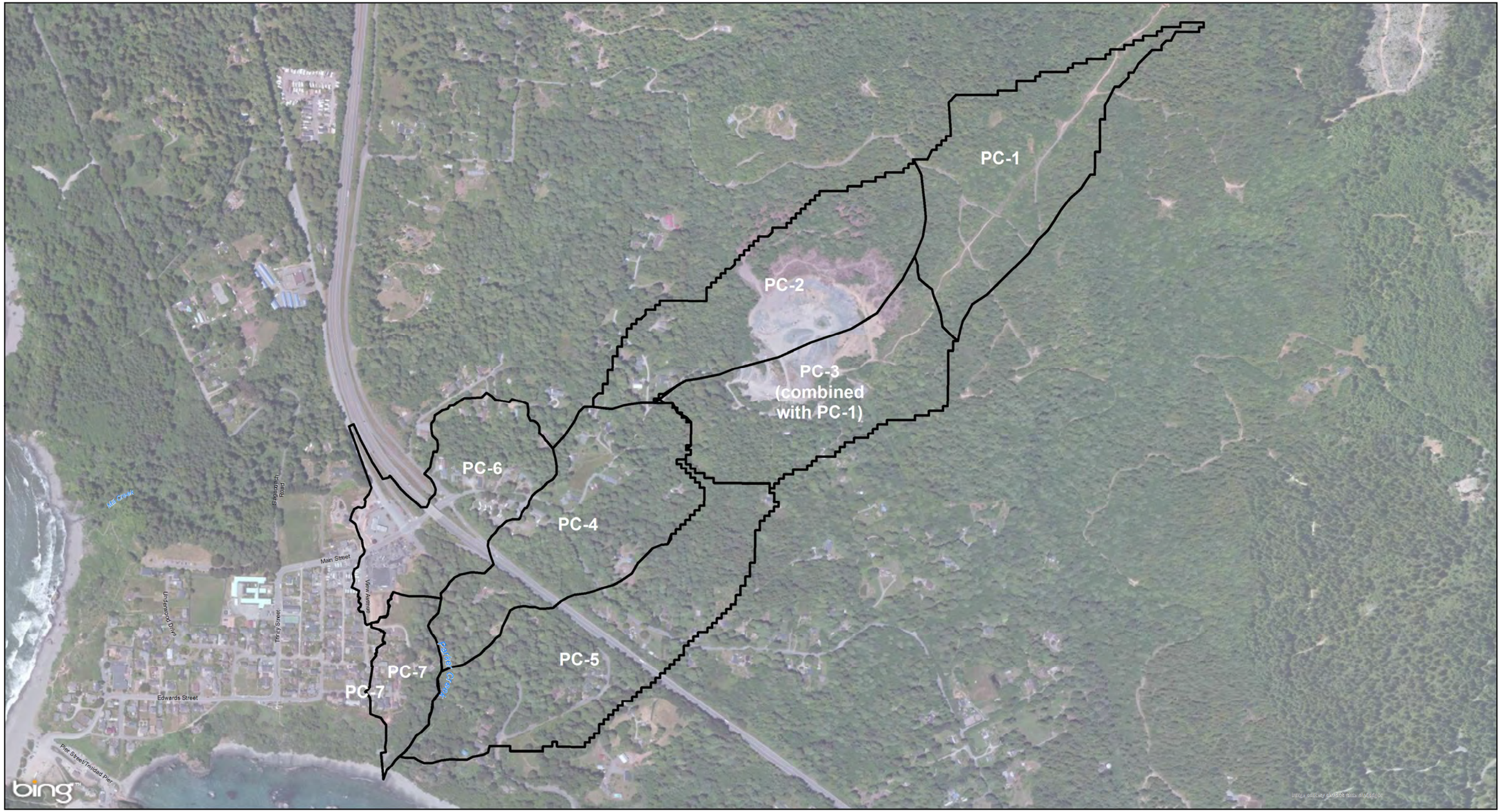

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0 250 500 750 1,000

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Parker Creek Sub-Basins

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Parker Creek Watershed Sub-Basins

Figure A-5

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\Figures\FA-5 Parker Creek Watersheds.mxd

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Data source: NOAA, CA Coastal Conservancy Coastal Lidar Project, 2012. GHD Inc., Field Points, 2012. Created by:amshows

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Appendix B

Groundwater Levels

MW-1 Groundwater Elevation and Precipitation

MW-2 Groundwater Elevation and Precipitation

MW-4 Groundwater Elevation and Precipitation

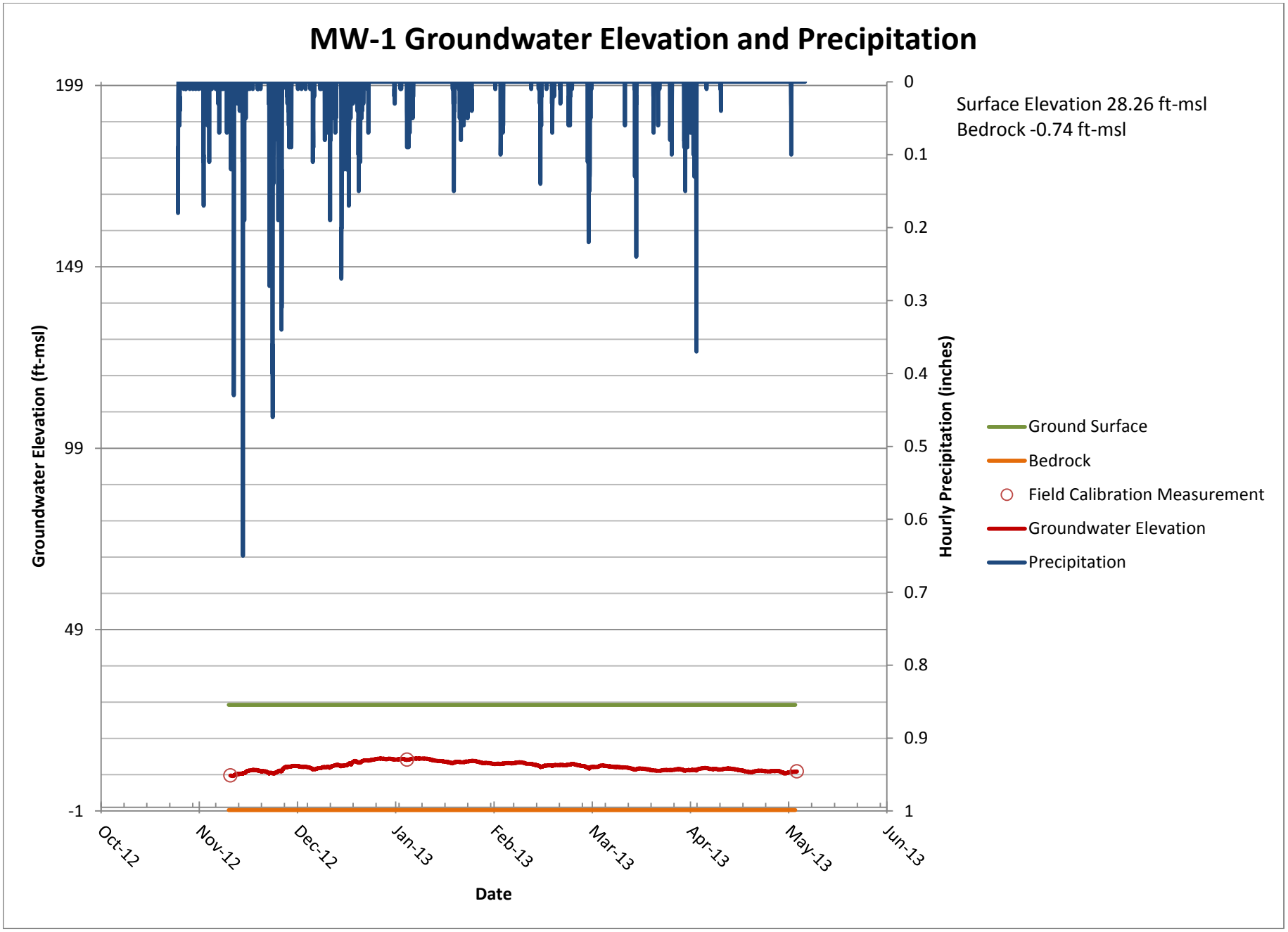
MW-5 Groundwater Elevation and Precipitation

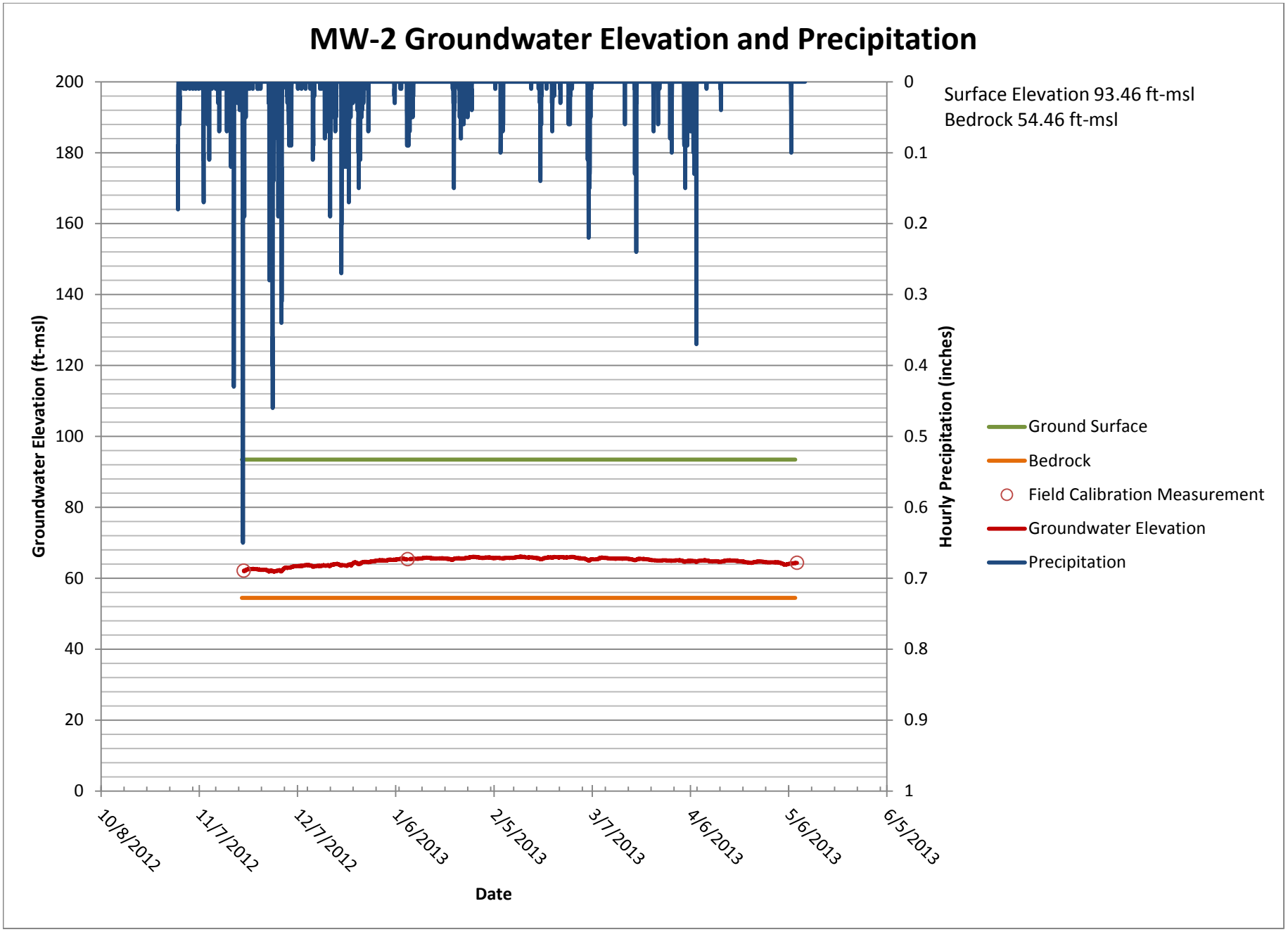
MW-6 Groundwater Elevation and Precipitation

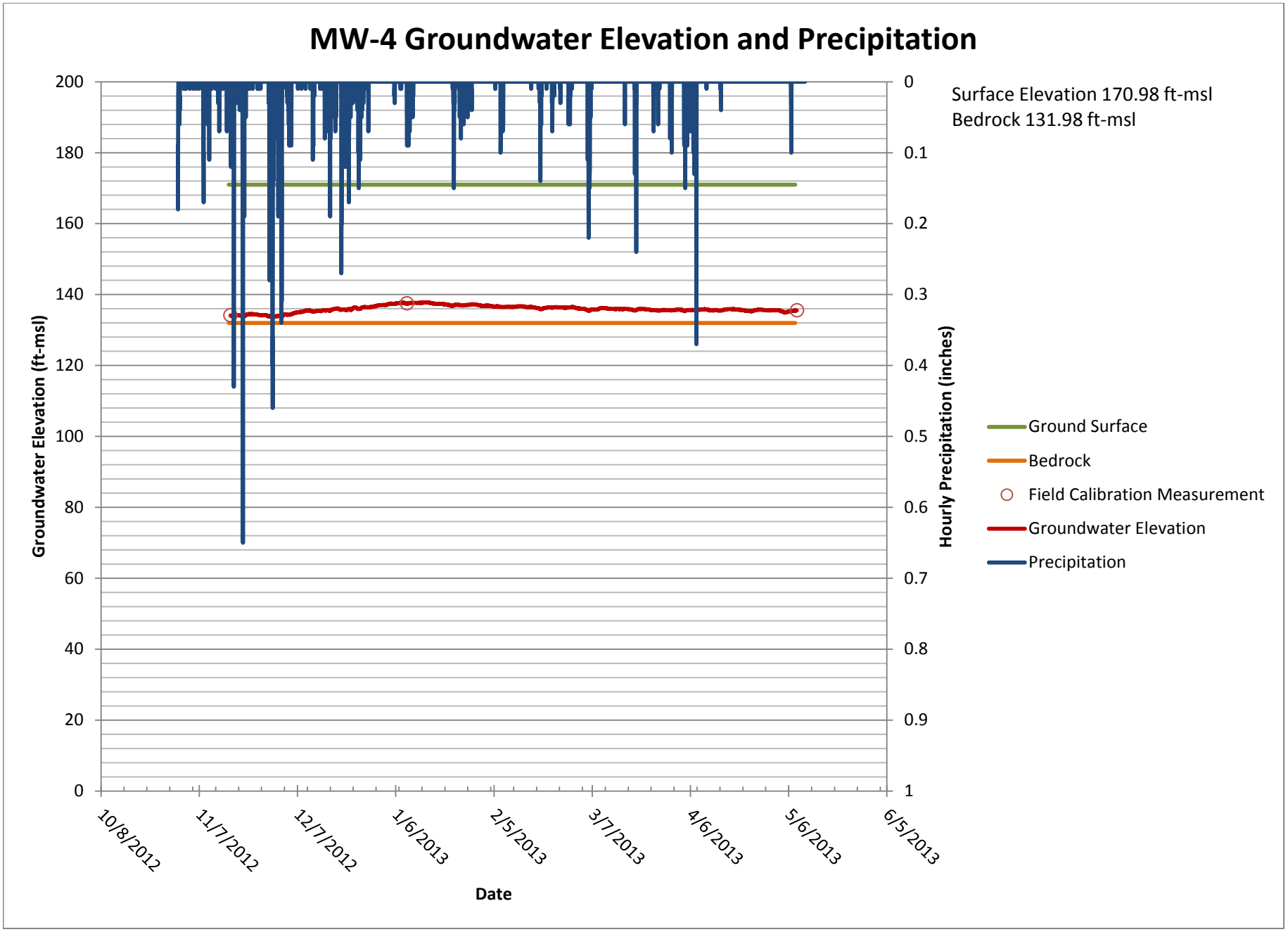
MW-7 Groundwater Elevation and Precipitation

