# Report for **Trinidad ASBS Stormwater Project**

## Groundwater Model Addendum For LID Zoning

Completed as part of the Citywide LID Planning & Construction Project

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# 1. Introduction

Trinidad is a small, disadvantaged, coastal community that is located near one of California’s designated Areas of Special Biological Significance (ASBS). The City has been proactively working to comply with ASBS discharge requirements, which is a challenge for a small city with limited funds and high annual precipitation. The majority of the City drains directly or indirectly to the ASBS. The City’s single stormwater outfall is designated as priority discharge #TR1032 and discharges into the ASBS as shown on Figure A1, 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. The City has completed comprehensive planning efforts, working with neighbors and area stakeholders to develop real solutions to these issues. Eventual implementation of all planned projects will allow the City to eliminate the stormwater outfall at the popular Launcher Beach thereby helping to protect the ASBS.

Trinidad Bay 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.

Currently the City's aging stormwater infrastructure still discharges untreated runoff into the ASBS at Launcher Beach. The current system is decades old with some sections not functioning as designed due to catch basins and pipes filled with sediment. There are several areas in the City where stormwater runoff is not collected in several areas and instead flows to open areas or in streets and gutters. The stormwater runoff then either infiltrates into the sandy soils or flows as overland surface flow, eventually reaching the ocean. The situation exacerbates erosion and transports sediment and potentially other contaminants into the ASBS. The approach to remedy this situation is focused on capturing stormwater runoff, conveying flow away from sensitive areas, treating it for constituents of concern, and then infiltrating the stormwater. This approach has already been implemented with two phases, including LID features on Trinity Street, Ocean Avenue, East Street, and Hector Street.

Factors to consider when instituting stormwater infiltration are groundwater interactions with septic disposal fields within the City and location of infiltration systems with respect to potential influences on bluff stability. The focus of the City’s stormwater infiltration design is to capture water that would be directly or indirectly discharged to the ASBS. The captured stormwater is then conveyed away from sensitive areas where it is treated, stored, and infiltrated so that changes to the groundwater levels in sensitive areas is minimized.

Gov. Jerry Brown declared a state of emergency for 50 California counties including Humboldt County that were drenched by December 2016 and January 2017 winter storms. The federal government declared a state of emergency for the same storm event helping California with support from FEMA. In Trinidad, the bluff adjacent to the Trinidad Memorial Lighthouse was affected by the storms and exhibited visual signs of slope instability with a fresh escarpment with fissures and slumping of the bluff in the previously dormant landslide (per SHN's March 24, 2017 report titled: "*Preliminary Assessment of Current Slope Stability Conditions, Trinidad Memorial Lighthouse, Edwards Street, Trinidad'*). As part of the City's response, the City directed GHD to collect groundwater data from the City's existing groundwater monitoring wells and use the new 2017 groundwater data to update the groundwater model with the goal of checking the model to see if the post-construction performance of the features implemented on Trinity and Ocean Avenue were performing as previously expected. The updated model would also provide the City with an updated existing conditions model for use in modeling future scenarios. As an outcome of this exercise, the City decided to not build one planned small LID feature on West Street as the model could not verify that the infiltrated stormwater from that project site would not end up at or near the slope instability adjacent to the Trinidad Memorial Lighthouse. The West Street LID project component was small and not a critical component of the overall stormwater project. The updated model indicated the two previous features implemented on Trinity and Ocean Avenue were performing as previously expected.

The updated existing conditions model was then used to model the City's remaining planned LID stormwater projects. The modifications to the model are described in detail in Section 4.2.3.

As part of this overall stormwater management effort, the City plans to establish rules, zoning, or other guidance that encourages private property owners to create LID systems on their property that support the City's overall stormwater objectives. LID systems capture, treat and slowly discharge stormwater runoff. LID features can either retain the stormwater and discharge to another disposal system (Bio Retention) or they can retain and infiltrate (Bio Infiltration) stormwater. The City wanted to determine locations within the City where Bio Retention is appropriate and where Bio Infiltration is appropriate.

With the full implementation of the City's planned LID stormwater projects modelled, the City next wanted to use the model to look to the future and model private implementation of LID systems. Working with the City Planner, potential future development based on current zoning was explored and input into the model. The modification to the model are described in detail in Section 4.2.4.

The long-term goal of the Project implementation 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). LID and BMPs will capture, treat, and infiltrate stormwater runoff from rainfall events, thereby minimizing stormwater pollutants that enter the ASBS. This addendum builds upon the *Groundwater Model Technical Report (*GHD 2013) completed as part of the City's ASBS Stormwater Improvement Project. The objective of this document is to present and discuss additional groundwater modeling efforts that evaluated the proposed projects and different infiltration scenarios, share the model output and analysis, and convey how these modeled scenarios were used for the project.

# 2. Approach

The primary driving objective of the City's stormwater improvements is to eliminate potential pollutants from entering the ASBS via the existing stormwater runoff. The City explored multiple options for stormwater treatment, storage and disposal. With limited area available for storage and streams also discharging to the ASBS, the capture, treatment, and infiltration of stormwater runoff was selected.

Prior to the implementation of the stormwater capture, treatment and infiltration projects, stormwater would either:

- flow in a partially functioning collection system which directly discharged to the ASBS,
- runoff impervious areas (roofs, streets, paved areas) and collect in puddles that directly infiltrated untreated runoff to groundwater, or
- runoff impervious areas and flow as surface runoff over the bluffs and discharge to streams, ocean and the bay.

To address these issues, the City's infrastructure improvements have focused on capturing stormwater runoff from streets and paved areas, diverting existing stormwater system flows from ocean discharge, and route that stormwater to treatment and infiltration facilities. The design of the these systems focused on capturing runoff that was either infiltrating near or surface flowing over the bluffs and routing that water to treatment and infiltration areas further away from the bluffs. Additionally, the infiltration system is designed to capture and store stormwater runoff from high intensity rainfall and slowly allow the infiltration of that stormwater to minimize the impacts on groundwater levels that otherwise could affect bluff stability.

When developing an approach to design treatment and infiltration options there are several constraints that need to be considered: required space for treatment and infiltration systems, groundwater influences on bluff stability, and infiltrated stormwater interacting with existing septic systems.

- **Required Space** – treatment, storage and infiltration systems need to be located on City property where they can be operated and maintained by City staff. These facilities need to be located in regions that have the topologic characteristics that will allow stormwater to flow via gravity without the need for pumping as the costs associated with maintenance and operation of a pumped system would be prohibitive. This constraint limits the areas of the City's streets and parking lots as potential treatment and infiltration areas.
- **Bluff Stability** – the design of the infiltration systems focuses on infiltrating the stormwater at a location and at an infiltration rate that minimizes the changes in groundwater elevations in the sensitive areas near the bluffs.
- **Septic System Interactions** – the infiltration of the treated stormwater may result in localized increases in groundwater elevations during and immediately after storm events. The infiltration systems must be located such that they do not cause localized groundwater elevations to raise to a level that could interact with septic systems. This results in location of infiltration areas sufficiently separated from existing septic system so that there are not groundwater interactions. These separation distances are consistent with the Humboldt County guidelines for septic system offsets and groundwater separation.

During the design process of the City's stormwater system a 3-dimensional groundwater model was used to evaluate the various design scenarios with respect the design constraints. The resulting analysis and design resulted in the future elimination of the direct ocean discharge and the treatment and capture of up to a 50-year storm event. The runoff from privately owned parcels also contributes to the City's total stormwater runoff. In an effort to mitigate and reduce overall stormwater runoff, the City wants to encourage private property owners to help do their part to help reduce stormwater runoff. Private property efforts to reduce stormwater may include: rain barrels, rain gardens, bio-swales, etc. These runoff mitigation efforts are commonly known as Low Impact Development (LID). A more thorough discussion of LID features may be found in the Humboldt County LID manual.

In general, LID features capture stormwater runoff, allow for passive treatment, and either increase infiltration or store stormwater and slowly release it. LID features that treat and slowly release stormwater are referred to as Bioretention and features the treat and infiltrate to groundwater are referred to as Bioretention with infiltration. Bioretention with infiltration is described in the Humboldt County LID Stormwater Manual under "Runoff Reduction Measures" and "Site Design Measures". While the description in the LID Manual include features that infiltrate and those that retain but don't infiltrate, this report segregates LID features into two categories: those that encourage infiltration and those that do not. These two types of LID features are discussed in more detail in Section 3 and in the Humboldt County LID manual (Appendix 3 Site Design Measures and Appendix 4 Bioretention).

To help support the current projects and plan for the future, the City would like to develop policies that promote Bioretention and Bioretention with infiltration (discussed in Section 3) that are consistent with the stormwater system design constraints. To do this, areas within the City where Bioretention and Bioretention with infiltration need to be established as a Zoning map. The development of the LID Zoning Map incorporated information from the geotechnical study, modeled and observed (monitored) groundwater conditions, and input from City Staff.

Once the LID Zoning map was drafted, the effects of the type of LID on the groundwater in each area was evaluated to demonstrate that it is consistent with the design constraints previously discussed. To demonstrate that the stormwater systems constraints are satisfied, the groundwater model is used to evaluate the potential effects LID features may have on groundwater and subsurface systems such as septic systems. Groundwater elevations under existing conditions were compared to different infiltrator configurations to determine the effects of infiltrating stormwater runoff. The groundwater model previously developed, calibrated, and verified was modified to evaluate the potential effects of future LID infiltrators. The hydrologic analysis and groundwater model development can be found in Sections 3 and 4. In general, the intent of the groundwater modeling is to support the planning and design process by showing the effects of the proposed features on the groundwater system to minimize impacts that could affect bluff stability.

The implementation of the upgrades to the City's stormwater system is occurring in discrete phases. The first phases of construction occurred in 2016 and 2018. These phases of construction resulted in the construction of several LID, treatment and infiltration facilities. A further phase of design and construction will complete the City's stormwater system and eliminate the direct discharge to the ocean for events up to the 50-year storm. The evaluation of the potential effects of these projects on the design constraints, using the groundwater model, are described in Section 4 (see Section 4 for scenario description). Additionally, an evaluation of the potential effects from the future development of currently undeveloped lots and all possible LID features installed in the proposed Zoning map are simulated in Scenario 4 (see Section 4 for scenario description).

The evaluation of the potential effects on bluff stability uses the changes in groundwater elevations near the bluff, as simulated in the groundwater model, with the slope stability analyses using the GeoStudio 2012 software, version 8.15.3. Spencer's Method of Slices was used, which satisfies force and moment equilibrium.

The analysis of the bluff stability first evaluated the base conditions as of 2016 (Scenario 1), with the subsurface info at the bluff then translating it horizontally landward with conservative properties derived from the available boring logs. The subsequent cases include the ground surface, bedrock, and max groundwater levels from the recent groundwater modeling efforts. The bluff stability model was then run under two conditions to compare the base condition in 2016 (Scenario 1) to the worst case condition of Full Buildout (Scenario 4). Slope stability analyses uses factors of safety (FS) to evaluate the potential instability of a slope. The components of a FS the driving forces and moments versus the resisting forces and moments. The moments are determined using the surface geometry, subsurface stratigraphy, soil strength, and groundwater levels.

$$FS = \frac{\sum Resisting\ Moments}{\sum Driving\ Moments}$$

When the driving moments equal the resisting moments, the factor of safety is unity. Unity is considered a metastable condition, where the slope is balanced between stability and movement. A FS less than unity would imply an unstable slope and an FS over unity would imply a stable slope.