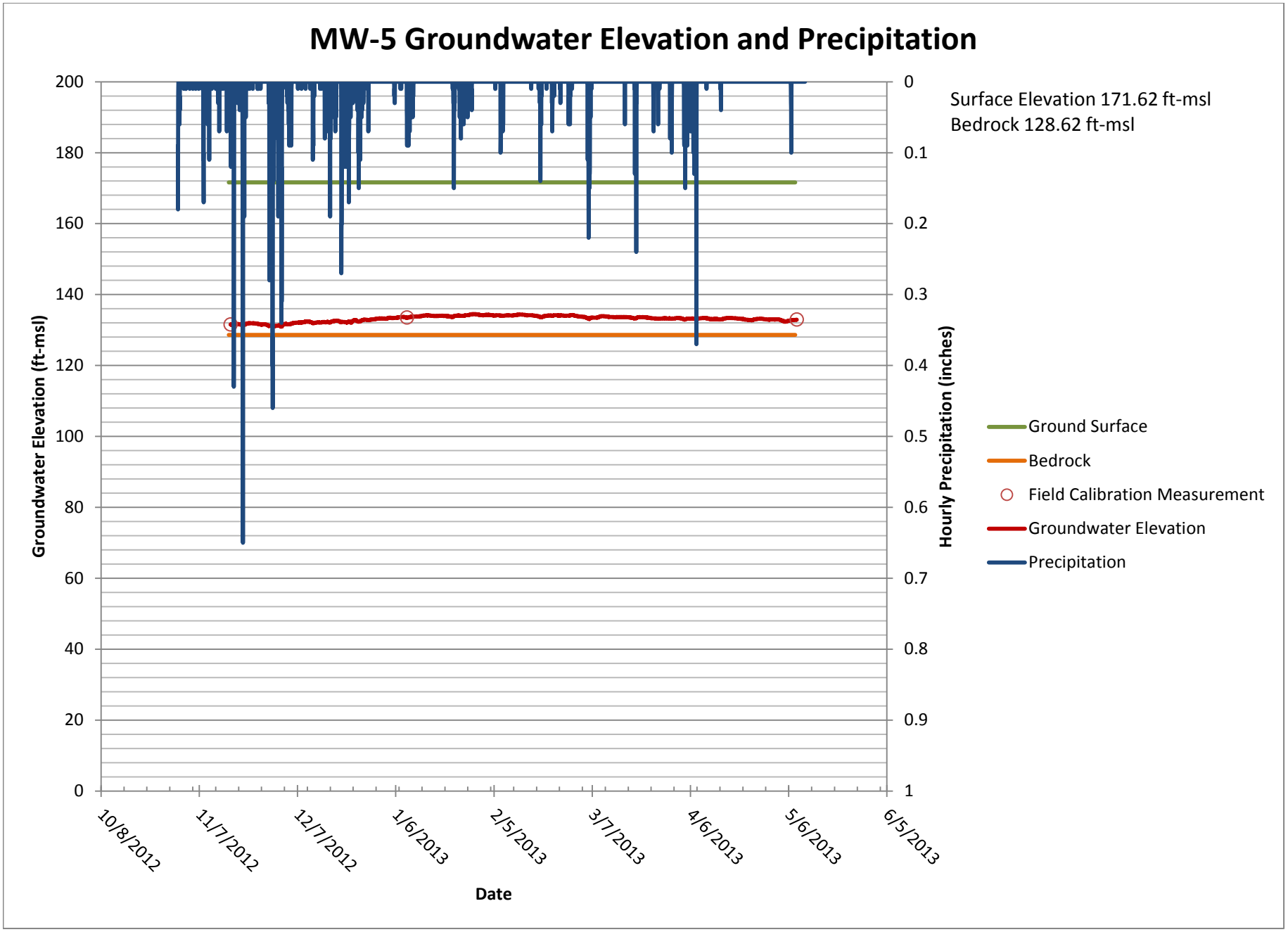
MW-8 Groundwater Elevation and Precipitation

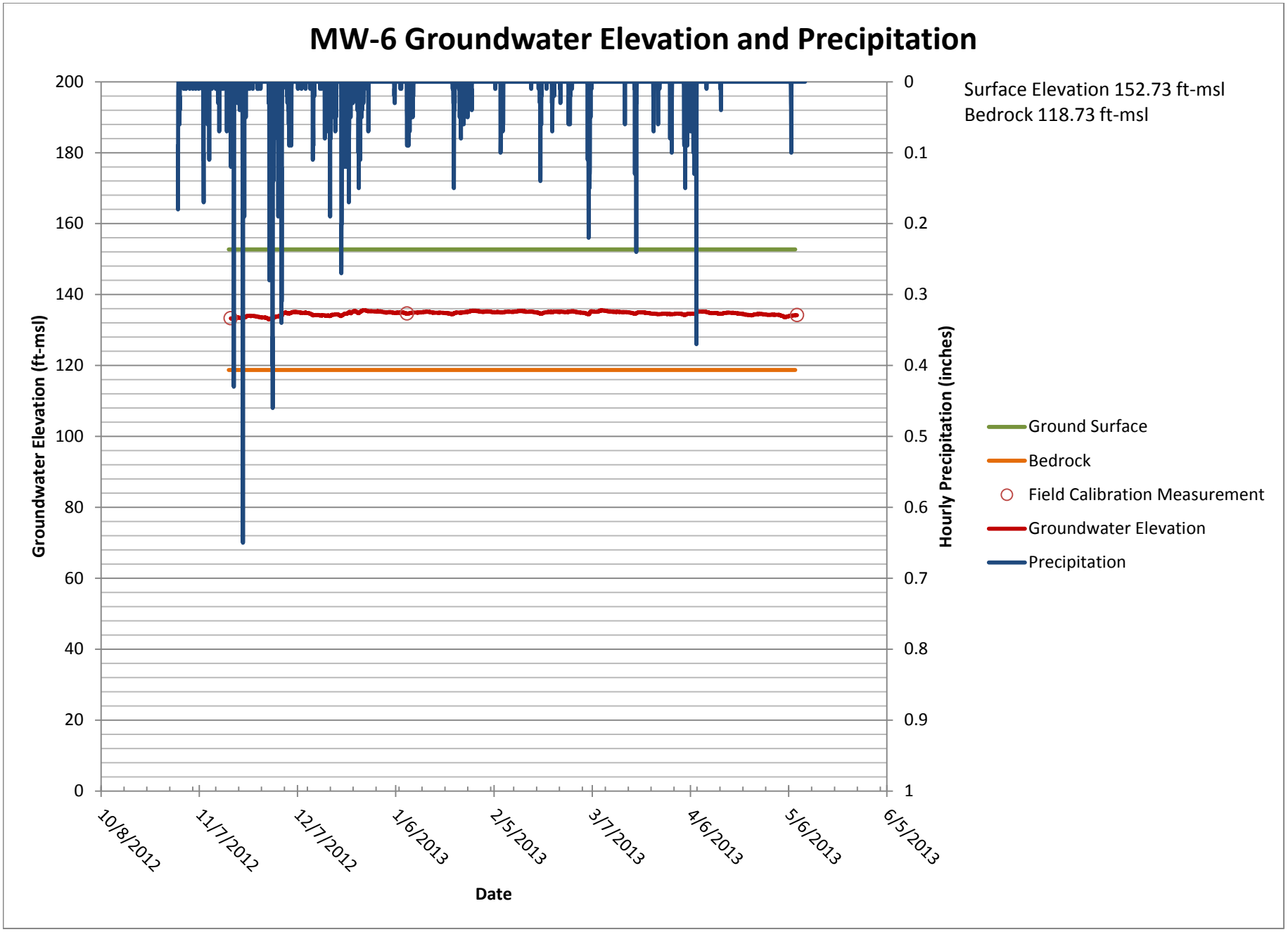
MW-9 Groundwater Elevation and Precipitation

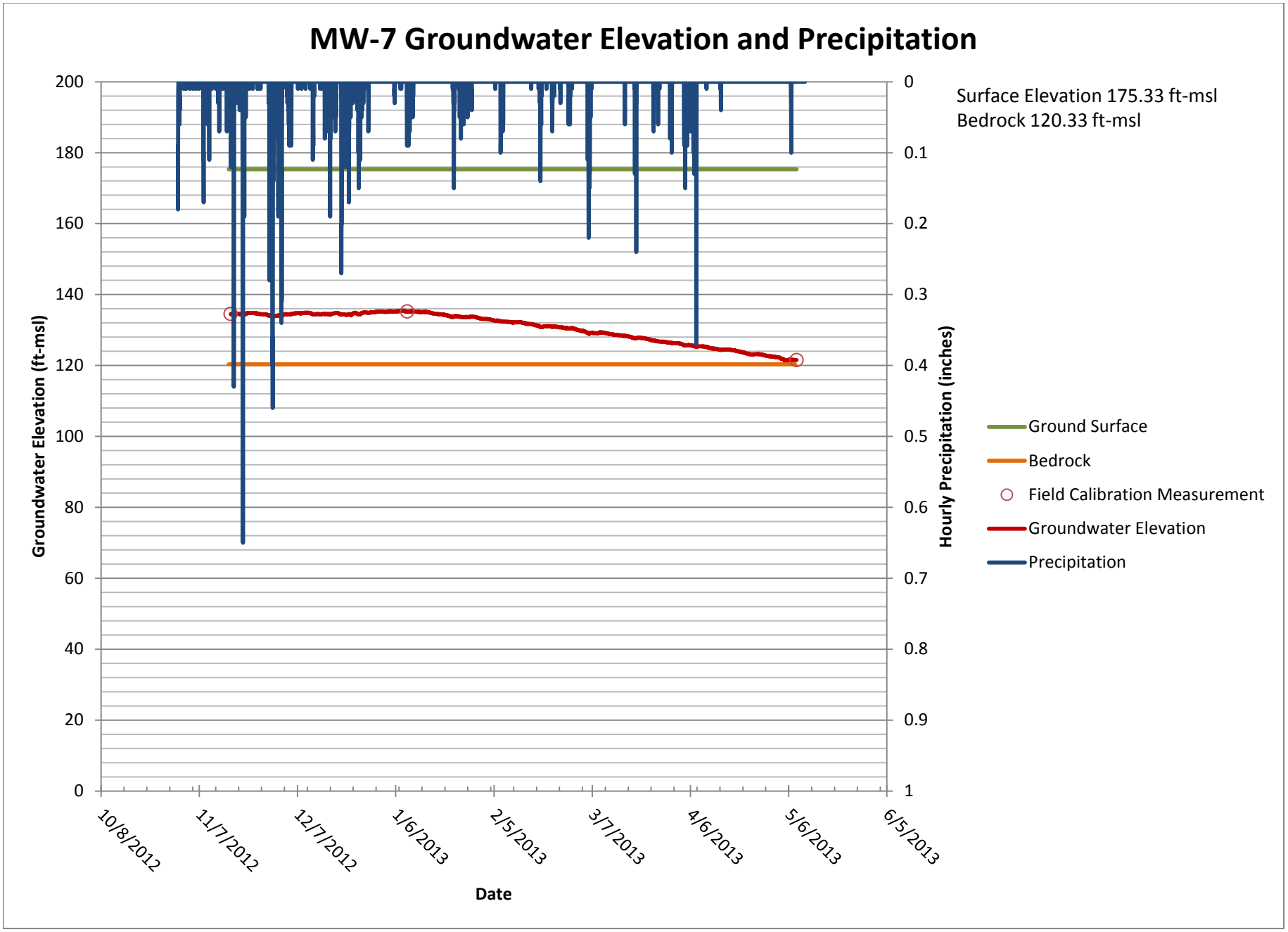

MW-1 Groundwater Elevation and Precipitation
Surface Elevation 28.26 ft-msl
Bedrock -0.74 ft-msl
Groundwater Elevation (ft-msl)
199
149
99
49
-1
Hourly Precipitation (inches)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Date
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation

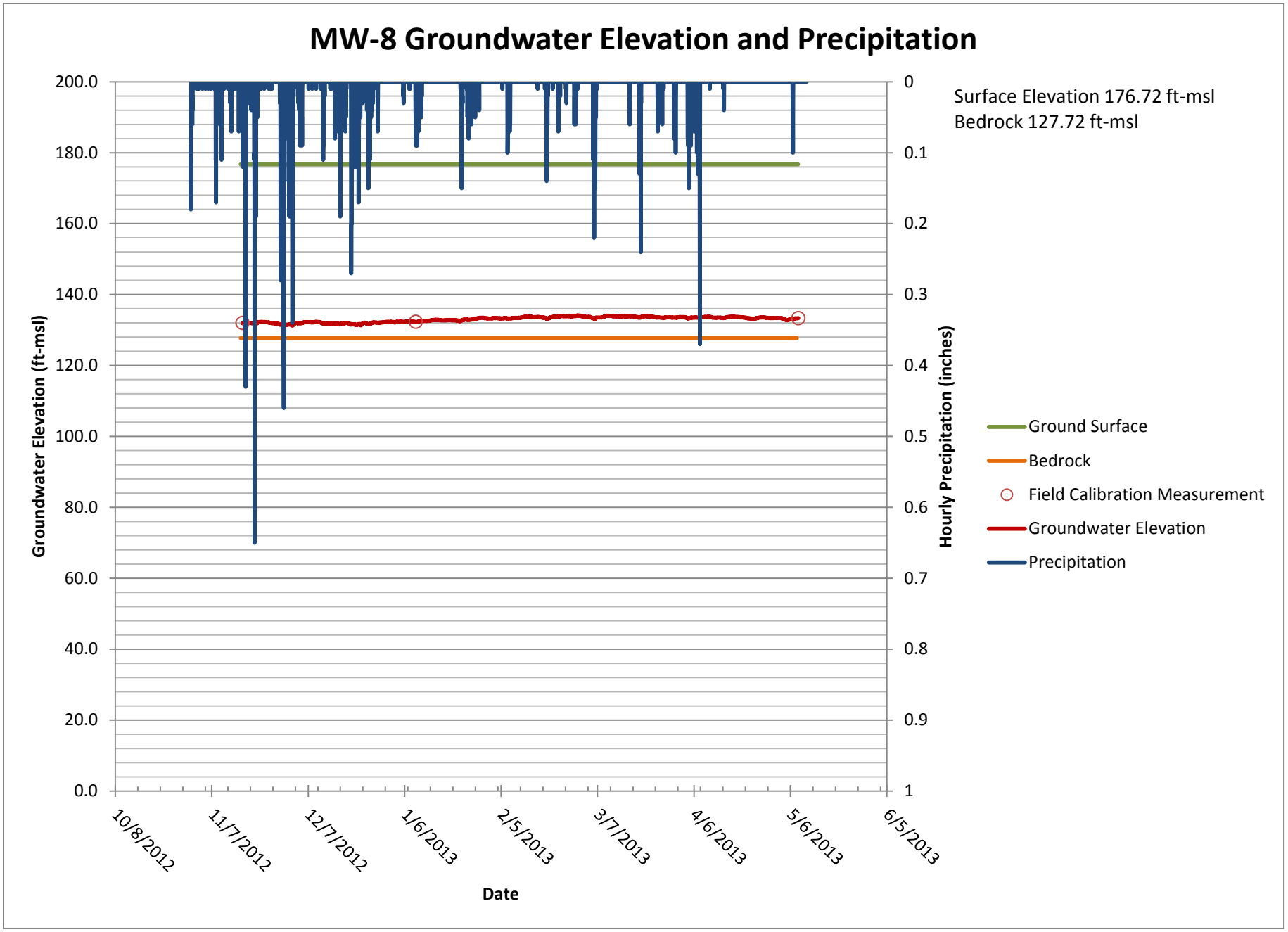

MW-2 Groundwater Elevation and Precipitation
Surface Elevation 93.46 ft-msl
Bedrock 54.46 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation

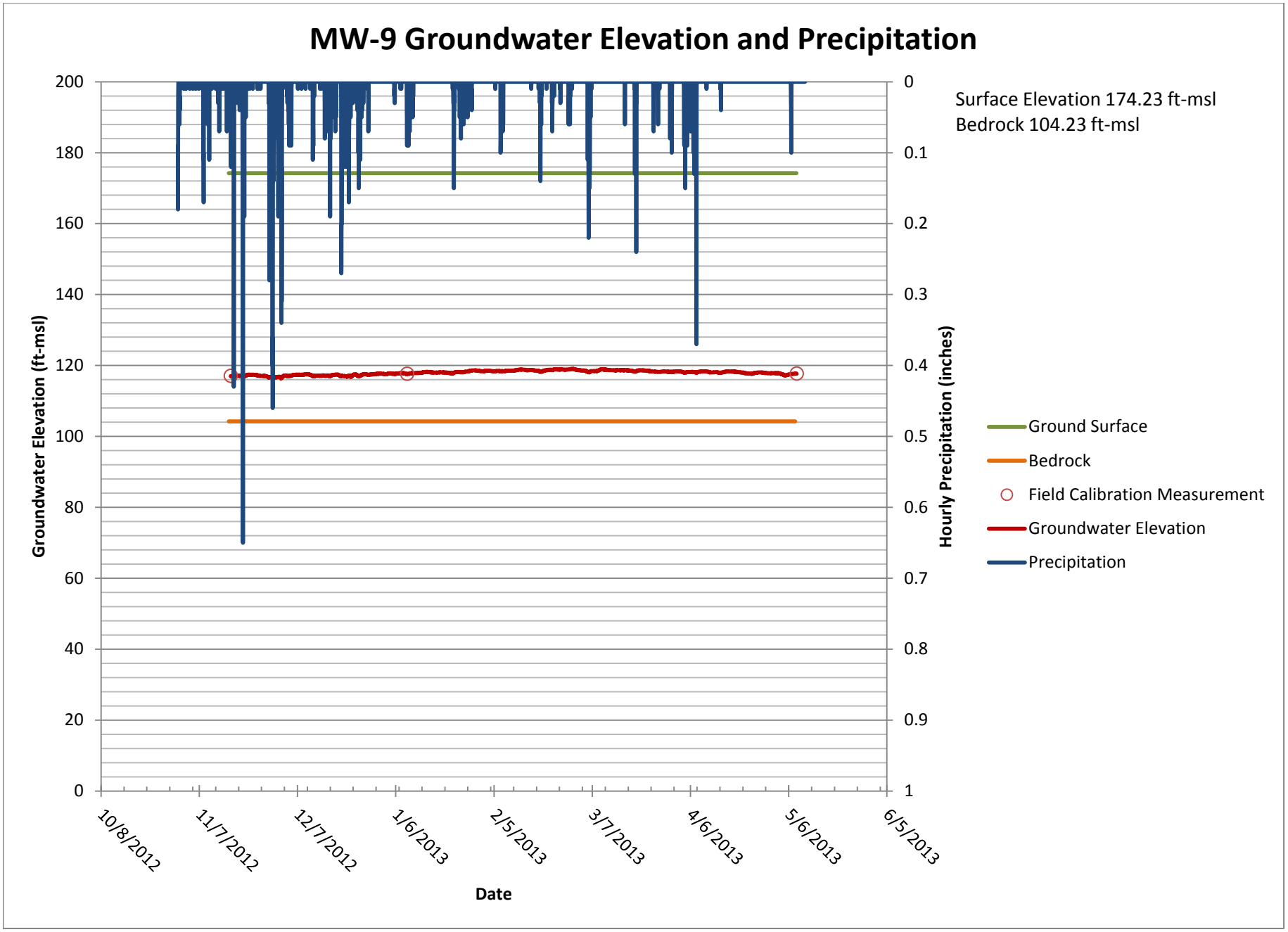

MW-4 Groundwater Elevation and Precipitation
Surface Elevation 170.98 ft-msl
Bedrock 131.98 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation


MW-5 Groundwater Elevation and Precipitation
Surface Elevation 171.62 ft-msl
Bedrock 128.62 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation


MW-6 Groundwater Elevation and Precipitation
Surface Elevation 152.73 ft-msl
Bedrock 118.73 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation


MW-7 Groundwater Elevation and Precipitation
Surface Elevation 175.33 ft-msl
Bedrock 120.33 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation


MW-8 Groundwater Elevation and Precipitation
Surface Elevation 176.72 ft-msl
Bedrock 127.72 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation


MW-9 Groundwater Elevation and Precipitation
Surface Elevation 174.23 ft-msl
Bedrock 104.23 ft-msl
Groundwater Elevation (ft-msl)
Hourly Precipitation (inches)
Date
200
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013
5/6/2013
6/5/2013
Ground Surface
Bedrock
Field Calibration Measurement
Groundwater Elevation
Precipitation

Appendix C

HEC-HMS Inputs

SCS CURVE NUMBER CALCULATION
Trinidad ASBS--Mill Creek

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-1	4.84E+06	0.174	Forest		0.00%	30		0.00%	55	3807835.14	78.72%	70		0.00%	77	3807835.137	78.72%	55.1
			Grassland		0.00%	39		0.00%	61	904694	18.70%	74		0.00%	80	904693.800	18.70%	13.8
			Impervious		0.00%	98		0.00%	98	124703.209	2.58%	98		0.00%	98	124703.209	2.58%	2.5
			Residential Estates (1 acre min.)		0.00%	51		0.00%	68		0.00%	79		0.00%	84	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		4837232.146	100.00%		0.000	0.00%		4837232.146	100.00%	71

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-2	4.00E+06	0.144	Forest		0.00%	30		0.00%	55	3208383.20	80.17%	70		0.00%	77	3208383.200	80.17%	56.1
			Grassland		0.00%	39		0.00%	61	668028.78	16.69%	74		0.00%	80	668028.779	16.69%	12.4
			Impervious		0.00%	98		0.00%	98	124975.05	3.12%	98		0.00%	98	124975.048	3.12%	3.1
			Residential Estates (1 acre min.)		0.00%	51		0.00%	68		0.00%	79		0.00%	84	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		4001387.027	99.98%		0.000	0.00%		4001387.027	99.98%	72

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-3	1519954.89	0.055	Forest		0.00%	30		0.00%	55	1429149.09	94.03%	70		0.00%	77	1429149.085	94.03%	65.8
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98	25749.65	1.69%	98		0.00%	98	25749.653	1.69%	1.7
			Gravel		0.00%	76		0.00%	85	65056.15	4.28%	89		0.00%	91	65056.150	4.28%	3.8
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		1519954.888	100.00%		0.000	0.00%		1519954.888	100.00%	71

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-4	2040508.88	0.073	Forest		0.00%	30		0.00%	55	1484696.26	72.76%	70		0.00%	77	1484696.260	72.76%	50.9
			Grassland		0.00%	39		0.00%	61	407954.00	19.99%	74		0.00%	80	407954.000	19.99%	14.8
			Impervious		0.00%	98		0.00%	98	64168.22	3.14%	98		0.00%	98	64168.219	3.14%	3.1
			Gravel		0.00%	76		0.00%	85	83690.40	4.10%	89		0.00%	91	83690.400	4.10%	3.7
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		2040508.879	100.00%		0.000	0.00%		2040508.879	100.00%	72

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-5	3931766.26	0.141	Forest		0.00%	30		0.00%	55	2828290.26	71.93%	70		0.00%	77	2828290.260	71.93%	50.4
			Grassland		0.00%	39		0.00%	61	65998.00	1.68%	74		0.00%	80	65998.000	1.68%	1.2
			Impervious		0.00%	98		0.00%	98	20805.39	0.53%	98		0.00%	98	20805.390	0.53%	0.5
			Gravel		0.00%	76		0.00%	85	1016672.61	25.86%	89		0.00%	91	1016672.615	25.86%	23.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		3931766.265	100.00%		0.000	0.00%		3931766.265	100.00%	75

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-6	773219.41	0.028	Forest		0.00%	30		0.00%	55	753943.10	97.51%	70		0.00%	77	753943.104	97.51%	68.3
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85	19276.31	2.49%	89		0.00%	91	19276.310	2.49%	2.2
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		773219.414	100.00%		0.000	0.00%		773219.414	100.00%	70

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-7	1579745.28	0.057	Forest		0.00%	30		0.00%	55	1045762.21	66.20%	70		0.00%	77	1045762.207	66.20%	46.3
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98	23297.45	1.47%	98		0.00%	98	23297.455	1.47%	1.4
			Gravel		0.00%	76		0.00%	85	510685.62	32.33%	89		0.00%	91	510685.622	32.33%	28.8
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		1579745.284	100.00%		0.000	0.00%		1579745.284	100.00%	77

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-8	1146001.21	0.041	Forest		0.00%	30		0.00%	55	1146001.21	100.00%	70		0.00%	77	1146001.208	100.00%	70.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		1146001.208	100.00%		0.000	0.00%		1146001.208	100.00%	70

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-9	4280677.41	0.154	Forest		0.00%	30		0.00%	55	3314125.24	77.42%	70		0.00%	77	3314125.238	77.42%	54.2
			Grassland		0.00%	39		0.00%	61	819195.20	19.14%	74		0.00%	80	819195.197	19.14%	14.2
			Impervious		0.00%	98		0.00%	98	74286	1.74%	98		0.00%	98	74285.538	1.74%	1.7
			Gravel		0.00%	76		0.00%	85	73071.44	1.71%	89		0.00%	91	73071.440	1.71%	1.5
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		4280677.413	100.00%		0.000	0.00%		4280677.413	100.00%	72

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
MC-10	2226775.46	0.080	Forest		0.00%	30		0.00%	55	2203847.48	98.97%	70		0.00%	77	2203847.475	98.97%	69.3
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98	22927.98	1.03%	98		0.00%	98	22927.980	1.03%	1.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		2226775.455	100.00%		0.000	0.00%		2226775.455	100.00%	70

SCS CURVE NUMBER CALCULATION
Trinidad ASBS--City Shed

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-1	2.87E+05	0.010	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	287287.91	100.00%	61		0.00%	75		0.00%	83		0.00%	87	287287.913	100.00%	61.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	287287.913	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		287287.913	100.00%	61

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-2	2.05E+05	0.007	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	205013.479	100.00%	61		0.00%	75		0.00%	83		0.00%	87	205013.479	100.00%	61.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	205013.479	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		205013.479	100.00%	61

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-3	153579.352	0.006	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	67956.352	44.25%	61		0.00%	75		0.00%	83		0.00%	87	67956.352	44.25%	27.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial	85623.000	55.75%	89		0.00%	92		0.00%	94		0.00%	95	85623.000	55.75%	49.6
			SUBTOTALS	153579.352	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		153579.352	100.00%	77

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-4	129677.692	0.005	Forest	43145.692	33.27%	30		0.00%	55		0.00%	70		0.00%	77	43145.692	33.27%	10.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	86532.000	66.73%	61		0.00%	75		0.00%	83		0.00%	87	86532.000	66.73%	40.7
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	129677.692	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		129677.692	100.00%	51

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-5	282239.366	0.010	Forest	160893.366	57.01%	30		0.00%	55		0.00%	70		0.00%	77	160893.366	57.01%	17.1
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	121346.000	42.99%	61		0.00%	75		0.00%	83		0.00%	87	121346.000	42.99%	26.2
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	282239.366	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		282239.366	100.00%	43

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-6	112606.198	0.004	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	112606.198	100.00%	61		0.00%	75		0.00%	83		0.00%	87	112606.198	100.00%	61.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	112606.198	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		112606.198	100.00%	61

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-7	230971.514	0.008	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	201546.000	87.26%	61		0.00%	75		0.00%	83		0.00%	87	201546.000	87.26%	53.2
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial	29425.514	12.74%	89		0.00%	92		0.00%	94		0.00%	95	29425.514	12.74%	11.3
			SUBTOTALS	230971.514	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		230971.514	100.00%	65

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-8	88446.698	0.003	Forest		0.00%	30		0.00%	55		0.00%	70		0.00%	77	0.000	0.00%	0.0
			Grassland	8046.000	9.10%	39		0.00%	61		0.00%	74		0.00%	80	8046.000	9.10%	3.5
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	80400.698	90.90%	61		0.00%	75		0.00%	83		0.00%	87	80400.698	90.90%	55.5
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	88446.698	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		88446.698	100.00%	59

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
CT-9	264478.985	0.009	Forest	108436.384	41.00%	30		0.00%	55		0.00%	70		0.00%	77	108436.384	41.00%	12.3
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98		0.00%	98		0.00%	98	0.000	0.00%	0.0
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)	95212.435	36.00%	61		0.00%	75		0.00%	83		0.00%	87	95212.435	36.00%	22.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial	60830.167	23.00%	89		0.00%	92		0.00%	94		0.00%	95	60830.167	23.00%	20.5
			SUBTOTALS	264478.985	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		264478.985	100.00%	55

SCS CURVE NUMBER CALCULATION
Trinidad ASBS--Parker Creek

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-1	2.74E+06	0.098	Forest		0.00%	30		0.00%	55	2213468.400	80.68%	70		0.00%	77	2213468.400	80.68%	56.5
			Grassland		0.00%	39		0.00%	61	91002.370	3.32%	74		0.00%	80	91002.370	3.32%	2.5
			Impervious		0.00%	98		0.00%	98	92943.882	3.39%	98		0.00%	98	92943.882	3.39%	3.3
			Gravel		0.00%	76		0.00%	85	345994.420	12.61%	89		0.00%	91	345994.420	12.61%	11.2
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		2743409.072	100.00%		0.000	0.00%		2743409.072	100.00%	73

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-2	2.09E+06	0.075	Forest		0.00%	30		0.00%	55	1487435.210	71.20%	70		0.00%	77	1487435.210	71.20%	49.8
			Grassland		0.00%	39		0.00%	61		0.00%	74		0.00%	80	0.000	0.00%	0.0
			Impervious		0.00%	98		0.00%	98	66510.764	3.18%	98		0.00%	98	66510.764	3.18%	3.1
			Gravel		0.00%	76		0.00%	85	535195.610	25.62%	89		0.00%	91	535195.610	25.62%	22.8
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		2089141.584	100.00%		0.000	0.00%		2089141.584	100.00%	76

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-4	1641258.005	0.059	Forest		0.00%	30		0.00%	55	1315222.643	80.14%	70		0.00%	77	1315222.643	80.14%	56.1
			Grassland		0.00%	39		0.00%	61	152587.466	9.30%	74		0.00%	80	152587.466	9.30%	6.9
			Impervious		0.00%	98		0.00%	98	155515.131	9.48%	98		0.00%	98	155515.131	9.48%	9.3
			Gravel		0.00%	76		0.00%	85	17932.765	1.09%	89		0.00%	91	17932.765	1.09%	1.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	0.000	0.00%		0.000	0.00%		1641258.005	100.00%		0.000	0.00%		1641258.005	100.00%	73

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-5	2075751.651	0.074	Forest	1033691.216	49.80%	30		0.00%	55	718327.794	34.61%	70		0.00%	77	1752019.011	84.40%	39.2
			Grassland	80107.979	3.86%	39		0.00%	61	55668.256	2.68%	74		0.00%	80	135776.235	6.54%	3.5
			Impervious	110894.279	5.34%	98		0.00%	98	77062.126	3.71%	98		0.00%	98	187956.405	9.05%	8.9
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	1224693.474	59.00%		0.000	0.00%		851058.177	41.00%		0.000	0.00%		2075751.651	100.00%	52