The effect of the proposed LID projects on bluff stability is evaluated by comparing the change in the factor of safety between the proposed project and the base condition. A thorough summary of the Slope Stability analysis is presented in the Slope Stability Analysis Memorandum in Appendix E.

# 3. LID Zoning

Two of the primary objectives of LID implementation are to provide water quality treatment and to mimic natural hydrologic conditions in developed areas. For the purposes of distinguishing suitable LID types within the project area, features herein are classified into two categories: bioretention and bioretention with infiltration. Typical LID features are categorized in Table 1. These two categories correspond with zoning areas within the City that specify for property owners where various LID types are suitable (discussed in Section 3.3). Brief descriptions of select LID features are discussed below. Excerpts from the Humboldt LID Stormwater Manual and the City of Santa Rosa LID Technical Design Manual are provided in Appendix F.

Table 1. Applicable category for typical LID features.

| LID Category | Tree Planters | Vegetated Swales | Rain Gardens | Infiltration Trenches | Rain Barrels | Green Roofs |
|---|---|---|---|---|---|---|
| Bioretention | x* | x* | x* | | x | x |
| Bioretention with Infiltration | x | x | x | x | | |

*Suitable for bioretention only if an impermeable layer that prevents infiltration is installed

### 3.1 Bioretention

Bioretention features are LID elements that reduce peak runoff, but do not allow infiltration into native soils. Although tree planters, vegetated swales, and rain gardens are often designed to include infiltration, they can also incorporate a liner or compacted clay soils and other soil types that prevent infiltration. Some bioretention features, such as lined tree planters and green roofs, can also provide pollutant removal (Figure 1).


Figure 1. Examples of installed (a) tree planters and (b) green roof.

Tree planters include grates that allow for stormwater runoff to enter the planter, which facilitates filtration through soil. In some instances, tree planters can be connected to each other, or to an existing storm drain system. If implemented within the Bioretention Only Zone, tree planters would need to be designed to prevent infiltration with an impermeable layer on the bottom and side walls. Green roofs are often composed of several layers that capture rainfall within the growth medium. Water gets released slowly via evaporation, transpiration, and discharge to roof drains. Other bioretention features, such as rain barrels, do not provide water quality treatment, but allow for capture and use at a later time. Rain barrels are typically designed to capture runoff from roofs or other impervious surfaces, where it is stored until rainfall subsides.

### 3.2 Bioretention with Infiltration

Tree planters, vegetated swales, and rain gardens are common LID features used to retain and infiltrate stormwater runoff. Vegetated swales, or bioswales, are gently-sloped channels lined with vegetation.

The vegetation slows the runoff, and provides pollutant removal, while also conveying runoff to the storm drain system. Rain gardens are typically composed of three basic layers: top soil, an amended soil layer, and a gravel storage layer. These LID features can be designed to provide retention, water quality treatment, and infiltration. Unlike rain gardens, infiltration galleries and trenches do not include growth media to facilitate water quality treatment. Instead, rock is placed in the gallery or trench. The void space provides storage for stormwater before it infiltrates into native soils.

### 3.3 Proposed Zoning Map

Prior to establishing the different LID zones within the City, the City's infrastructure that was designed to eliminate stormwater discharge to Trinidad Bay (designated as an ASBS) was developed. These stormwater infrastructure features are required for the City to comply with State Water Resources Control Board regulations. After the planning and modeling of these features was complete, the LID Zoning Areas for private parcels within the City was developed. These areas, shown in Figure A3 (Appendix A) were determined taking into consideration the City's infrastructure, groundwater monitoring data, groundwater modeling results, geotechnical analyses, and City staff input.

## 4. Model Development

This section of the report describes the modifications made to the original groundwater model that was created, calibrated, and independently-validated in 2013 for the first phase of this project. The groundwater model was first modified to reflect existing 2016 conditions that include the stormwater system modifications and infiltrators constructed in 2014.

The results of this modified model for a 50-year storm event was used as the "base" scenario, which provides a basis from which to compare the groundwater level effects of potential future LID features being considered. Several scenarios that reflect various configurations of LID features, whether installed on City or private property were evaluated. Areas of particular interest of the evaluation are potential effects of the horizontal extents of the areas influenced by the LID infiltration, vertical interactions with existing septic systems, and the interaction at boundary conditions specifically relating to bluff stability. A total of four model runs, or scenarios, were developed for this groundwater analysis:

1. 2016 Conditions
2. 2018 Conditions
3. Full Storm Water System
4. Buildout

The first three scenarios represent different phases of LID development within City right-of-way. The different features that were included for each of the scenarios are shown in Figure A2 of Appendix A. Note that the LID features are additive (e.g., LID features in Scenario 1 are included in all subsequent scenarios). The fourth scenario builds upon Scenario 3, but includes potential development on private property.

Infiltrators are included in the groundwater model using the Well Package within the groundwater modeling software. Injection rather than extraction wells were used to simulate the flux into the model at the location of each infiltrator. The number of wells that is used to represent a single LID infiltrator is proportional to the footprint of the actual infiltrator. The runoff volume that enters an infiltrator is assumed to be evenly distributed across the infiltrator. From a groundwater modeling perspective, only LID features that infiltrate, rather than detain or convey, stormwater runoff are of interest and reflected in the groundwater model. The detention of stormwater is accounted for in the creation of the input files. Because the infiltrators are generally less than ten to fifteen feet below ground surface (BGS), the wells are included in Layer 1 of the model.

To determine the amount of water that enters the groundwater model via the infiltrators, a hydrologic analysis external to the groundwater model was performed. To complete this hydrologic analysis, results from the previous phase of work were used. The previously-delineated sub-watersheds (Figure 2 in Appendix A) and their runoff hydrographs developed in the Army Corp's HEC-HMS software were used to develop hydrographs for each infiltrator. A detailed description of the HEC-HMS model is provided in Section 3 Groundwater Model Technical Report, September 2013.

### 4.1 Groundwater Level Monitoring

The model results were verified with the collection of groundwater elevation data from the nine existing groundwater monitoring wells. Once the model was updated, the results of the model were compared with actual observed groundwater levels. Groundwater level data was collected from before and after the 2018 LID construction project. The direction from the City to initiate groundwater occurred in the fall but after early storms. The first significant storm event monitored was in January 2018. Monitoring wells down-gradient of the 2018 construction effort include: MW-1; MW-2; MW-5; and MW-9. The groundwater elevation in these four wells were compared by evaluating the change in water level during similar intensity storms at a similar time of year. The pre-construction comparison period is from January 16, 2018 through January 27, 2018. A 1.69" maximum amount of precipitation occurred on January 24$^{th}$ of that period. The post-construction period is from January 9, 2019 to January 20, 2019. A 2.26" maximum amount of precipitation was recorded on January 20$^{th}$ of the post-construction period of comparison.

Groundwater elevation in response to similar pre-construction and post-construction storms at MW-1 are shown in Figure D-11 and Figure D-12, respectively. The water level during the period of pre-construction goes from an elevation of 8.5 to 9.9 ft, showing a 1.4 ft increase in response to the precipitation event.

Groundwater elevation in response to similar pre-construction and post-construction storms at MW-2 are shown in Figure D-13 and Figure D-14, respectively. The water level during the period of pre-construction goes from an elevation of 61.1 to 61.3 ft, showing a 0.2 ft increase in response to the precipitation event. The water level during the period of post-construction goes from an elevation of 60.6 to 60.6 ft, showing no change in response to the precipitation event.

Groundwater elevation in response to similar pre-construction and post-construction storms at MW-5 are shown in Figure D-15 and Figure D-16, respectively. The water level during the period of pre-construction goes from an elevation of 131.0 to 131.2 ft, showing a 0.2 ft increase in response to the precipitation event. The water level during the period of post-construction goes from an elevation of 130.2 to 130.3 ft, showing a 0.1 ft increase in response to the precipitation event.

Groundwater elevation in response to similar pre-construction and post-construction storms at MW-9 are shown in Figure D-17 and Figure D-18, respectively. The water level during the period of pre-construction goes from an elevation of 113.9 to 113.9 ft, showing no response to the precipitation event. The water level during the period of post-construction goes from an elevation of 114.4 to 114.4 ft, again showing no response to the precipitation event.

While the observed storm events were much smaller than the 50-year event simulated, the groundwater monitoring data indicate that the new LID infiltration features are functioning appropriately and changes in groundwater elevation in the vicinity of the LID features has not appreciably changed from before and after the construction. No two storm events are the same in intensity and duration but the groundwater response to the recent storm events is consistent with previous storm events that were monitored in the years prior to construction.

### 4.2 Infiltrator Hydrographs

For each infiltrator and scenario, an infiltration hydrograph was developed. To determine each infiltration hydrograph, the amount of runoff for each sub-watershed that is conveyed to each infiltrator was determined. One foot contours were used to delineate the percent area of each sub-watershed that contributes to each infiltrator. These percentages were used to assign to each infiltrator portions of the HEC-HMS output hydrographs. The resulting hydrograph quantified the runoff that reaches each infiltrator. The actual runoff and infiltration rate of stormwater infiltrated into the model at each infiltrator was determined using the Green-Ampt Method (Gupta 2008), which determines that amount of water that infiltrates soil based on soil moisture conditions and static head. Table 2 shows the Green-Ampt Model parameters used. Parameters were determined based on the 2012 geotechnical analysis report.

Table 2. Green-Ampt model parameter values from indicated sources.

| Parameter | Value | Units | Source |
|---|---|---|---|
| Initial uniform water content | 0.12 | - | Gupta 2008 |
| Porosity | 0.3 | - | Gupta 2008 |
| Suction head at wetting front | 0.0151 | ft | Gupta 2008 |
| Effective hydraulic conductivity | 0.04 | ft/min | GHD 2012 |
| Depth to bedrock | 50 | ft | GHD 2012 |

In addition to soil parameters, the volume of infiltration is a function of the depth of water and the surface area over which water can infiltrate. It was conservatively assumed that all runoff that reaches the infiltrators is immediately stored in the infiltrators. In reality, the treatment chambers attenuate runoff and the LID system provides more storage than accounted for in the Green-Ampt calculations. For scenarios in which all stormwater runoff was not infiltrated, a bypass volume was calculated and assumed to be surface flow to the Trinidad ASBS outfall.

## 4.3 Model Runs

Table 3 provides a description for the four model runs, or scenarios, completed. Scenario 1 and 2 reflect conditions as of 2016 and 2018, respectively. Scenario 3 reflects the maximum LID construction within City right-of-way. Scenario reflects maximum buildout on both public and private property.

Table 3. Scenarios modeled.

| Scenario | Infiltrators Included* |
|---|---|
| 1: Base 2016 | Trinity and Ocean |
| 2: Base 2018 | Trinity, Ocean, East, Rain Garden, Hector |
| 3: Full storm system | Trinity, Ocean, East, Rain Garden, Hector, Underwood, HSU, Parking Lot |
| 4: Buildout | Trinity, Ocean, East, Rain Garden, Hector, Underwood, HSU, Parking Lot |

*Infiltrator names correspond with those shown in Figure A2 in Appendix A.

### 4.3.1 Scenario 1: Base 2016

Scenario 1 reflects conditions in 2016. Since the original groundwater model was developed, two infiltrators (Trinity and Ocean shown in Figure A2 in Appendix A) were constructed. Table 4 shows the percent of sub-watershed area, and therefore percent of sub-watershed hydrograph, that contributes to each of the two infiltrators. The 'Not Captured' percentage of each sub-watershed hydrograph flows to ASBS outfall (Figure A1 in Appendix A) and is not included in the groundwater model. It is assumed that the water not captured flows overland, down streets and ultimately discharges to non-point surface discharges. Results from the Green-Ampt model are shown in Figures 1 and 2 of Appendix B. The 'Runoff Rate' is the stormwater runoff that reaches the infiltrator, 'Infiltration Rate' is the amount of runoff that is infiltrated, 'Bypass Rate' is the amount of water that reaches the infiltrator but cannot be infiltrated or stored, and 'Storage Volume' is the amount of water stored in the infiltrator.

Table 4. Percent area of sub-watersheds captured by indicated infiltrators for Scenario 1.

| Sub-Watershed | Trinity | Ocean | Not Captured |
|---|---|---|---|
| CT1 | 30% | 65% | 5% |
| CT2 | 20% | 0% | 80% |
| CT3 | 85% | 0% | 15% |

### 4.3.2 Scenario 2: Base 2018

Scenario 2 is representative of the components constructed in 2016 and 2018. This includes the addition of three infiltrators (Rain Garden, Hector, and East shown in Figure A2 in Appendix A). Table 5 shows the percent of sub-watershed area, and therefore percent of sub-watershed hydrograph, that contributes to each of the infiltrators. Similar to Scenario 1, the 'Not Captured' percentage of each sub-watershed hydrograph flows to ASBS outfall (Figure A1 in Appendix A) and is not included in the groundwater model. Results from the Green-Ampt model are shown in Figures 3 through 8 of Appendix B.

Table 5. Percent area of sub-watersheds captured by indicated infiltrators for Scenario 2.

| Sub-Watershed | Trinity | Ocean | East | Rain Garden | Hector | Not Captured |
|---|---|---|---|---|---|---|
| CT1 | 30% | 65% | 5% | 0% | 0% | 0% |
| CT2 | 20% | 0% | 10% | 0% | 0% | 70% |
| CT3 | 85% | 0% | 0% | 0% | 0% | 15% |
| CT4 | 0% | 0% | 0% | 15% | 20% | 65% |

### 4.3.3 Scenario 3: Full Storm Water System

Scenario 3 includes all infiltrators shown in Figure 2 in Appendix A. Table 6 shows the percent of sub-watershed area, and therefore percent of sub-watershed hydrograph, that contributes to each of the infiltrators. Note that there is not an infiltrator in CT9, which eliminates the need for a change from the original model. The Parking Lot infiltrator is assumed to capture all runoff not captured by the remaining infiltrators. While Scenario 1 and 2 infiltrators were designed in the previous phase of this project, the infiltrators unique to Scenario 3 (Underwood, HSU, and lower Parking Lot) were sized to capture all of the runoff flow from their associated sub-watersheds and any flow not captured by the previously installed infiltration features, thus, eliminating any bypass flow. Results from the Green-Ampt model are shown in Figures 9 through 17 of Appendix B.

Table 6. Percent area of sub-watersheds captured by indicated infiltrators for Scenario 3.

| Sub-Watershed | Trinity | Ocean | East | Rain Garden | Hector | Under-wood | HSU | Edwards | Parking Lot |
|---|---|---|---|---|---|---|---|---|---|
| CT1 | 30% | 65% | 5% | 0% | 0% | 0% | 0% | 0% | 0% |
| CT2 | 20% | 0% | 10% | 0% | 0% | 0% | 0% | 70% | 0% |
| CT3 | 85% | 0% | 0% | 0% | 0% | 0% | 0% | 15% | 0% |
| CT4 | 0% | 0% | 0% | 15% | 20% | 0% | 0% | 65% | 0% |
| CT5 | 0% | 0% | 0% | 0% | 0% | 50% | 50% | 0% | 0% |
| CT6 | 0% | 0% | 0% | 0% | 0% | 20% | 0% | 80% | 0% |
| CT7 | 0% | 0% | 0% | 0% | 0% | 10% | 15% | 75% | 0% |
| CT8 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 95% |
| CT10 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

### 4.3.4 Scenario 4: Full Buildout

In addition to the same infiltrators that were included in the Full Storm Water System, the Full Buildout scenario includes septic systems and LID infiltrators that may be constructed on private property that is not yet developed. Potential development was analyzed with the City Planner for the number of dwelling units per parcel. Parcels that were identified as areas for potential development are shown in Figure 3 of Appendix A. For Scenario 4, septic systems were added to all parcels identified for development. LID infiltrators were added to the parcels located within the LID Zone area (shown in Figure 3 of Appendix A).

### *Septic Systems*

A discussion of how septic loading rates were determined based on water use data can be found in the Groundwater Model Technical Report, September 2013. Septic loading data from the original groundwater model provided a basis for estimating potential future development loading rates. Excluding anomalous data points that did not accurately represent residential units (e.g., restaurants), the average septic loading rate per parcel was applied to the estimated number of potential dwelling units. The number of potential dwelling units was estimated based on the allowable density of the zone (e.g., one dwelling unit per 8,000 SF for Urban Residential areas). For the available data, the average loading per resident was 15.5 cubic feet per day. This value represents the loading rate for an entire parcel, which may have more than a single dwelling rate. Applying the average loading rate of 15.5 CF/day provides a conservative estimate for each new parcel's loading rate.

In the original groundwater model, the required area for a septic system was determined based on the number of bedrooms per building, which was estimated using aerial imagery. Because dwelling units are not defined by a number of bedrooms, a different approach was developed for determining the required area for a given septic system. Consistent with the original groundwater model, a percolation rate of 4 inches/hour was used. With this percolation rate, the maximum loading rate was conservatively assumed to be 0.4 gal/ft$^2$/day. The required area for a septic system was then determined using the maximum loading rate and the previously-discussed septic loading rate. Aerial imagery and topography data were used to determine potential septic system locations. It should be noted that at exact location of individual septic systems were not available and the representation in the model do not indicate actual septic locations. A qualitative evaluation of each parcel was made and the likely location a septic leach line was approximated for representation in the model. With size and resolution of the groundwater model any discrepancy between the true location and approximated location would have a negligible effect on the model results. The more critical factor is the septic loading rate applied to each parcel. The septic loading or flow rates, as described above is appropriate for the size of the facilities or dwelling and is consistent with County guidelines for determining septic loading rates.

### *LID Infiltrators*

An LID Zone area (Figure A3 of Appendix A) was determined based on the known bedrock and geological features in the vicinity. These characteristics are discussed in the main report, and depicted in Figures E-1 and E-4 of the main report appendix. The LID Zone area is intended to provide placement guidance for features that infiltrate runoff. LID features may be constructed beyond the extents of the LID Zone, but it is recommended other LID features, such as those intended to retain or store runoff, be considered for these areas.

Rather than the 50-yr storm event applied to the LID infiltrators within the City's right-of-way, the more typical 2-year storm event was used for these infiltrator hydrographs. Consistent with the Phase II Municipal Separate Storm Water Sewer System (MS4) Permit, the Humboldt County LID Design manual requires that LID features be designed for different storm events dependent upon the project type. The largest storm event (2-year, 24-hour) for LID design was applied to the potential LID infiltrators.

Runoff was assigned to infiltrate over the same area as the septic systems, thereby providing a conservative scenario in which groundwater levels would increase the most. Hydrographs generated during the original groundwater modeling efforts (discussed in the main report) for the 2-year storm event were used to determine the amount of runoff to apply to the infiltrators. A percentage, based on contributing area, of the subwatershed hydrographs was uniformly-distributed over the 24-hour storm to an infiltrator based on the contributing area. A uniform distribution of the runoff was considered more representative of these infiltrators, which attenuate peak flows.

# 5. Model Results

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 groundwater model output results from this scenario were used to compare potential future LID scenarios. Results are presented and discussed in the following sections.

## 5.1 Scenario 1

The groundwater elevation results for Scenario 1 suggest that maximum groundwater elevations for the Trinity and Ocean infiltrators is approximately 170 ft and 175 ft, respectively. These elevations occur in the center of the infiltrators (Figure C1 in Appendix C). Groundwater levels appear to be largely unaffected by the infiltrators approximately 30 feet away from the infiltrators, where groundwater elevations are approximately 150 ft. The results of this scenario are consistent with the design and previous modeling expectations and are now part of the base conditions.

## 5.2 Scenario 2

Negligible differences were observed between Scenario 1 and Scenario 2 for groundwater elevations around the Trinity and Ocean infiltrators (Figures C2 and C3 in Appendix C). This result was anticipated because infiltrator hydrographs for the two scenarios were approximately the same. Among the four new infiltrators, the East infiltrator showed the greatest increase in groundwater elevations. At the center of the infiltrator, the maximum change in groundwater elevation was 19 feet. Groundwater elevations increased from 152 ft to 171 ft. It should be noted that this increase only occurs directly below the infiltrator and the effect of increased groundwater elevations quickly dissipates with horizontal distance away from the infiltration. At approximately 22 feet from the infiltrator, groundwater elevations returned to those of the base scenario. This result is consistent with previously modeled infiltrators. The locations of predicted increase in groundwater levels are evaluated for potential conflicts with potential septic systems. There were no septic system conflicts found. Results for all four infiltrators introduced for Scenario 2 are shown in Table 7.

Table 7. Summary of groundwater model results for Scenario 2 compared to Scenario 1.

| Infiltrator | Maximum Groundwater Elevation (ft) | Maximum Change in Groundwater Elevation (ft) | Distance to No Change (ft) |
|---|---|---|---|
| East | 171 | 19 | 22 |
| Rain Garden | 168 | 15 | 20 |
| Hector | 165 | 11 | 23 |

Because the primary point of interest is groundwater elevations with respect to septic systems for this analysis, only infiltrators that result in a change in groundwater elevation near a septic system are evaluated for potential septic-groundwater interaction. The East infiltrator is the only infiltrator that meets this criterion for Scenario 2 (Figure 2). Figure 2 shows only the East infiltrator (solid blue rectangle) and surrounding septic systems (black polygons). Surrounding the infiltrator, the blue lines represent the 10-ft contour lines of groundwater elevation. Although the contour lines overlap with the septic system (shown by the black lines) the infiltrator contours do not interact with the septic contours.