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-6	1248679.409	0.045	Forest	342722.281	27.45%	30		0.00%	55	258544.878	20.71%	70		0.00%	77	601267.159	48.15%	22.7
			Grassland	114527.789	9.17%	39		0.00%	61	86398.157	6.92%	74		0.00%	80	200925.946	16.09%	8.7
			Impervious	230630.316	18.47%	98		0.00%	98	173984.274	13.93%	98		0.00%	98	404614.590	32.40%	31.8
			Gravel	23866.877	1.91%	76		0.00%	85	18004.837	1.44%	89		0.00%	91	41871.715	3.35%	2.7
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70	0.000	0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	711747.263	57.00%		0.000	0.00%		536932.146	43.00%		0.000	0.00%		1248679.409	100.00%	66

Basin	Total Area ft2	Total Area mi2	Land Use	CN (AMC II) A		CN	B		CN	C		CN	D		CN	SUBTOTALS Area (ft2)	SUBTOTALS %	COMPOSITE CN
PC-7	428676.519	0.015	Forest	210513.170	49.11%	30		0.00%	55		0.00%	70		0.00%	77	210513.170	49.11%	14.7
			Grassland	147026.830	34.30%	39		0.00%	61		0.00%	74		0.00%	80	147026.830	34.30%	13.4
			Impervious	71136.519	16.59%	98		0.00%	98		0.00%	98		0.00%	98	71136.519	16.59%	16.3
			Gravel		0.00%	76		0.00%	85		0.00%	89		0.00%	91	0.000	0.00%	0.0
			Residential Estates (1/2 acre min.)		0.00%	54		0.00%	70		0.00%	80		0.00%	85	0.000	0.00%	0.0
			Residential Single Family (10,000 ft2 min.)		0.00%	57		0.00%	72		0.00%	81		0.00%	86	0.000	0.00%	0.0
			Residential Single Family (6,000 ft2 min.)		0.00%	61		0.00%	75		0.00%	83		0.00%	87	0.000	0.00%	0.0
			Multi-Family Residential, Res. (6,000 ft2 min.)		0.00%	77		0.00%	85		0.00%	90		0.00%	92	0.000	0.00%	0.0
			Industrial		0.00%	81		0.00%	88		0.00%	91		0.00%	93	0.000	0.00%	0.0
			Commercial		0.00%	89		0.00%	92		0.00%	94		0.00%	95	0.000	0.00%	0.0
			SUBTOTALS	428676.519	100.00%		0.000	0.00%		0.000	0.00%		0.000	0.00%		428676.519	100.00%	44

TR-55 Worksheet: Time of Concentration (Tc) or Travel Time
SCS Lag Time Calculation
Trinidad ASBS

SUBBASIN FLOW PATH		MC-1	MC-2	MC-3	MC-4	MC-5	MC-6	MC-7	MC-8	MC-9	MC-10	MC-11	MC-12	MC-13	MC-14	MC-15	MC-16	MC-17	MC-18	PC-1	PC-2	PC-3
Sheet Flow (applicable to Tc only)																						
1. Surface Description (table 3-1)		Forest	Forest	Forest	Grass	Forest	Grass	Forest	Forest	Grass	Forest	Grass	Forest	Forest	Forest	Grass	Grass	Grass	Grass	Forest	Forest	
2. Mannings Roughness Coeff., n (Table 3-1)		0.4	0.4	0.4	0.24	0.4	0.011	0.4	0.4	0.24	0.4	0.24	0.4	0.4	0.4	0.24	0.24	0.24	0.24	0.4	0.4	
3. Flow Length, L (total L ≤ 300 ft)		300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	
4. Two-yr 24-hr rainfall, P_2		3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	Deleted From Model
Top Elevation		405	405	307	295	290	250	256	207	243	202	200	197	145	162	120	50	63	68	200	197	
Bottom Elevation		380	397	293	270	280	240	243	198	238	188	195	185	123	145	110	47	60	65	200	195	
5. Land Slope, s		0.0833333	0.02667	0.04667	0.08333	0.03333	0.03333	0.04333	0.03	0.01667	0.04667	0.01667	0.04	0.07333	0.05667	0.03333	0.01	0.01	0.01	0.02	0.00667	
6. Tt = ((.007*(nL)^.8)/((P_2^.5)*(s^.4))	(hr)	**0.45**	**0.71**	**0.57**	**0.30**	**0.65**	**0.04**	**0.58**	**0.68**	**0.57**	**0.57**	**0.57**	**0.60**	**0.47**	**0.52**	**0.43**	**0.70**	**0.70**	**0.70**	**0.80**	**1.24**	
Shallow Concentrated Flow 1																						
7. Surface Description (paved or unpaved)		unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	
8. Flow Length, L		3846	866	1970	1844	3003	1369	1762	799	4797	947	1510	2769	1140	3305	1511	953	792	2024	4763	3861	
Top Elevation		380	397	293	270	280	240	243	198	238	188	195	185	123	145	110	47	60	65	200	195	
Bottom Elevation		243	310	235	235	200	195	200	143	145	104	120	67	67	40	65	20	35	15	136	83	
9. Watercourse slope, s		0.0356214	0.10046	0.02944	0.01898	0.02664	0.03287	0.0244	0.06884	0.01939	0.0887	0.04967	0.04261	0.04912	0.03177	0.02978	0.02833	0.03157	0.0247	0.01344	0.02901	
10. Average veolocity, Vp	(ft/s)	3.05	5.11	2.77	2.22	2.63	2.93	2.52	4.23	2.25	4.81	3.60	3.33	3.58	2.88	2.78	2.72	2.87	2.54	1.87	2.75	
11. Tt = (L)/3600*V	(hr)	**0.351**	**0.047**	**0.198**	**0.230**	**0.317**	**0.130**	**0.194**	**0.052**	**0.593**	**0.055**	**0.117**	**0.231**	**0.089**	**0.319**	**0.151**	**0.097**	**0.077**	**0.222**	**0.707**	**0.390**	
Shallow Concentrated Flow 2																						
7. Surface Description (paved or unpaved)		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
8. Flow Length, L		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Top Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Bottom Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
9. Watercourse slope, s		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
10. Average veolocity, Vp	(ft/s)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
11. Tt = (L)/3600*V	(hr)	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
Channel Flow																						
12. Channel roughness, n		na	0.05	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
13. Cross sectional flow area, a		na	28.00	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
14. Wetted Perimeter, Pw		na	18.00	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
15. Hydraulic radius, r=a/Pw		na	1.56	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Top Elevation		na	310	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Bottom Elevation		na	125	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
16. Channel slope, s		na	0.06187	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
17. V=(1.49*r^.67*s^.5)/n		na	9.97	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
18. Flow Length, L		na	2990	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
19. Tt = L/3600*v	(hr)	**0.000**	**0.083**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
Pipe 1 Flow																						
12. Pipe roughness, n		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
13. Pipe Diameter (ft)		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
14. Hydraulic radius, r=(D/4)		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Top Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Bottom Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
15. Pipe slope, s		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
17. V=(1.49/n)(r^.667)(s^.5)	(ft/s)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
18. Flow Length, L		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
19. Tt = L/3600*v	(hr)	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
Pipe 2 Flow																						
12. Pipe roughness, n		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
13. Pipe Diameter (ft)		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
14. Hydraulic radius, r=(D/4)		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Top Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
Bottom Elevation		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
15. Pipe slope, s		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
17. V=(1.49/n)(r^.667)(s^.5)	(ft/s)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
18. Flow Length, L		na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	
19. Tt = L/3600*v	(hr)	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	
20. Total Basin Tc	(hr)	**0.80**	**0.84**	**0.76**	**0.53**	**0.97**	**0.17**	**0.78**	**0.73**	**1.16**	**0.62**	**0.69**	**0.83**	**0.56**	**0.84**	**0.58**	**0.80**	**0.77**	**0.92**	**1.50**	**1.63**	
21. Tlag = .6*Tt	(min)	**29**	**30**	**28**	**19**	**35**	**6**	**28**	**26**	**42**	**22**	**25**	**30**	**20**	**30**	**21**	**29**	**28**	**33**	**54**	**59**	

SUBBASIN FLOW PATH		PC-4	PC-5	PC-6	PC-7	PC-8	CT-1	CT-2	CT-3	CT-4	CT-5	CT-6
Sheet Flow (applicable to Tc only)												
1. Surface Description (table 3-1)		Forest	Forest	Forest	Paved	Forest	Paved	Paved	Paved	Paved	Grass	Grass
2. Mannings Roughness Coeff., n (Table 3-1)		0.4	0.4	0.4	0.011	0.4	0.011	0.011	0.011	0.011	0.24	0.24
3. Flow Length, L (total L ≤ 300 ft)		300	300	300	300	300	300	300	300	300	300	130
4. Two-yr 24-hr rainfall, P_2		3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
Top Elevation		96	96	80	55	68	49	53	54	52	53	52
Bottom Elevation		80	90	73	51	63	46	51	52	50	48	50
5. Land Slope, s		0.05333	0.02	0.02333	0.01333	0.01667	0.01	0.00667	0.00667	0.00667	0.01667	0.01538
6. Tt = ((.007*(nL)^.8)/((P_2^.5)*(s^.4))	(hr)	**0.54**	**0.80**	**0.75**	**0.05**	**0.86**	**0.06**	**0.07**	**0.07**	**0.07**	**0.57**	**0.30**
Shallow Concentrated Flow 1												
7. Surface Description (paved or unpaved)		unpaved	unpaved	unpaved	unpaved	unpaved	unpaved	paved	paved	paved	unpaved	unpaved
8. Flow Length, L		1241	1800	470	617	596	611	293	681	330	755	427
Top Elevation		80	90	73	51	63	46	51	52	50	48	50
Bottom Elevation		63	59	63	45	45	45	50	50	45	35	40
9. Watercourse slope, s		0.0137	0.01722	0.02128	0.00972	0.0302	0.00164	0.00341	0.00294	0.01515	0.01722	0.02342
10. Average veolocity, Vp	(ft/s)	1.89	2.12	2.35	1.59	2.80	0.65	1.19	1.10	2.50	2.12	2.47
11. Tt = (L)/3600*V	(hr)	**0.183**	**0.236**	**0.055**	**0.108**	**0.059**	**0.260**	**0.069**	**0.172**	**0.037**	**0.099**	**0.048**
Shallow Concentrated Flow 2												
7. Surface Description (paved or unpaved)		na	na	na	na	na	na	na	na	na	na	na
8. Flow Length, L		na	na	na	na	na	na	na	na	na	na	na
Top Elevation		na	na	na	na	na	na	na	na	na	na	na
Bottom Elevation		na	na	na	na	na	na	na	na	na	na	na
9. Watercourse slope, s		na	na	na	na	na	na	na	na	na	na	na
10. Average veolocity, Vp	(ft/s)	na	na	na	na	na	na	na	na	na	na	na
11. Tt = (L)/3600*V	(hr)	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Channel Flow												
12. Channel roughness, n		na	0.05	0.05	na	na	na	na	na	na	na	na
13. Cross sectional flow area, a		na	28.00	28.00	na	na	na	na	na	na	na	na
14. Wetted Perimeter, Pw		na	18.00	18.00	na	na	na	na	na	na	na	na
15. Hydraulic radius, r=a/Pw		na	1.56	1.56	na	na	na	na	na	na	na	na
Top Elevation		na	59	63	na	na	na	na	na	na	na	na
Bottom Elevation		na	30	48	na	na	na	na	na	na	na	na
16. Channel slope, s		na	0.03563	0.05068	na	na	na	na	na	na	na	na
17. V=(1.49*r^.67*s^.5)/n		na	7.56	9.02	na	na	na	na	na	na	na	na
18. Flow Length, L		na	814	296	na	na	na	na	na	na	na	na
19. Tt = L/3600*v	(hr)	**0.000**	**0.030**	**0.009**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Pipe 1 Flow												
12. Pipe roughness, n		na	na	0.012	na	na	na	na	na	na	na	na
13. Pipe Diameter (ft)		na	na	2.5	na	na	na	na	na	na	na	na
14. Hydraulic radius, r=(D/4)		na	na	0.63	na	na	na	na	na	na	na	na
Top Elevation		na	na	52	na	na	na	na	na	na	na	na
Bottom Elevation		na	na	48	na	na	na	na	na	na	na	na
15. Pipe slope, s		na	na	0.00719	na	na	na	na	na	na	na	na
17. V=(1.49/n)(r^.667)(s^.5)	(ft/s)	na	na	7.70	na	na	na	na	na	na	na	na
18. Flow Length, L		na	na	556	na	na	na	na	na	na	na	na
19. Tt = L/3600*v	(hr)	**0.000**	**0.000**	**0.020**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Pipe 2 Flow												
12. Pipe roughness, n		na	na	na	na	na	na	na	na	na	na	na
13. Pipe Diameter (ft)		na	na	na	na	na	na	na	na	na	na	na
14. Hydraulic radius, r=(D/4)		na	na	na	na	na	na	na	na	na	na	na
Top Elevation		na	na	na	na	na	na	na	na	na	na	na
Bottom Elevation		na	na	na	na	na	na	na	na	na	na	na
15. Pipe slope, s		na	na	na	na	na	na	na	na	na	na	na
17. V=(1.49/n)(r^.667)(s^.5)	(ft/s)	na	na	na	na	na	na	na	na	na	na	na
18. Flow Length, L		na	na	na	na	na	na	na	na	na	na	na
19. Tt = L/3600*v	(hr)	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
20. Total Basin Tc	(hr)	**0.72**	**1.06**	**0.83**	**0.16**	**0.92**	**0.32**	**0.14**	**0.24**	**0.11**	**0.67**	**0.35**
21. Tlag = .6*Tt	(min)	**26**	**38**	**30**	**6**	**33**	**11**	**5**	**9**	**4**	**24**	**13**

Appendix D

HEC-HMS Figures

D1: Discharge Hydrographs for the 24-hour Storm Events for the Mill Creek Watershed (Uncalibrated)

D2: Discharge Hydrographs for the 24-hour Storm Events for the City Watershed at the Discharge Location (Uncalibrated)

D3: Discharge Hydrographs for the 24-hour Storm Events for the Parker Creek Watershed (Uncalibrated)

Figure D1: Discharge Hydrographs for the 24-hour storm events for the Mill Creek watershed (Uncalibrated)