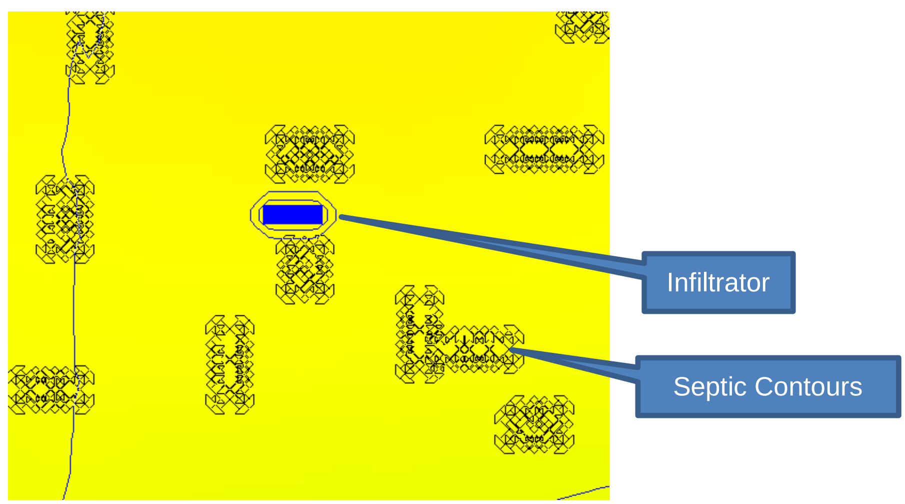



Figure 2. East infiltrator results in the groundwater model graphical user interface.

The minimum difference in elevation between the groundwater level and surface is approximately 18 feet where the septic system and change in groundwater elevation overlap. Typical septic system trenches are installed around three to four feet deep below grade surface (bgs), and the county requires a minimum three-foot separation between septic systems and groundwater elevation. Thus, a minimum difference of seven feet is assumed a sufficient difference in elevation between the groundwater elevation and a septic system and we have approximately 11 feet of separation.

### 5.3 Scenario 3

As anticipated, results for the infiltrators introduced in the previous scenarios remained approximately the same as those of the previous results. Results for the infiltrators introduced in Scenario 3 are shown in Figures 4 and 5 of Appendix C and summarized in Table 8. No changes in groundwater elevations were observed near a septic system.

Table 8. Summary of groundwater model results for Scenario 3 compared to Scenario 1.

| Infiltrator | Maximum Groundwater Elevation (ft) | Maximum Change in Groundwater Elevation (ft) | Distance to No Change (ft) |
|---|---|---|---|
| Underwood | 168 | 14 | 23 |
| HSU | 102 | 12 | 24 |
| Parking Lot | 34 | 12 | 140 |

### 5.4 Scenario 4

Although additional LID features and septic systems were included within each of the Parcels with Potential for Development (shown in Figure A3 of Appendix A), a difference was only observed in a single area (shown in Figure C7 of Appendix C). This location is an undeveloped parcel on in the Mill Creek drainage, near Stagecoach Dr. The increase in groundwater level is due to the assumed septic loading applied to the parcel. Due to the large parcel size and the potential to develop more dwelling units, septic loading rates were greater for this area. Changes in groundwater levels did not exceed four feet, which occurs in the center of the septic system. The septic leach field location within the parcel was assumed and any future development would need to follow City and County guidelines for siting the leach field. The position of the leach field in this analysis does not imply that septic sizing and location procedures are necessarily appropriate for future development. No other changes in groundwater levels were observed for the new buildout features. These results were anticipated because the new buildout features were designed to accommodate septic loading rates and the two-year storm event, rather than the 50-year storm event that the City infiltrators were designed to capture.

### 5.5 Maximum Recharge

In addition to the above four scenarios, an additional model run was evaluated. As discussed in the Groundwater Model Technical Report, September 2013, recharge is applied to all model cells to represent infiltration in any permeable areas. The purpose of the additional model run was to explore the worst-case scenario in the context of groundwater levels. That is, the scenario in which the maximum stormwater runoff is infiltrated into the groundwater model thus increasing groundwater levels and decreasing the vertical distance between groundwater levels and septic systems. Essentially we wanted to confirm that the model could show there is a limit to how much stormwater should be infiltrated. Numerous scenarios could be explored for determining the maximum groundwater levels. For this evaluation, the worst-case scenario was assumed to be the scenario in which all precipitation that did not enter the groundwater model via infiltrators was distributed and infiltrated across the pervious areas of the model. This volume of water was captured in the model recharge. The recharge volume was determined on a sub-watershed scale and proportionally distributed based on the recharge zones shown in Figure E-4 of the Trinidad ASBS Stormwater Project Groundwater Model Technical Report (GHD

2013). .For the area north of Van Wycke St. in CT9, all precipitation was conservatively assumed to be converted to recharge.

As expected, applying the maximum recharge to the model resulted in groundwater levels that exceeded the ground surface, which suggests that the subsurface is fully saturated. Saturation was anticipated because this scenario assumes that all rainfall that lands within the watershed is captured and infiltrated. Because saturation was reached, the model was not able to infiltrate all of the rainfall runoff. For the first three scenarios, the storm event lasted approximately 36 hours. For maximum recharge scenario the model could not proceed after approximately five hours. The results of this simulation indicate that it is not feasible or desirable to capture and infiltrate all stormwater. It also reinforces our understanding that future LID design features should include detention elements.

# 6. Conclusions

The results of this groundwater model analysis and a geotechnical analysis of slope stability indicate that the proposed LID features included in Scenarios 2 and 3 will not result in groundwater levels that exceed proximity requirements with respect to septic systems and that the groundwater elevations near the bluffs are not changed. The minimum vertical distance between groundwater and a septic system is 18 feet, sufficiently greater than the minimum requirement of seven feet. When the maximum possible modeled recharge is included in the model the model failed to run to completion because the simulated groundwater elevations exceed the ground surface. It should be noted that the maximum possible recharge included 100% of all precipitation falling within a watershed, with no runoff. These results show that infiltrating all stormwater runoff is not feasible or desirable with the current capacity of existing stormwater detention systems.

The evaluation of the future full buildout of all parcels (Scenario 4) indicate that groundwater levels do not exceed proximity requirements with respect to septic systems and that the groundwater elevations near the bluffs are essentially not changed.  The groundwater model has proved a useful tool to understand the impacts on the groundwater system from specific proposed LID/BMPs.

## References

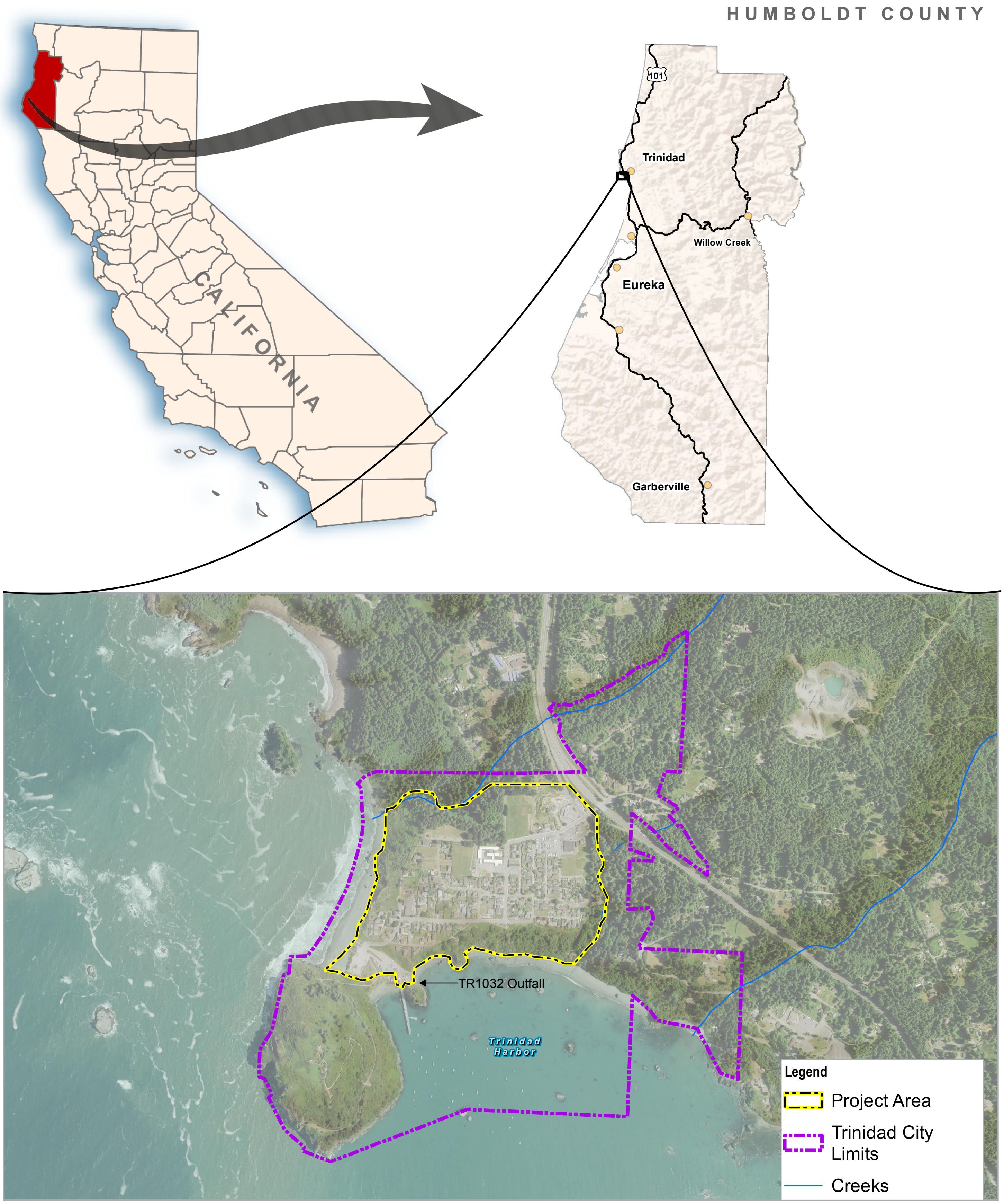
GHD 2013. Report for Trinidad ASBS Stormwater Project Groundwater Model Technical Report

Gupta, S. 2008. Hydrology and Hydraulic Systems, 3rd Ed. Waveland Press.

County of Humboldt. 2016. Humboldt Low Impact Development Stormwater Manual v2.0.

City of Santa Rosa. 2012. City of Santa Rosa LID Technical Design Manual, Revision 2.

# Appendix A: Project Maps




Paper Size ANSI A

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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

GHD

**City of Trinidad**
**ASBS Stormwater Improvement Project**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

## Vicinity

## FIGURE A1

N:\US\Eureka\Projects\111\11136537 Trinidad-OPC Citywide LID Assist\08-GIS\Maps\Deliverables\FinalReport\11136537_A1_Vicinity.mxd
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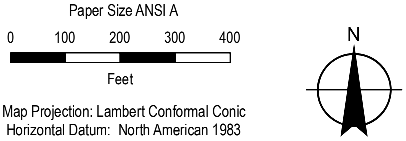
Data source: Humboldt County creeks; StreetMapUSA, Boundaries, 2010; Sources: Esri, USGS, NOAA. Created by: jclark2


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

**City of Trinidad**
**ASBS Stormwater Improvement Project**

**Project Components**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**FIGURE A2**

N:\US\Eureka\Projects\111\11136537 Trinidad-OPC Citywide LID Assist\08-GIS\Maps\Deliverables\FinalReport\11136537_A2_ProjectComponents_RevC.mxd
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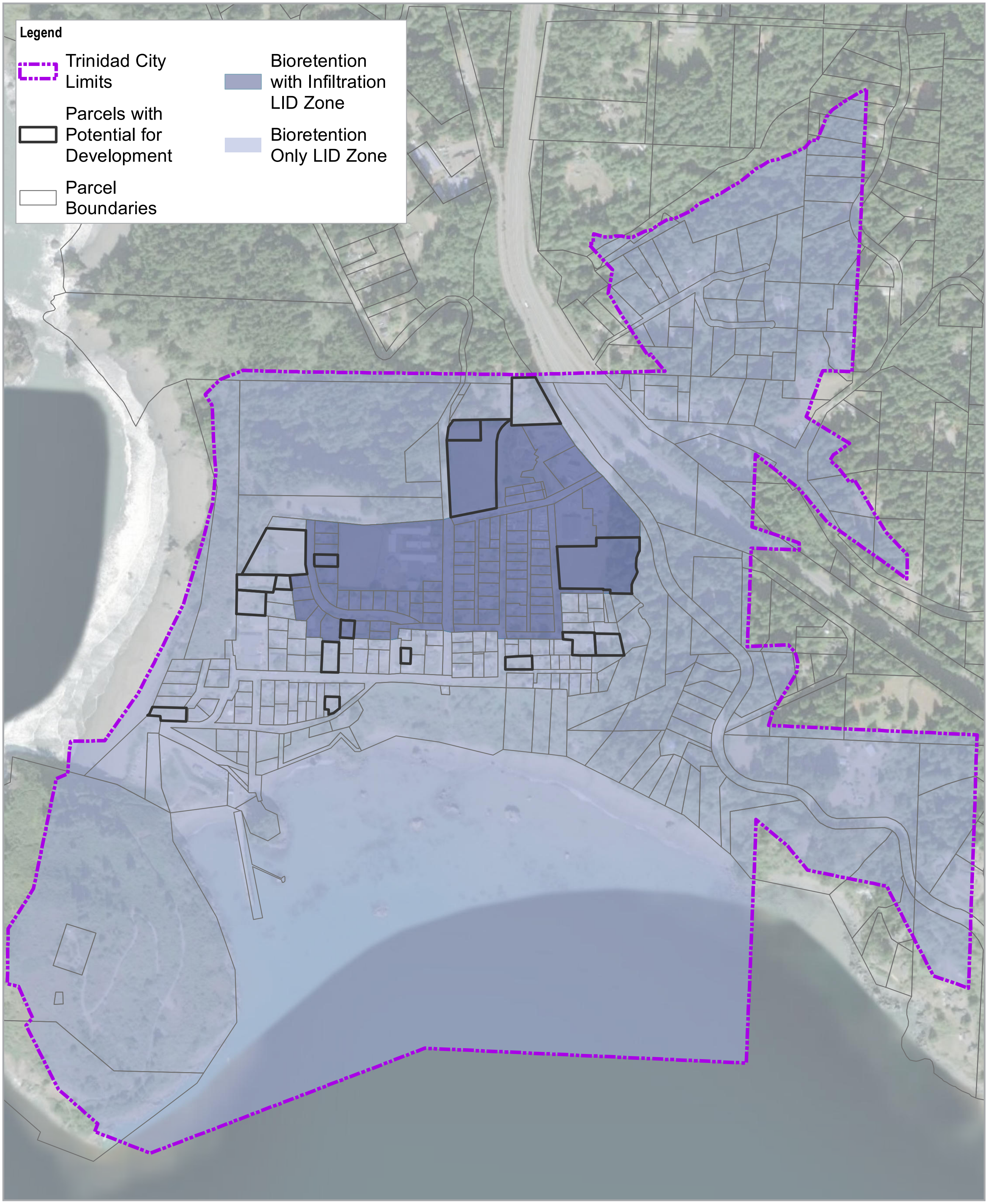
Data source: GHD: LID features locations, watershed boundaries; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Created by: jclark2




Paper Size ANSI A

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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 of Trinidad**
**ASBS Stormwater Improvement Project**

**LID Zones and Potential Development**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**FIGURE A3**

N:\US\Eureka\Projects\111\11136537 Trinidad-OPC Citywide LID Assist\08-GIS\Maps\Deliverables\FinalReport\11136537_A3_ProjectComponents_RevC.mxd
Print date: 22 Jan 2019 - 09:35

Data source: GHD: LID zone area; County of Humboldt parcels, 2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
Created by: jclark2