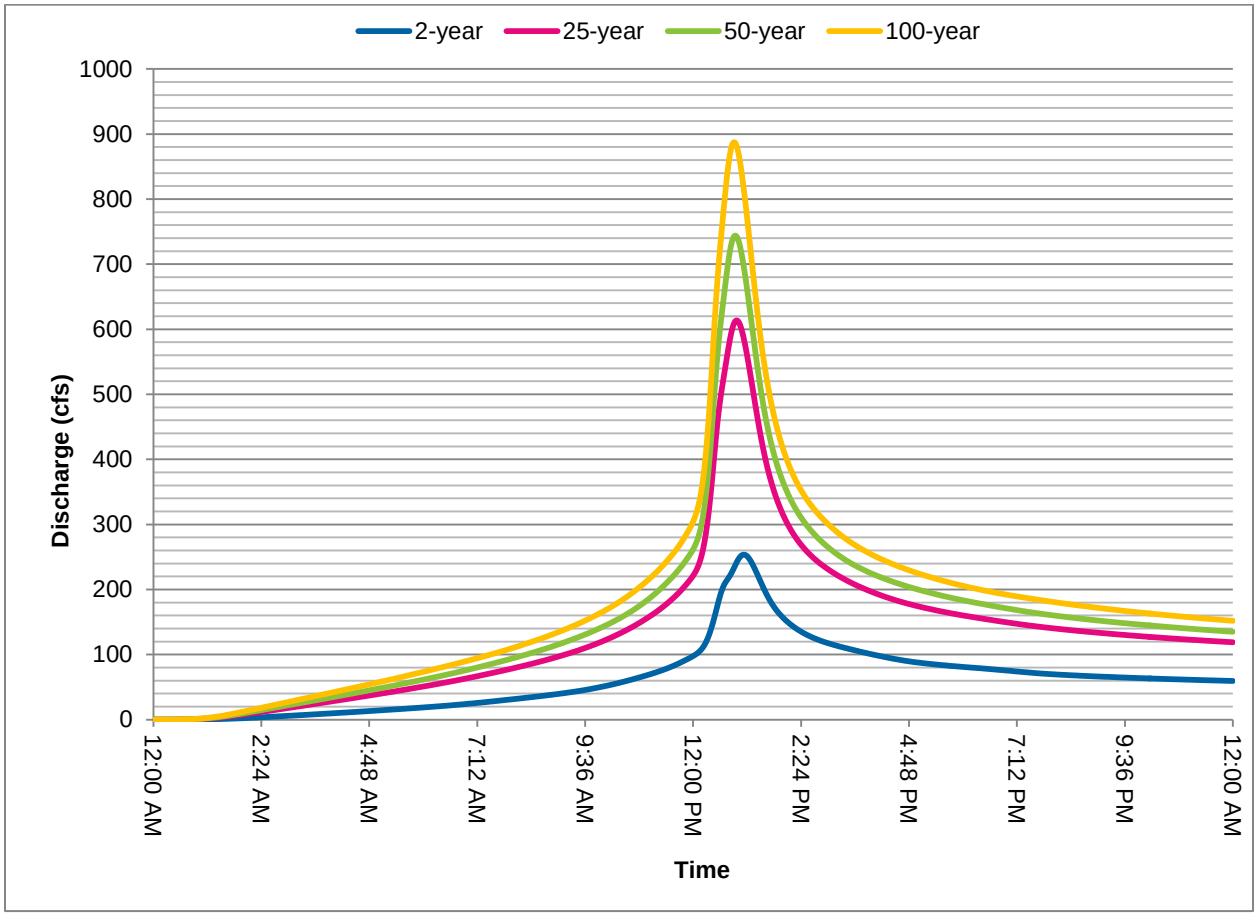


Figure D2: Discharge Hydrographs for the 24-hour Storm Events for the City Watershed at the Discharge Location (Uncalibrated)

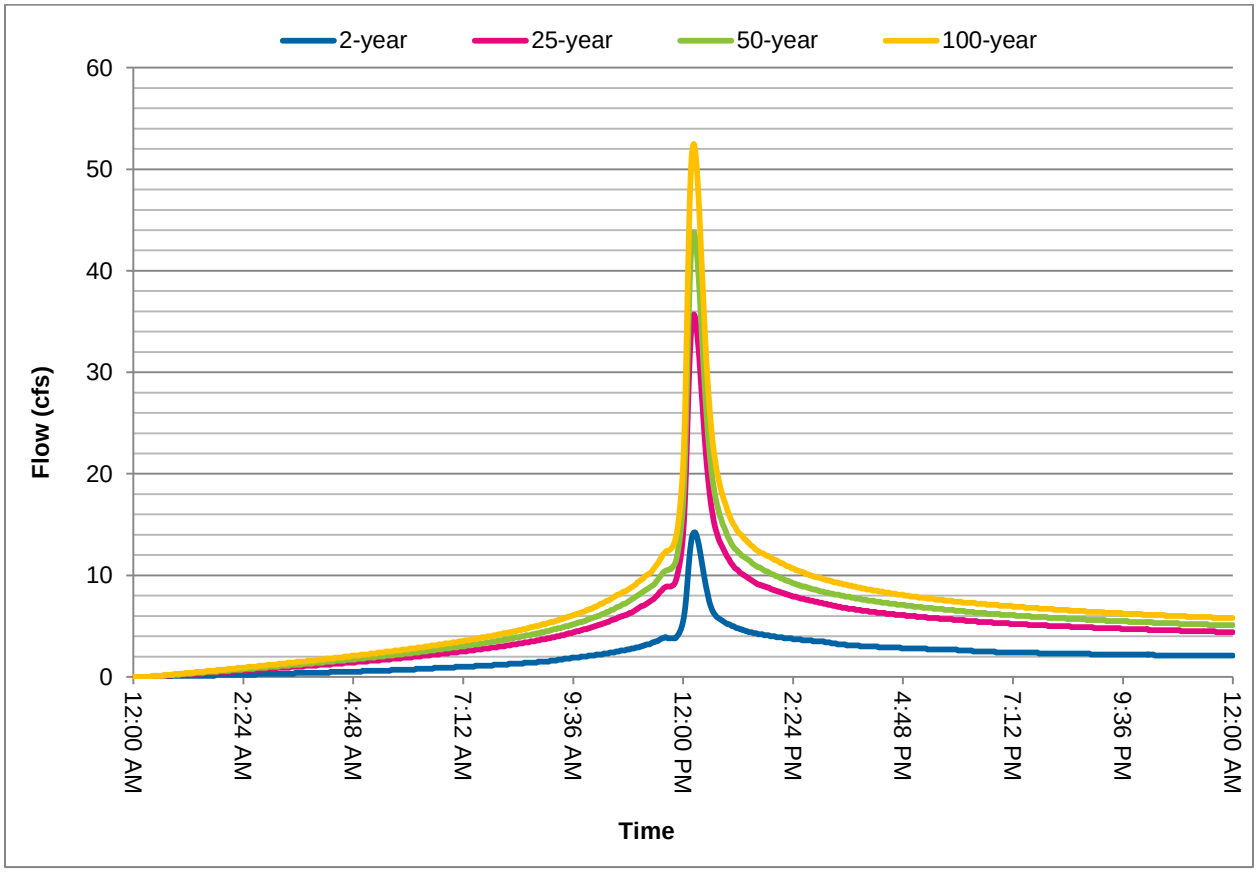
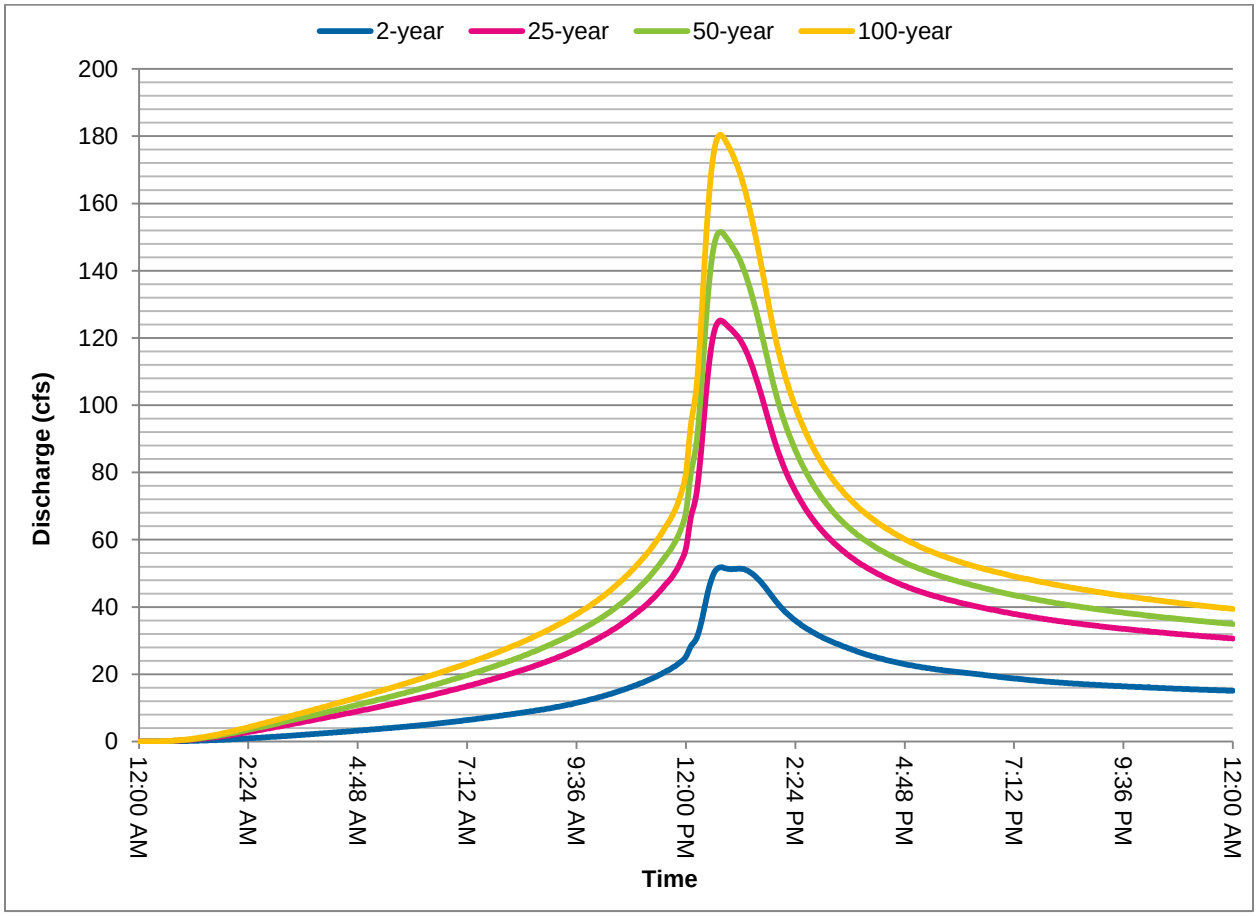


Figure D3: Discharge Hydrographs for the 24-hour Storm Events for the Parker Creek Watershed (Uncalibrated)



Appendix E

Groundwater Model Figures

E-1 Geological Model

E-2 Groundwater Model Hydraulic Conductivity Zones in Layers 1 and 2

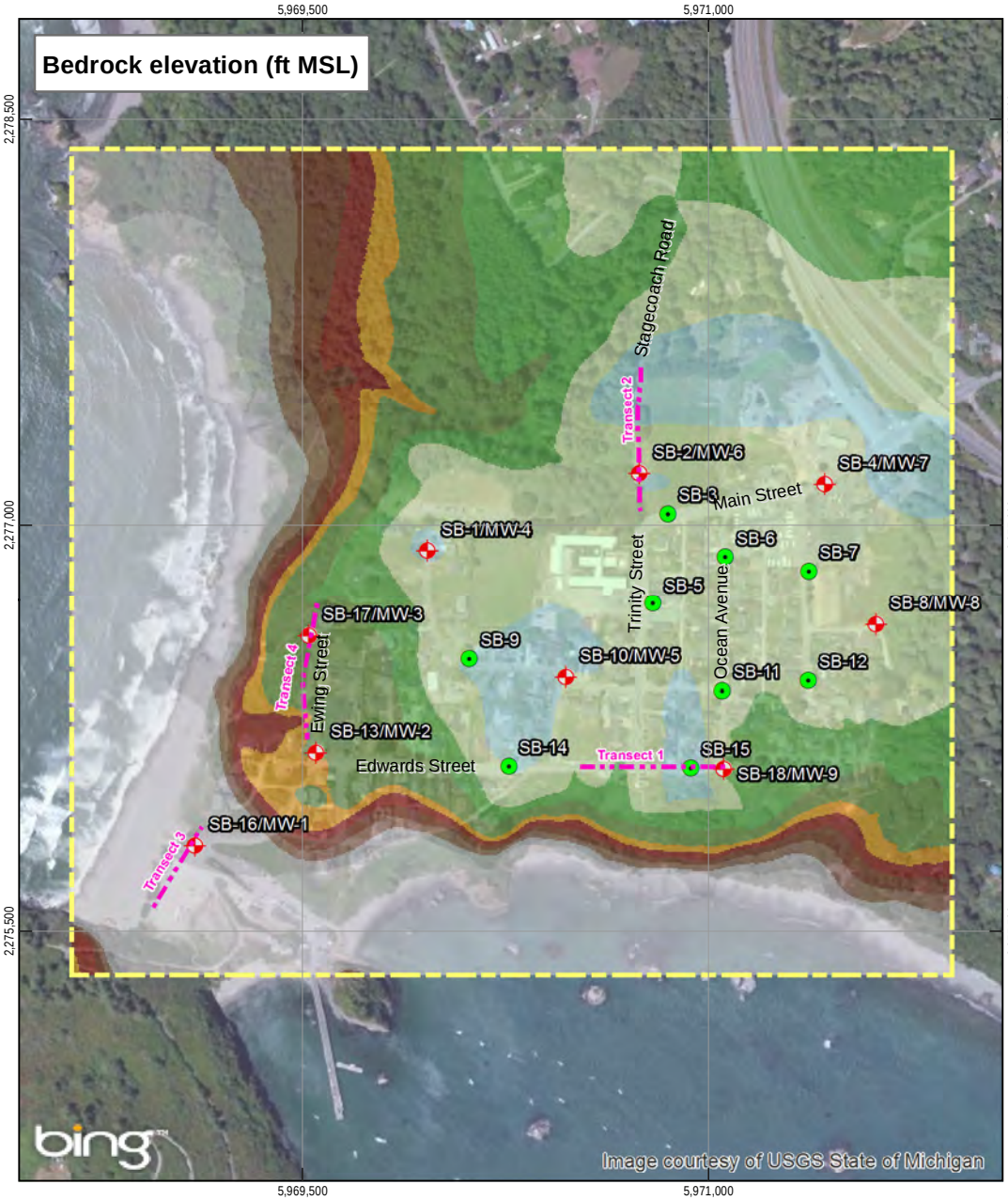
E-3 Groundwater Model Hydraulic Conductivity Layers 1 and 2

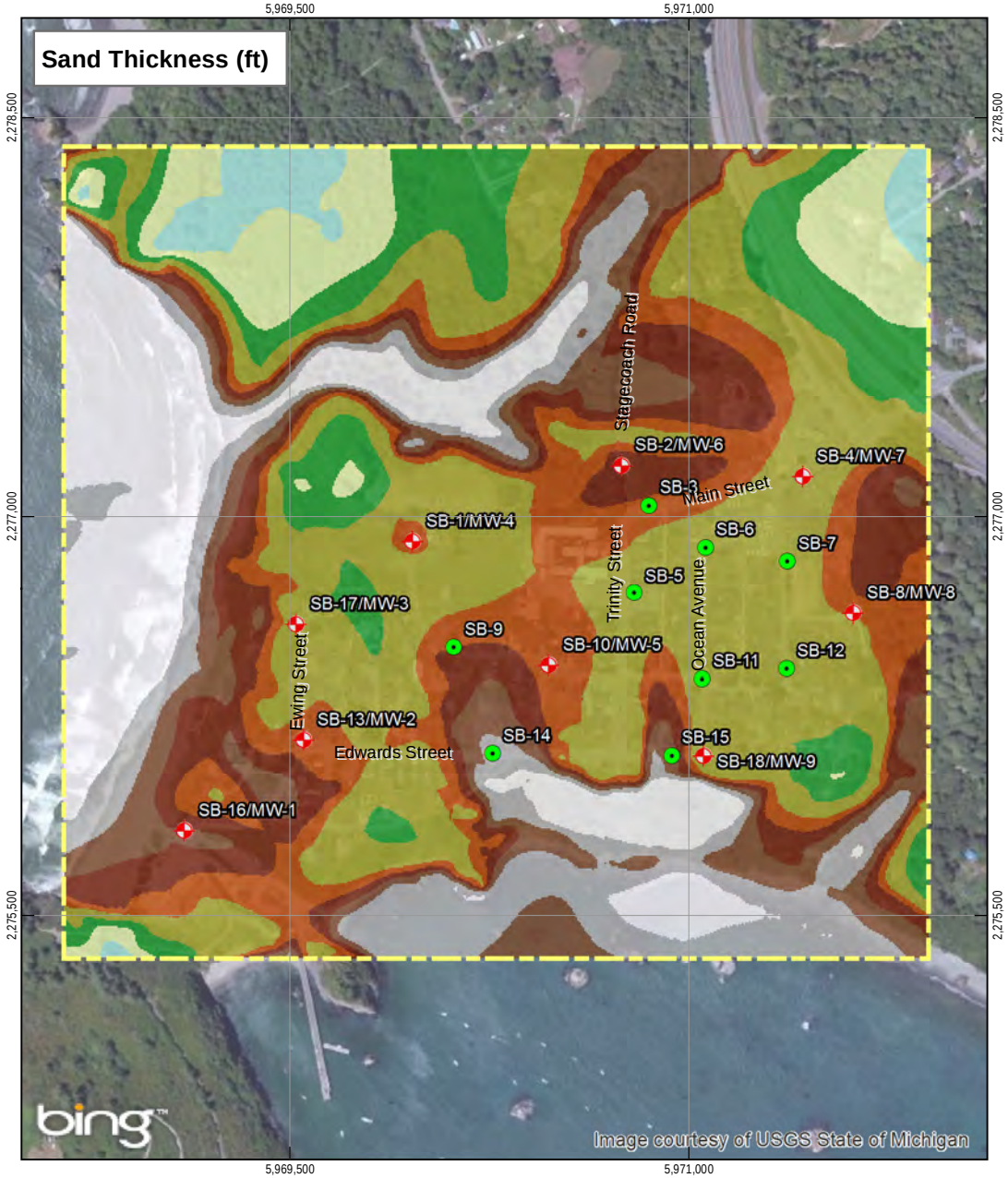
E-4 Groundwater Model Boundary and Recharge Zones