# Appendix B: Infiltrator Hydrographs Developed using Green-Ampt

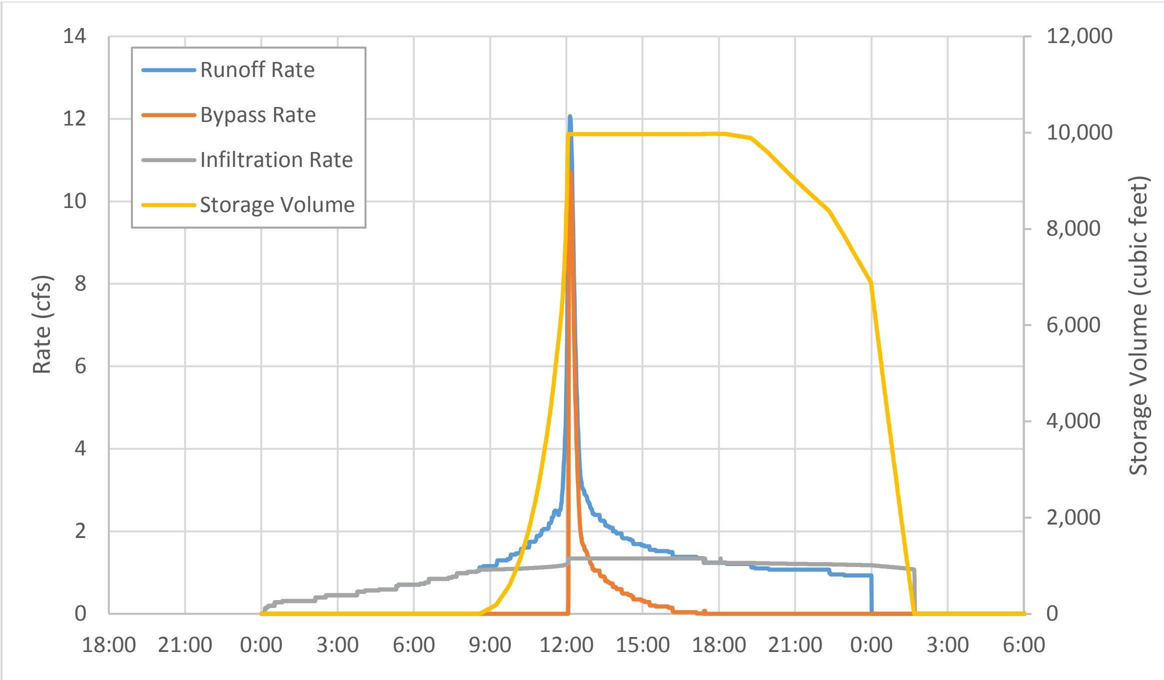



**Figure 1. Scenario 1, Trinity Infiltrator.**

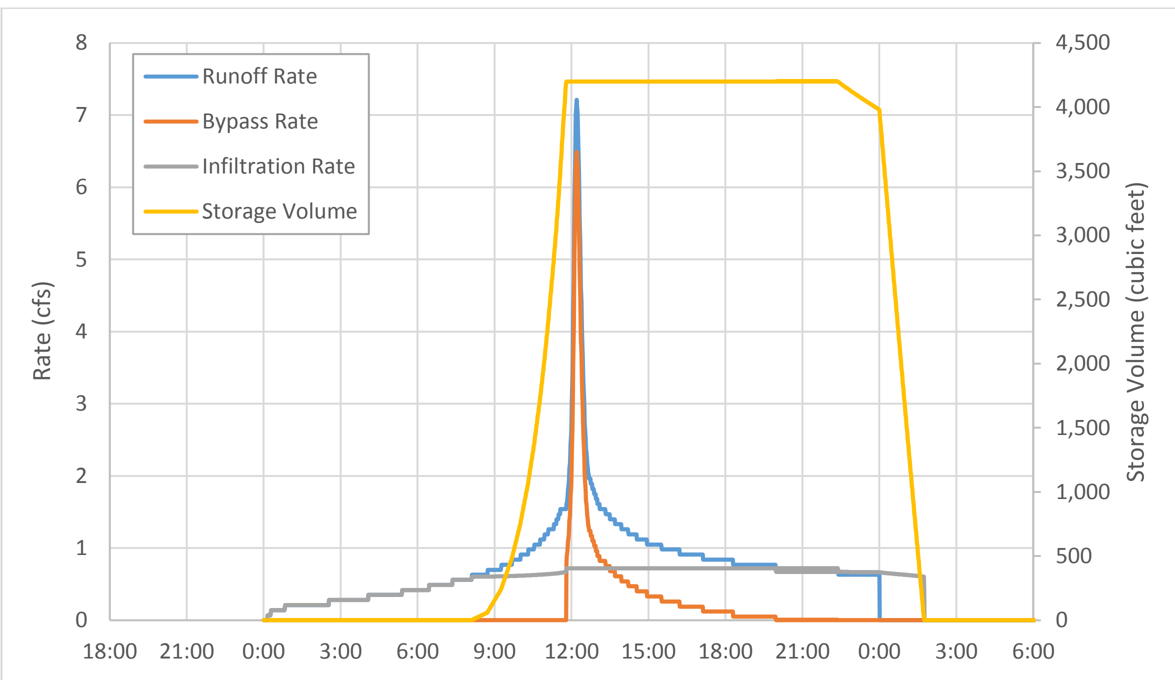



**Figure 2. Scenario 1, Ocean Infiltrator.**

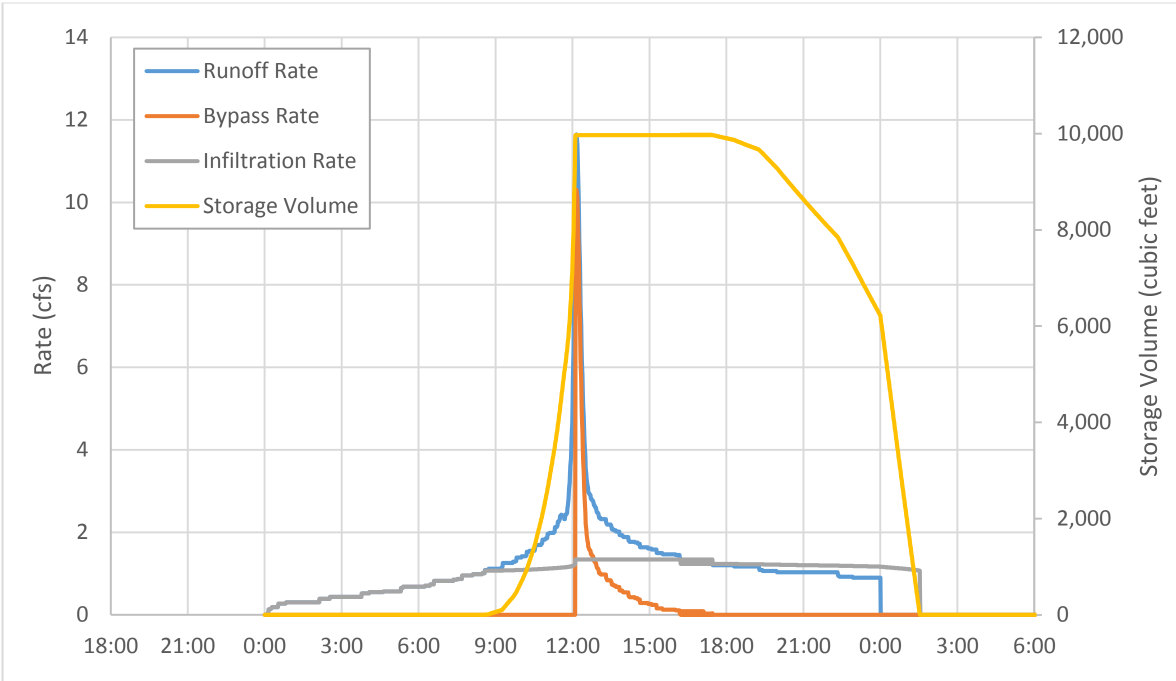



**Figure 3. Scenario 2, Trinity Infiltrator.**

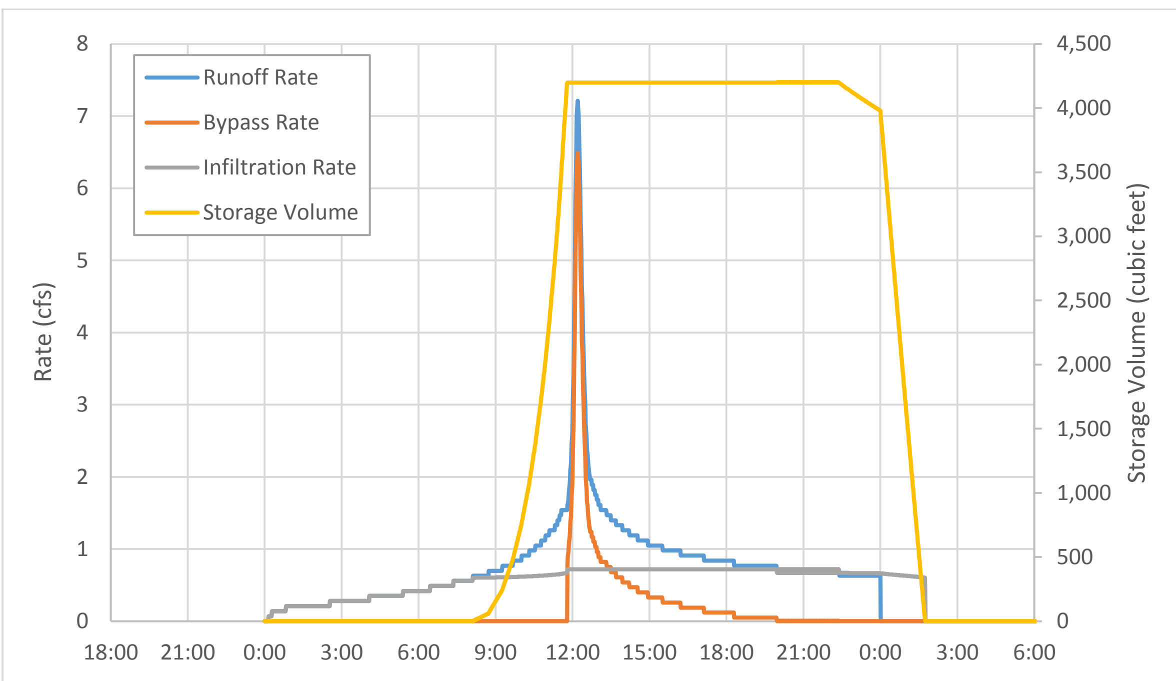



**Figure 4. Scenario 2, Ocean Infiltrator.**

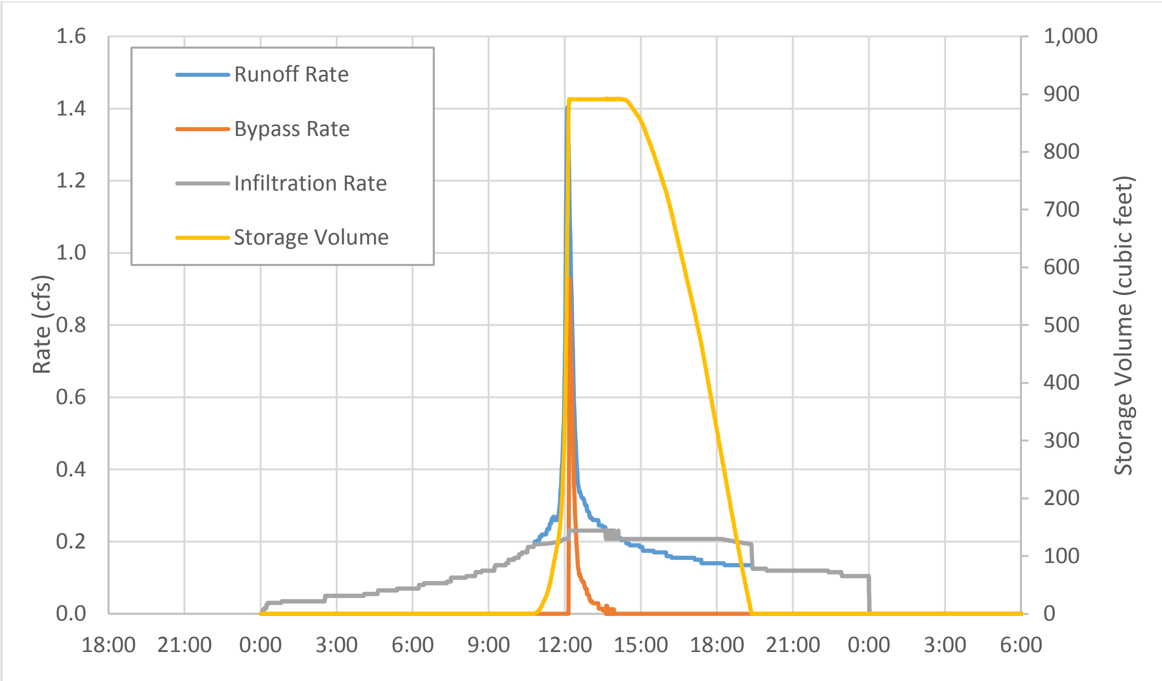



**Figure 5. Scenario 2, East Infiltrator.**

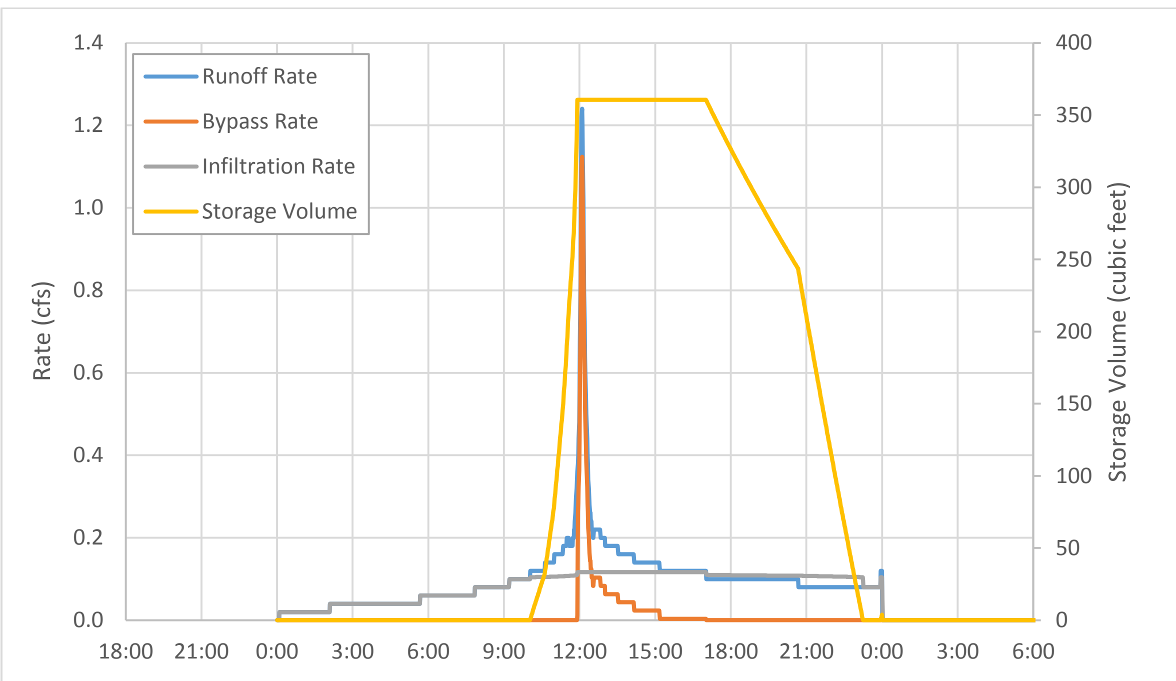



**Figure 6. Scenario 2, Hector Infiltrator.**

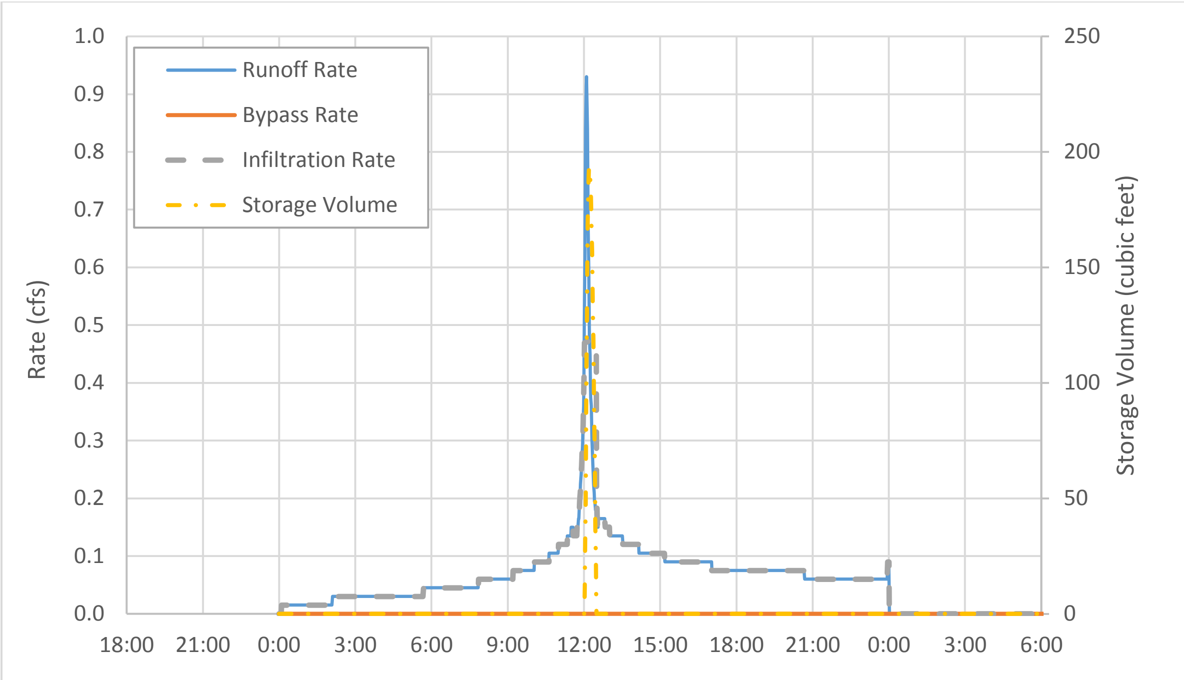



**Figure 7. Scenario 2, Rain Garden Infiltrator.**

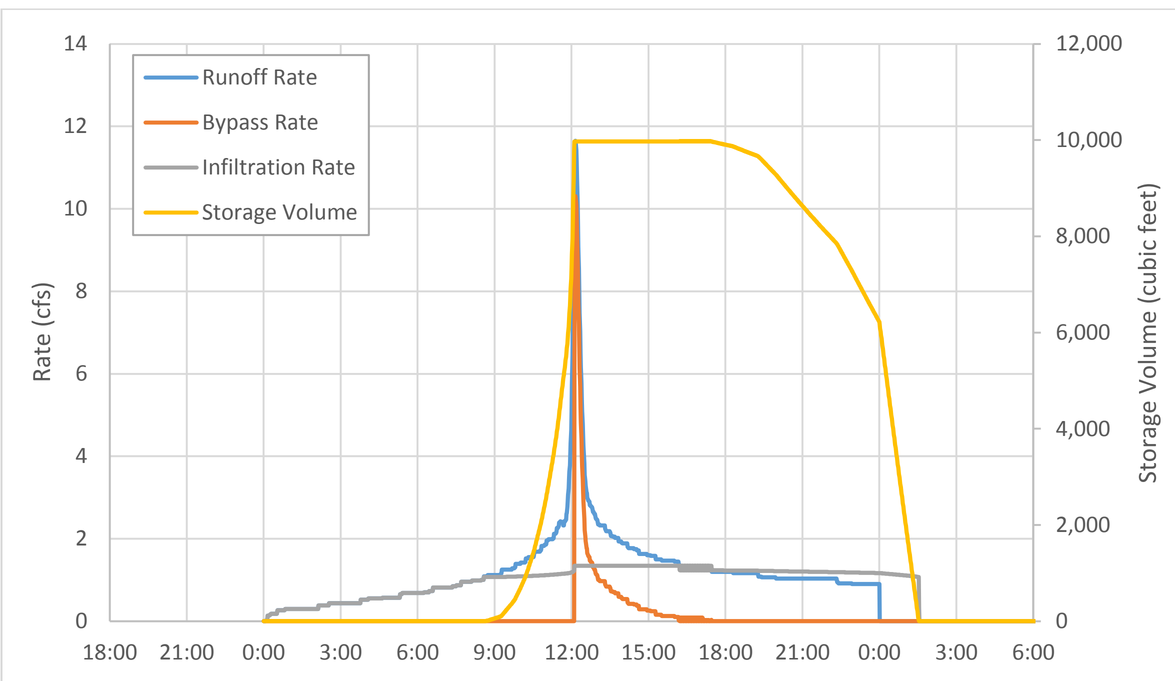



**Figure 8. Scenario 3, Trinity Infiltrator.**

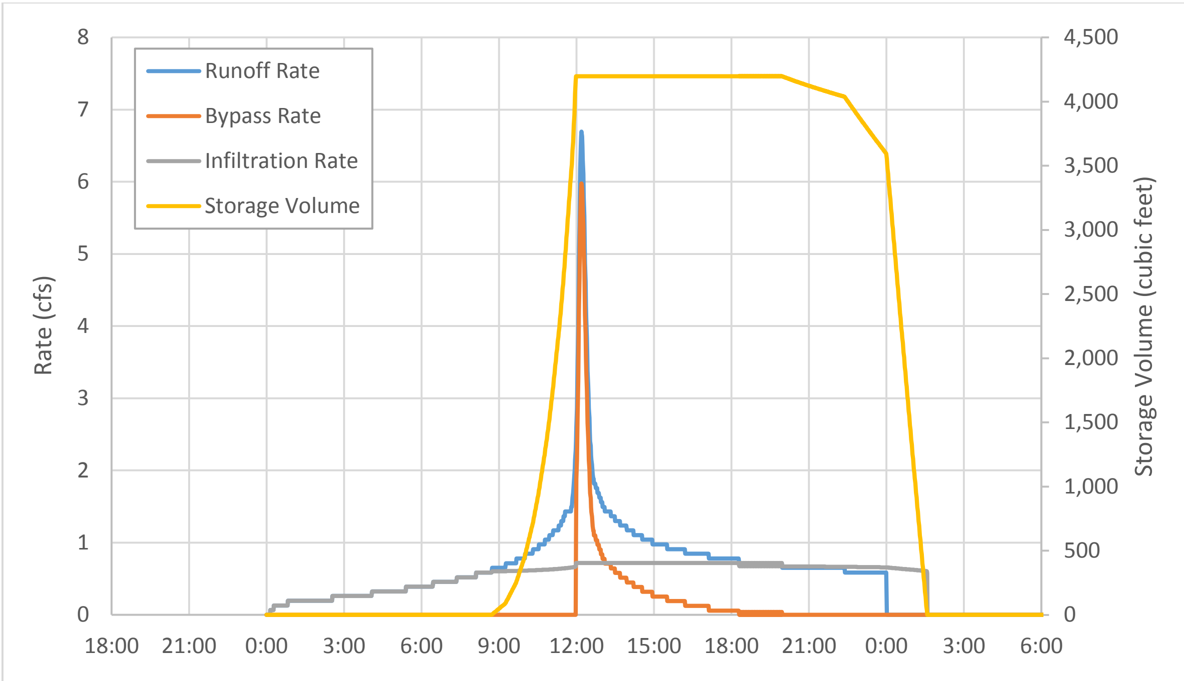



**Figure 9. Scenario 3, Ocean Infiltrator.**

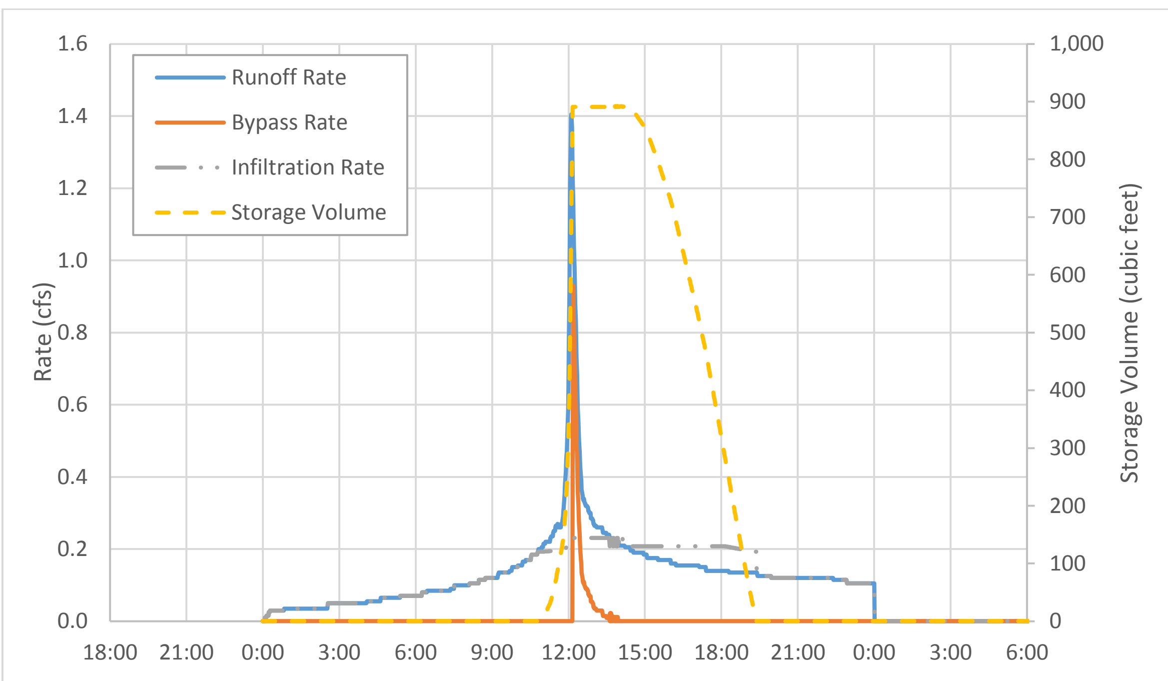