E-5 Stormwater Management

E-6 Groundwater Modeling Infiltration Feature Locations

E-7 Groundwater Modeling Results (Wet Season) with Cross-Sections





Paper Size A4

0 100 200 400 600 800

Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Bedrock Elevation (ft MSL)
- -29 - 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 75
- 75 - 100
- 100 - 125
- 125 - 145.4

Sand Thickness (ft)
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50- 75
- 75 - 100
- 100 - 125
- 125 - 148.2

Groundwater Model Domain

Monitoring Well / Soil Bore
- Soil Bore
- Monitoring Well
- Geophysical Transect (Seismic Reflection & Electrical Resistivity)

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
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Geological Model

Figure E-1

C:\Trinidad ASBS GIS Temp\E-1_Bedrock_Rev.mxd

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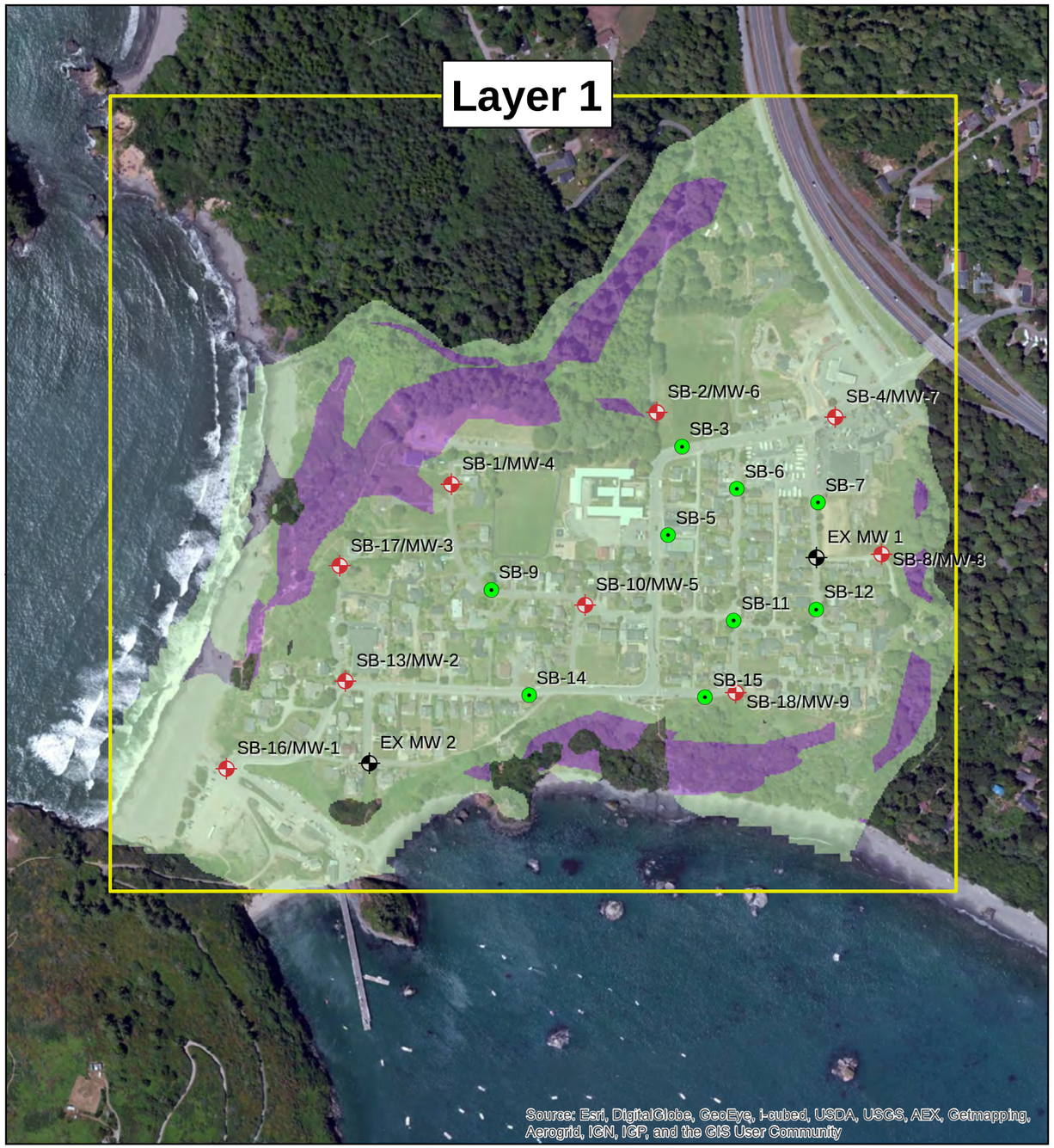
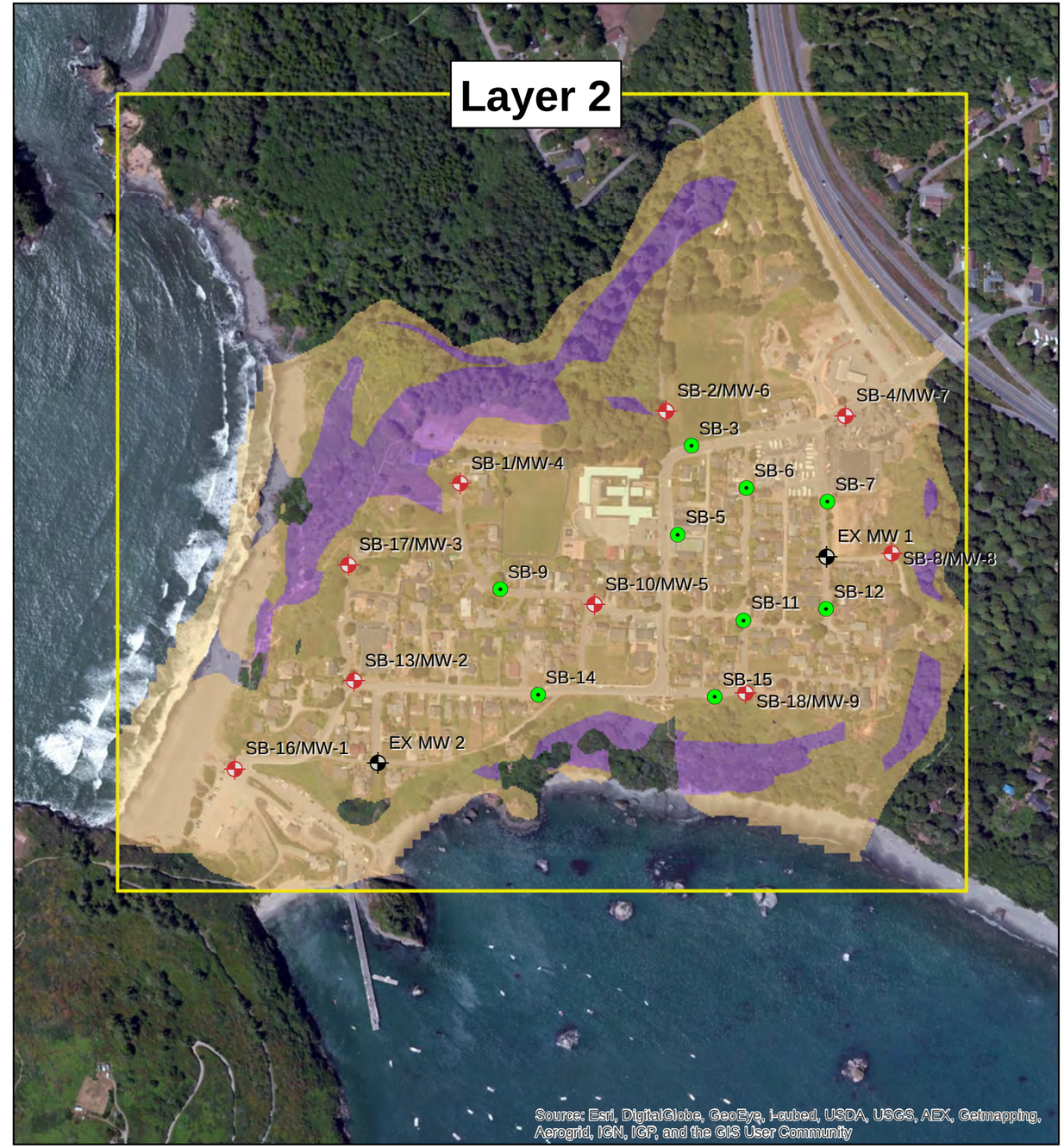
Data source: Bing, Aerial Maps, 2012. GHD, Bedrock Elevation, 2013. GHD, Sand Thickness, 2013. GHD, Groundwater Model Domain, 2013. Created by:emgutierrez





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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

Soil Boring

Monitoring Well

Preexisting Monitoring Well

Zone 1 Upper Marine Terrace

Zone 2 Coastal Bluffs

zone

Zone 4 Marine Terrace

Zone 4 Marine Terrace

Zone 2 Coastal Bluffs

City of Trinidad
Trinidad ASBS Stormwater Project

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Groundwater Model
Hydraulic Conductivity Zones in Layers 1 and 2

Figure E-2

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\GW Tech Memo\GW Model Conductivity.mxd

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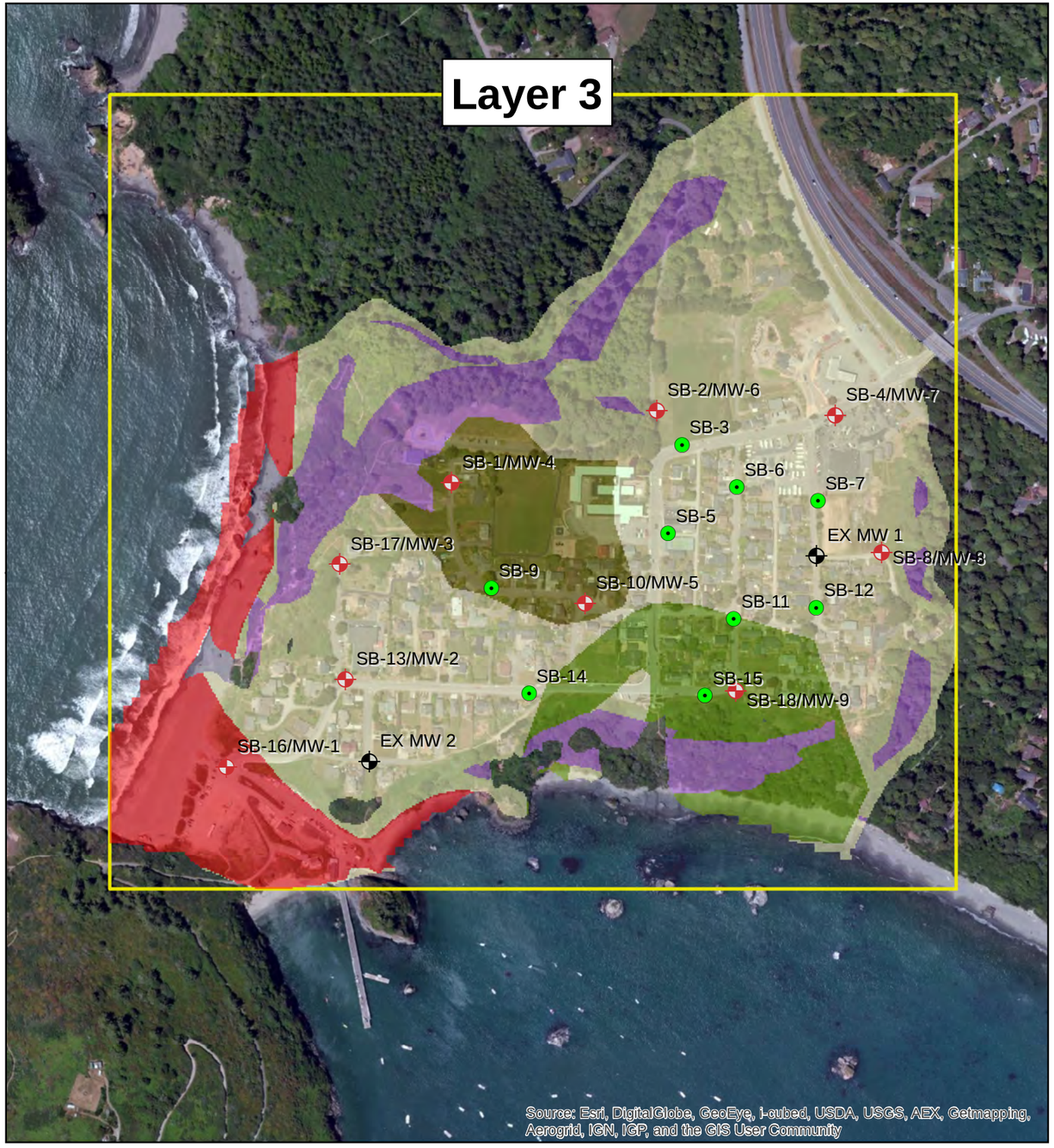

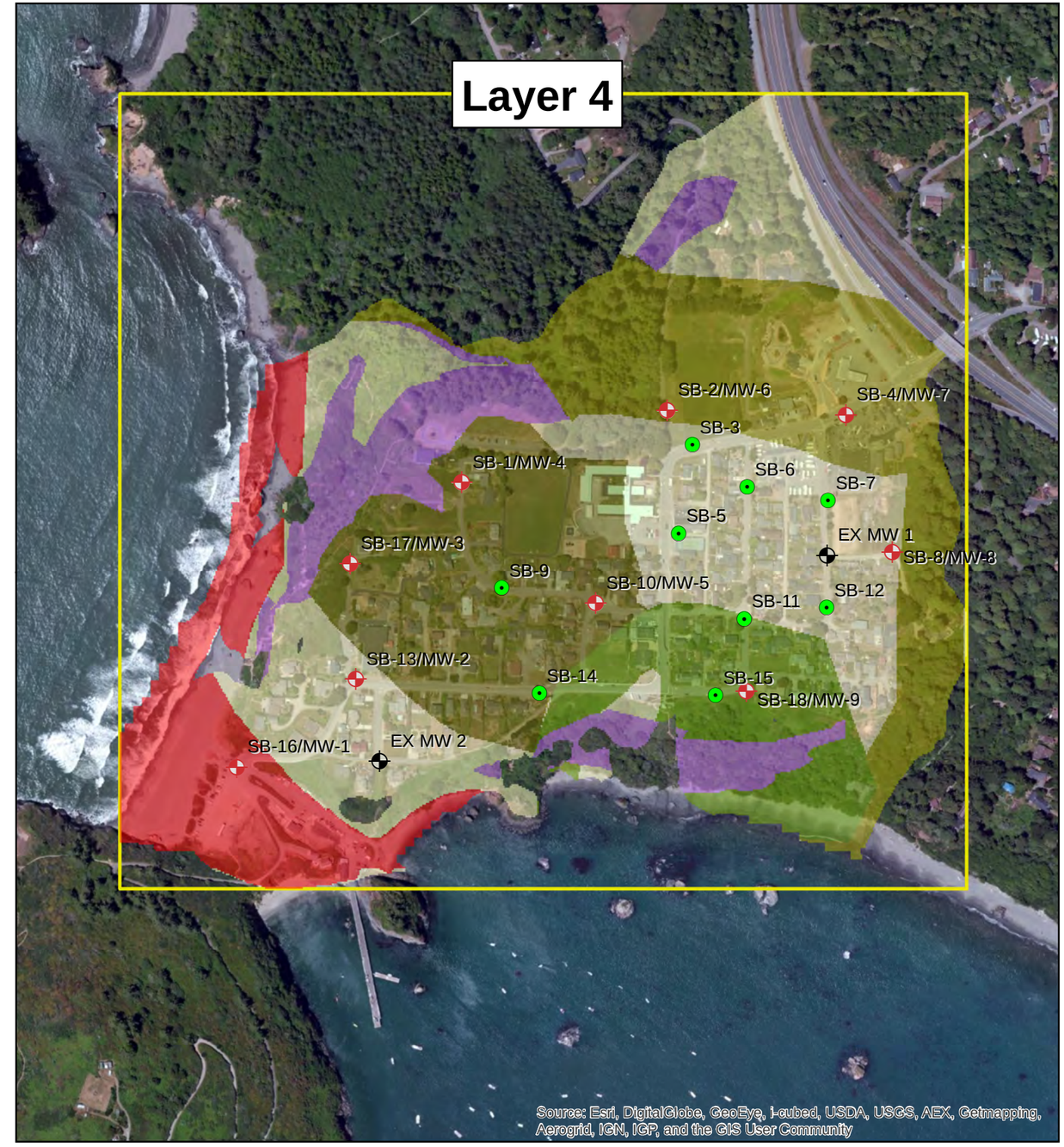

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

- Soil Boring
- Monitoring Well
- Preexisting Monitoring Well
- Model Domain

- Zone 3 Lower Marine Terrace
- Zone 4 Lower Marine Terrace
- Zone 5 Lower Marine Terrace
- Zone 6 Consolidated Region
- Zone 7 Unconsolidated Beach Sand

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Groundwater Model
Hydraulic Conductivity Zones in Layers 3 and 4

Figure E-3

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\GW Tech Memo\GW Model Conductivity Layer 3 4.mxd

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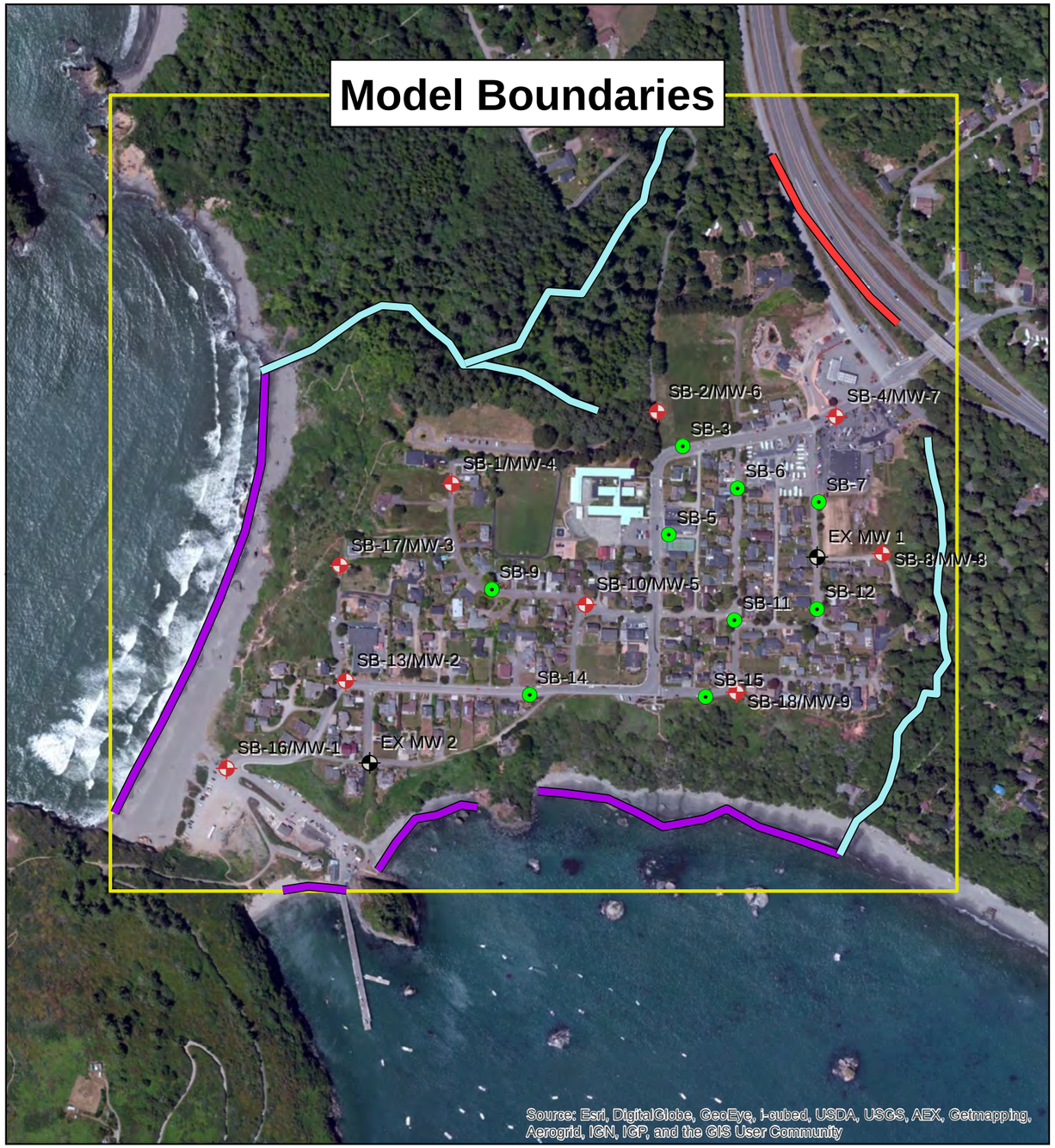

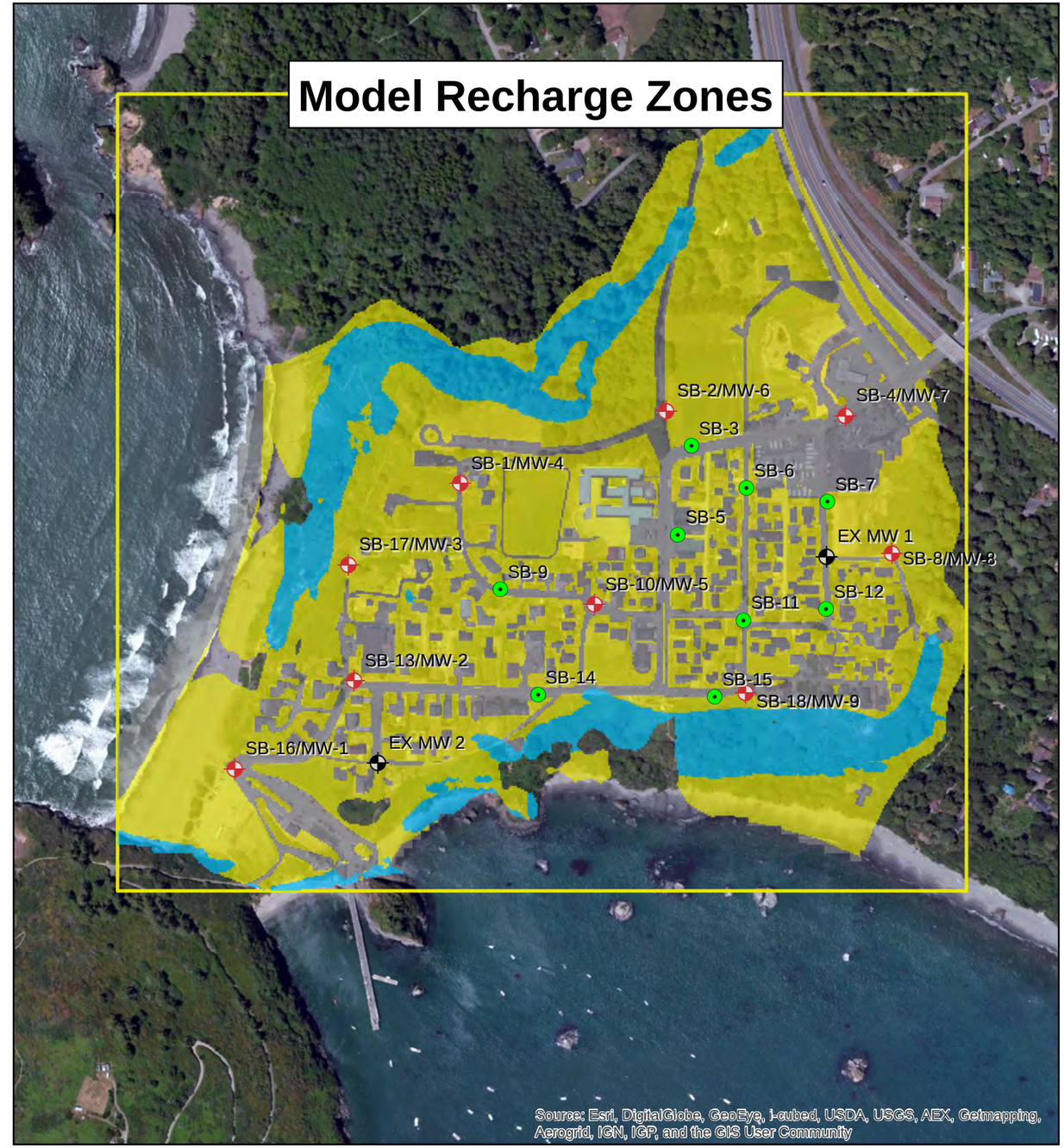

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

- Soil Boring
- Monitoring Well
- Preexisting Monitoring Well
- Constant Head Coastline
- Constant Head Highway 101
- Creek
- Impervious
- Slope
- Flat City
- Model Domain

City of Trinidad
Trinidad ASBS Stormwater Project

Groundwater Model Boundary And Recharge Zones

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Figure E-4

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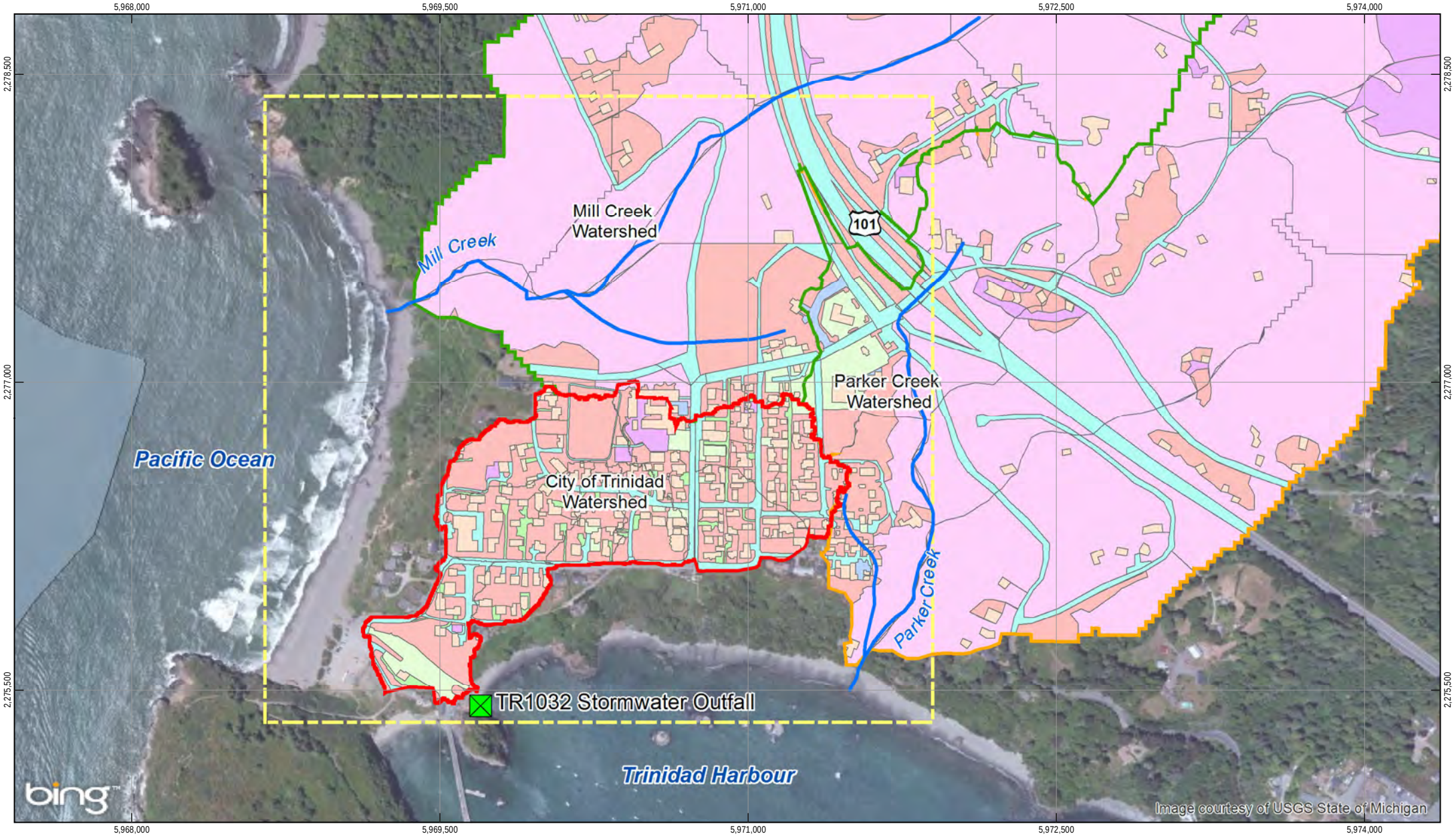

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

City Watershed
Mill Creek Watershed
Parker Creek Watershed
Groundwater Model Domain

Land Use
Building
Dirt Road
Forest/Trees
Open Field or Lawn
Parking Lot
Paved Road or Sidewalk
gravel/disturbed
other
Creek

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Stormwater Management

Figure E-5

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\GW Tech Memo\FE-5_StormwaterManagement.mxd

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Data source: Bing, Aerial Maps, 2012. GHD, Field Points, 2012. GHD, Creeks, 2012. GHD, Groundwater Model Domain, 2012. City of Trinidad, Areas of Special Biological Significance, 2011. GHD, Stormwater Outfall, 2012. Created by:emgutierrez

Paper Size 11" x 17" (ANSI B)

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

LEGEND

- Soil Boring
- Monitoring Well
- Preexisting Monitoring Well
- Model Domain
- Stormwater Infiltration Feature

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
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Date	15 Oct 2013

Groundwater Modeling
Infiltration Feature Locations

Figure E-6

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\GW Tech Memo\GW Modeling Infiltration Basins.mxd

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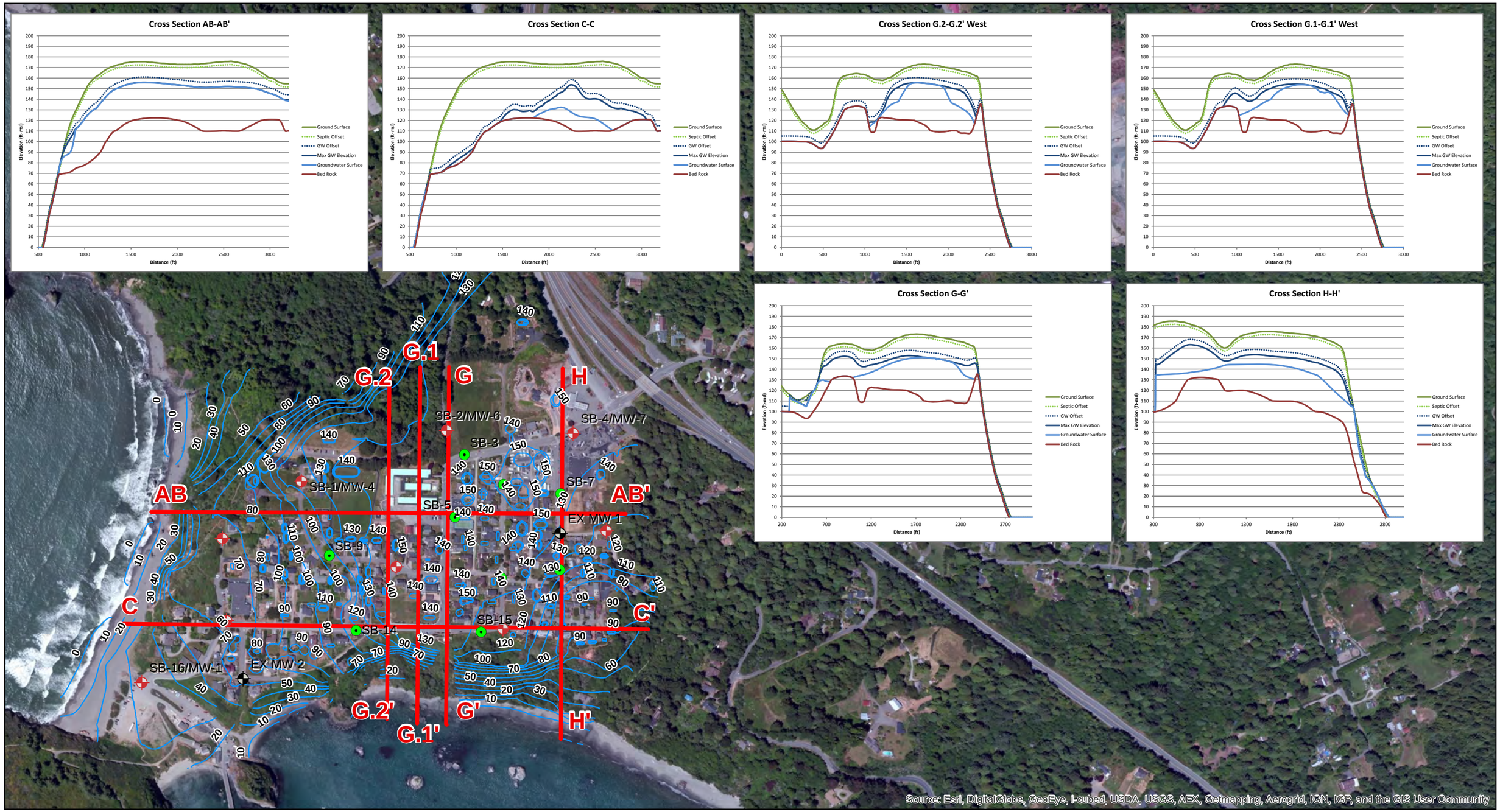

Paper Size 11" x 17" (ANSI B)

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Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

N

LEGEND

- Soil Boring
- Monitoring Well
- Preexisting Monitoring Well
- Cross Section
- Modeled GW Elevations (ft)

City of Trinidad
Trinidad ASBS Stormwater Project

Job Number	0106311005
Revision	A
Date	15 Oct 2013

Groundwater Modeling Results (Wet Season) With Cross-Sections

Figure E-7

G:\01063 City of Trinidad\01063-11-005 Trinidad ASBS Stormwater Ph1\08-GIS\Maps\GW Tech Memo\GW Modeling Results.mxd

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Appendix F

HydroGeoLogic, Inc. Trinidad Model Review Memo

Memorandum

TO: Patrick Sullivan, GHD

FROM: Varut Guvanasen, HGL

DATE: September 5, 2013

SUBJECT: Trinidad Model Review

SUMMARY

A review of the City of Trinidad groundwater model was conducted and is summarized in this memorandum. The model was found to be consistent with the conceptual model outlined in the Geotechnical Analysis Report (GHD, 2012). The model was calibrated with observed potentiometric elevations in a steady-state mode. The model is considered technically appropriate for applications in engineering design and evaluation. It is also recommended that sensitivity analysis be conducted to bracket the model's predictive limits.

---

1. BACKGROUND

The City of Trinidad (the City) is undertaking a project to make changes to the City stormwater drainage system. The objective of the City's Stormwater System Project is to capture and treat stormwater runoff from rainfall events by redirecting the runoff into underground infiltration galleries constructed in multiple locations within the City. The new stormwater system will replace the City's existing stormwater system, initially constructed in the early 1970's, discharges to a single 32-inch stormwater outfall, which discharges to Trinidad Bay.

GHD has developed a groundwater model to simulate groundwater flow within the City of Trinidad and surrounding areas. The model has been calibrated using observed groundwater elevation data and subsequently utilized to assess the impact due to implementation of infiltration galleries. As part of GHD's QA/QC program, HGL was contracted to review the model developed to ensure that the simulation code (MODFLOW-SURFACT (HGL, 2011)) was appropriately applied and the that the results are consistent with observed data.

2. COMPUTER SIMULATION CODE

The groundwater flow modeling computer code MODFLOW-SURFACT (HGL, 2011) was

used for the simuation of groundwater flow for the model area. MODFLOW-SURFACT is an enhanced version of the USGS modular three-dimensional groundwater flow code (McDonald and Harbaugh, 1988). MODFLOW-SURFACT was selected because of the following capabilities and attributes:

- Compatibility with the USGS MODFLOW;
- Rigorous simulation of the free surface conditions in unconfined aquifers;
- Seepage face boundary capability; and
- Robust and numerically efficient flow equation solver.

Of special importance are the second, third, and fourth attributes. These attributes are important to a computationally efficient, robust and accurate solution to a relatively large model with relatively thin saturated zones in many areas in the marine terrace.

3. DOCUMENTS AND COMPUTER FILES

The following documents and computer files were provided to HGL:

- Geotechnical Analysis Report (GHD, 2012);
- Draft Report: Trinidad ASBS Stormwater Phase I (GHD, 2013a);
- Technical Note on septic tank loading rates (GHD, 2013b);
- Two sets of model input/output files:
    - TrinRev2_Base (base case, steady state, one stress period)
    - TransV2Des50 (50-year design, transient, 150 stress periods); and
- Water level vs time and daily precipitation plots at eight observation wells from November 2012 to May 2013.

4. CONCEPTUALIZATION

The groundwater model study area covers an area of 228 acres. The area includes the City of Trinidad, located in Humboldt County, CA, and surrounding areas. The study area is bound by Mill Creek to the north, Highway 101 and Parker Creek to the east, and the Pacific Ocean to the west and Trinidad Bay to the south. It is primarily covered by three watersheds: Mill Creek; the City of Trinidad; and Parker Creek.

The hydrogeology of the study area consists of (GHD, 2012):

- A Pleistocene unconfined sandy marine terrace aquifer generally composed of medium to well graded silty sands; underlain by
- Franciscan Complex bedrock.

The sandy aquifer is not currently used for extraction purposes, due to its low overall storage capacity, relatively shallow depth, and proximity to the residential septic systems. Depth to water table ranges from about 15 feet below ground surface (BGS) to 55 feet BGS across the study area, and is primarily controlled by the Fransciscan Complex bedrock.

Data for depth to bedrock were obtained from a total of 18 soil borings (identified as SB-1 to SB-18) across the study area to varying depths to provide an indication of the depth to bedrock and the terrace stratigraphy. The data were used to complement the bedrock elevation surface across the study area, developed as part of the *Geotechnical Analysis* (GHD, 2012).

In the sandy aquifer, the stratigraphy in the upper 3 to 5 feet to the surface is characterized by loose to compact disturbed and mixed fill materials of imported river gravel, sand, and silt (GHD, 2013a). Underlying the upper fill and silty sand layer, the majority of the subsurface materials encountered were generally dominated by loose, poorly graded, fine and medium-grained sand down to bedrock.

5. DEVELOPMENT AND CALIBRATION OF THE MODEL

5.1 Model Development

The model area was discretized into 6.56 x 6.56 ft cells aligned north-south, resulting in 465 rows and 495 columns to provide adequate resolution to model the septic tanks and the stormwater infiltration design options. The model was configured to simulate steady state conditions. The model grid used was considered adequately fine and appropriate for the inclusion of hydrologic and hydrogeologic features in the project area.

In order to simulate the septic tanks and stormwater infiltration design options, and provide adequate vertical resolution, the model was separated into five model layers. Layer 1 has a uniform thickness of 3 ft, which is the average depth below ground surface of septic tanks. Layers 2, 3, and 4 represent the unconfined sandy marine terrace. Layer 5, originally used to represent the Franciscan Complex bedrock or the aquitard, is inactive. In a given column, Layers 2, 3, and 4 are of identidcal thickness. The total thickness of these three layers varies across the model domain and ranges from 2 to 145 ft, with an average thickness of 45 ft.

The groundwater model boundary conditions are discussed below.

- Constant head boundaries: Constant head boundary conditions were applied to the model boundary cells in Layer 1 along the west and part of the southern boundary to mimic coastline. The constant-head cells along the coast were assigned a head of 0 ft MSL The constant-head cells adjacent to Highway 101 were assigned to the model in Layer 2. These cells were assigned a uniform head of 136 ft AMSL.
- Rivers: River boundary conditions were included in the model to simulate the flow of water into and out of the aquifer from Mill and Parker Creek (and tributaries). The river bed elevation was assigned as the layer 2 top elevation minus 0.33 ft, and was set to equal the stage height in order to prevent leakage from the River boundary to the aquifer. These water bodies were simulated as gaining streams only.
- Seeps: The regions identified as seeps in the Geotechnical Analysis Report (GHD, 2012) were classified as seepage face boundaries in the groundwater model.

- Septic Tanks: The septic tanks were incorporated into the groundwater model using injection wells to simulate fluxes into the model at the locations of respective septic systems. The injection wells were set in Layer 1 (based on the fact that septic system trenches are cut to around 3-4 feet deep), and each cell within a property's septic system was assigned a constant discharge rate.

- Recharge: Recharge was divided into three major zones: pervious (0.007 ft/day – 30.7 inches/year); impervious(0 ft/day); and high slope area (greater than 45°) (0.0007 ft/day – 3.1 inches/year).

5.2 Consistency between the Model and Observed Data

Potentiometric elevation data from nine observation wells were available from November 2012 to May 2013. The observed potentiometric elevations at these wells were relatively steady and their variation with time was relatively small. A comparison between the observed and simulated potentiometric elevations (from the base case) at these wells is given in Table 1 below. At all wells, except MW-3, water levels were continuously recorded every 15 minutes. At MW-3, water level was manually monitored twice during the period of observation.

Table 1 Comparison between the Simuulated and Observed Potentiometric Elevations

Well MW-	Observed (ft) High	Observed (ft) Low	Average (ft)	Simulated (ft)	Difference (ft)
1	13.4	8.8	11.1	10.7	0.4
2	65.5	62.0	63.4	63.4	0.1
3	84.6	81.5	83.1	80.9	2.1
4	137.7	133.8	135.3	138.2	-2.8
5	133.6	131.2	132.2	129.8	2.5
6	135.5	133.2	134.3	132.2	2.2
7	135.4	134.0	134.7	137.1	-2.5
8	132.5	131.5	132.0	129.0	3.0
9	117.8	116.6	117.2	117.6	-0.4
			Mean Error (ft)		0.5
			Mean Absolute Error (ft)		1.8
			Range (ft)		124.2

The comparison in Table 1 suggests that, based on the pseudo steady-state conditions between November 2012 to May 2013, the model favorably agrees with the observed data. The mean absolute error of 1.8 ft (1.5 percent of the range)is well within the normal criterion of 6.2 ft (5 percent of the range) and the mean error of 0.5 ft (0.4 percent of the range) indicates that the model bias is relatively small.

5.3 Discretization and Boundary Conditions

The following were verified/inspected:

- Vertical and horizontal discretization was verified. Elevation of the bottom of Layer 4 was verified against bedrock elevation information in the Geotechnical Analysis Report (GHD, 2012). The two elevation distributions were found to be similar but not identical. It was assumed that the elevation used in the model was based on more detailed and more recent information.
- Locations of general head boundaries, rivers, and seepage surface were verified against maps given in GHD (2012).
- Steady-state recharge distribution was inspected. Recharge was found to be within a possible range (maximum recharge is approximately 50% of the total precipitation during the observation period).
- Septic tank injection rates were also inspected to ensure that they were input correctly.

5.4 Hydraulic Conductivity

One of the key model parameters is hydraulic conductivity in the marine terrace aquifer. Data for the sandy material in the marine terrace indicate that hydraulic conductivity of the sandy material is on the order of 70 ft/day. However, the value is not based on direct measurements but rather on correlations between hydraulic conductivity and grain size distribution (GHD, 2012). The general hydraulic conductivity values used in the model to represent the marine terrace generally vary between 2 to 6 ft/day which is smaller than that based on grain size distribution. However, these values are within the range of hydraulic conductivity values in published literature (de Marsily, 1986). Many investigators including Eggleston and Rojstaczer (2001) found that measured hydraulic conductivity values could be much smaller than those determined based on grain size distributions. The model's hydraulic conductivity values of coastal bluffs and unconsolidated beach sands are 0.005 and 15 ft/day, respectively. These values are consistent with the published ranges for fine sands and sands, respectively (de Marsily, 1986).

5.5 Transient Simulations

The model was extended for transient applications. A specific yield value of 0.1 was assumed. This value is within a published range of specific yield values for fine sands and silts (Todd, 1976).

5.6 Quality of Simulation Results

MODFLOW-SURFACT generates quantitative information relating to the quality of the simulation results at the end of each simulation run. The final calibration run and the transient run had water balance errors of 0.06 and 0.01 percent, respectively. Simulation results are considered good when water balance errors are less than 1 percent.

6. SUMMARY AND RECOMMENDATIONS

6.1 Summary

The model for the City of Trinidad has been reviewed. The model was found to be consistent with the conceptual model outlined in GHD (2012). The model was verified against observed potentiometric elevation at nine observation wells. Material properties and recharge were found to be within reasonable ranges. Based on the data available, the model was found to be consistent with field observations.

The model developed based on a standard procedure. The model was calibrated with mean absolute error of 1.8 ft or 1.5 percent of the range of observed potentiometric elevation. The model is considered technically appropriate for applications in engineering design and evaluation.

6.2 Recommendations

The following are recommended:

- Sensitivity Analysis: Sensitivity analysis should be performed to quantify the model's predictive limits. At least two parameters, hydraulic conductivity and recharge should be included. Other possible parameters include: degree of hydraulic conductivity anisotropy, stream configuration and associated hydraulic properties, and boundary conditions.
- For transient model applications, the model should be used with caution as it has not been calibrated with transient data. Additional sensitivity analyses to bracket the range of storage parameter uncertainty should be performed.

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