**Figure 10. Scenario 3, East Infiltrator.**

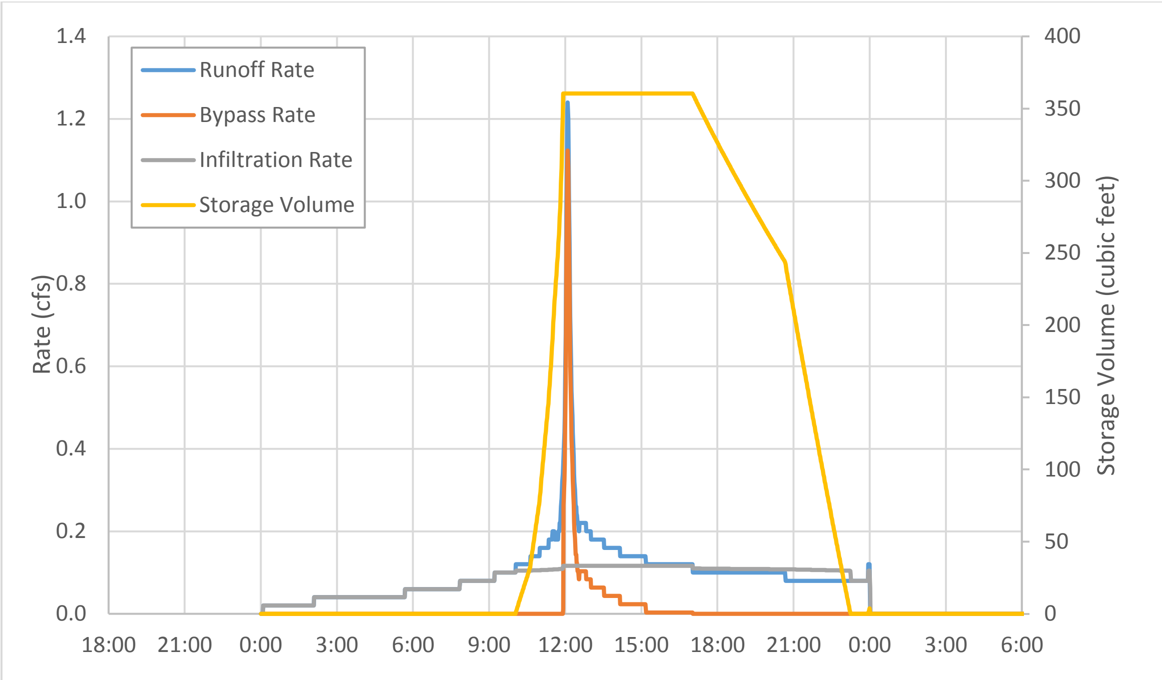



**Figure 11. Scenario 3, Hector Infiltrator.**

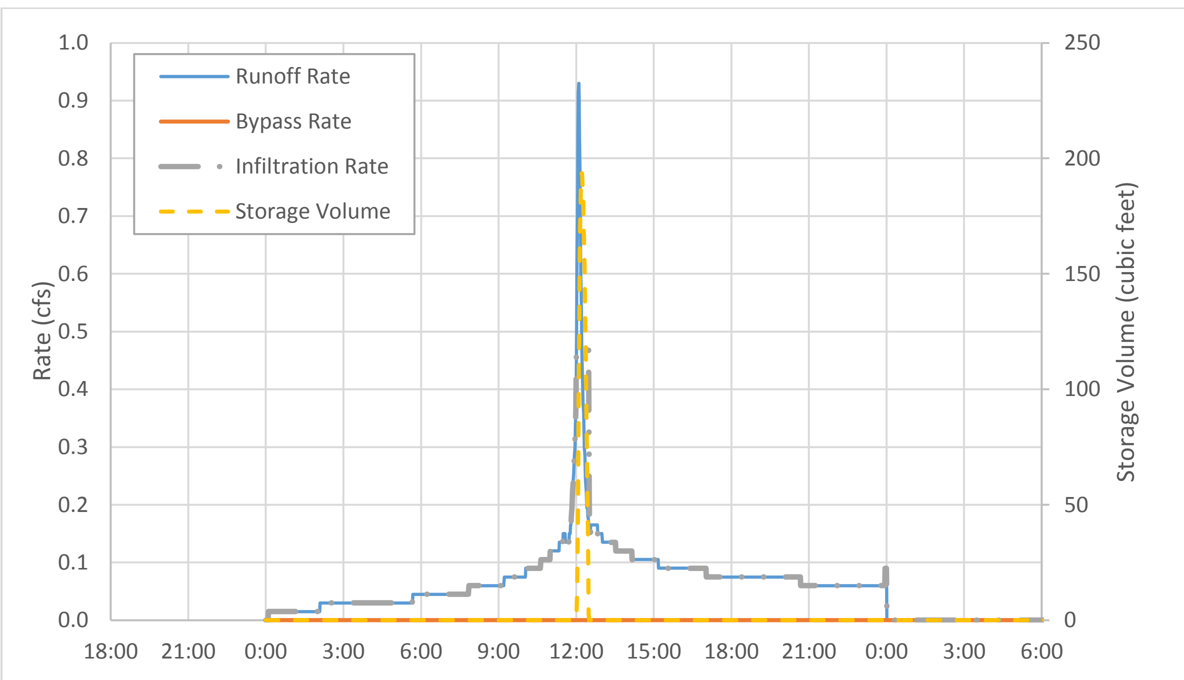



**Figure 12. Scenario 3, Rain Garden Infiltrator.**

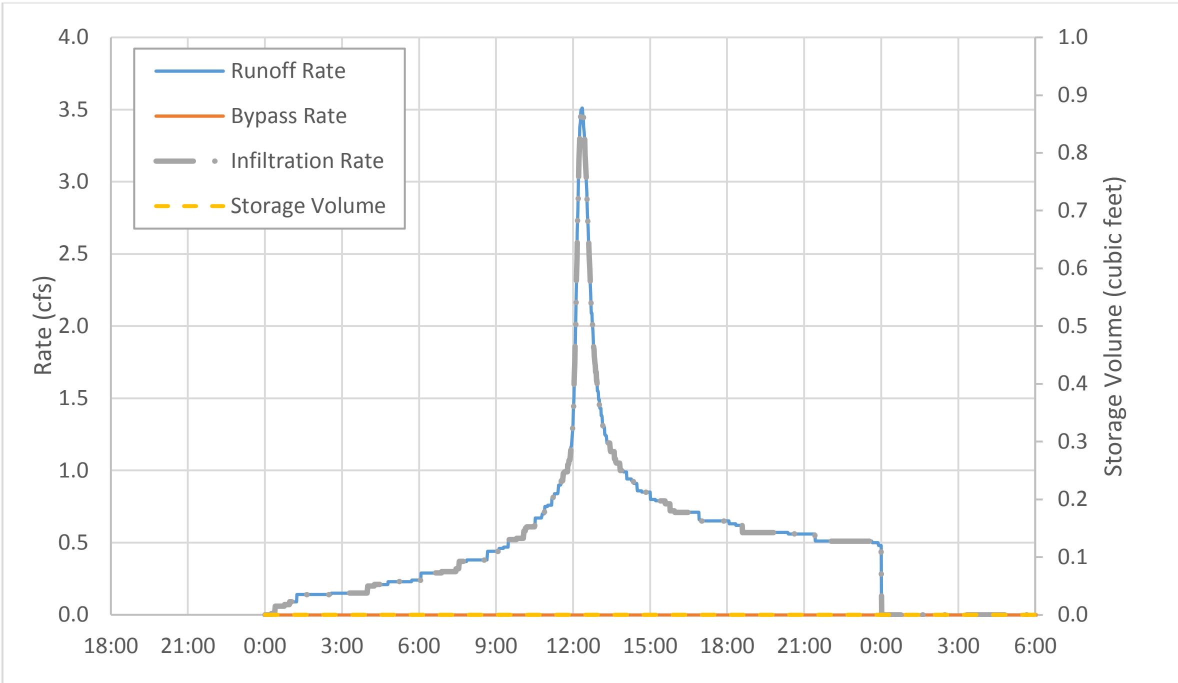



**Figure 13. Scenario 3, Underwood Infiltrator.**

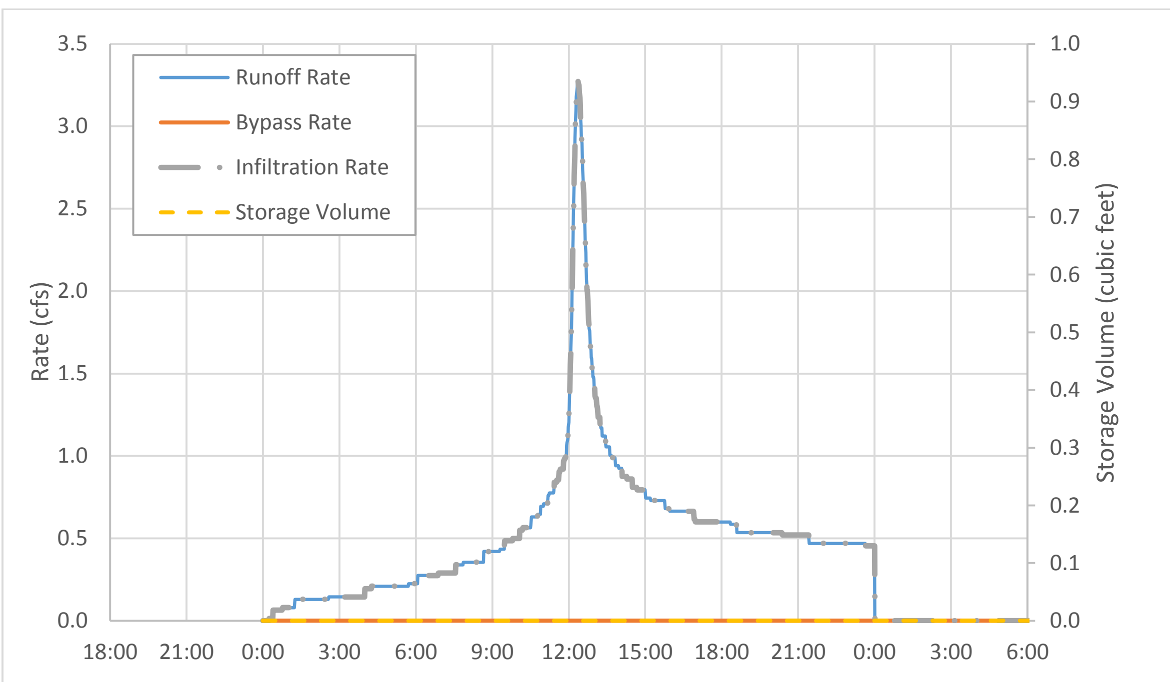



**Figure 14. Scenario 3, Ewing Infiltrator.**

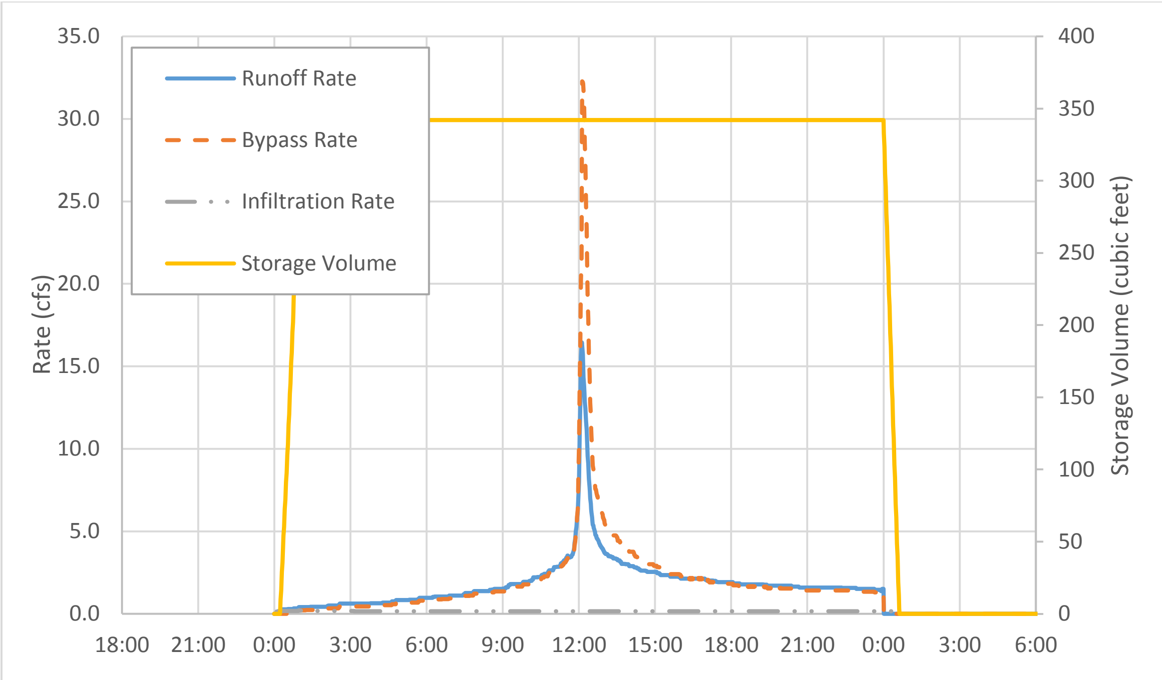



**Figure 15. Scenario 3, Edward 1 Infiltrator.**

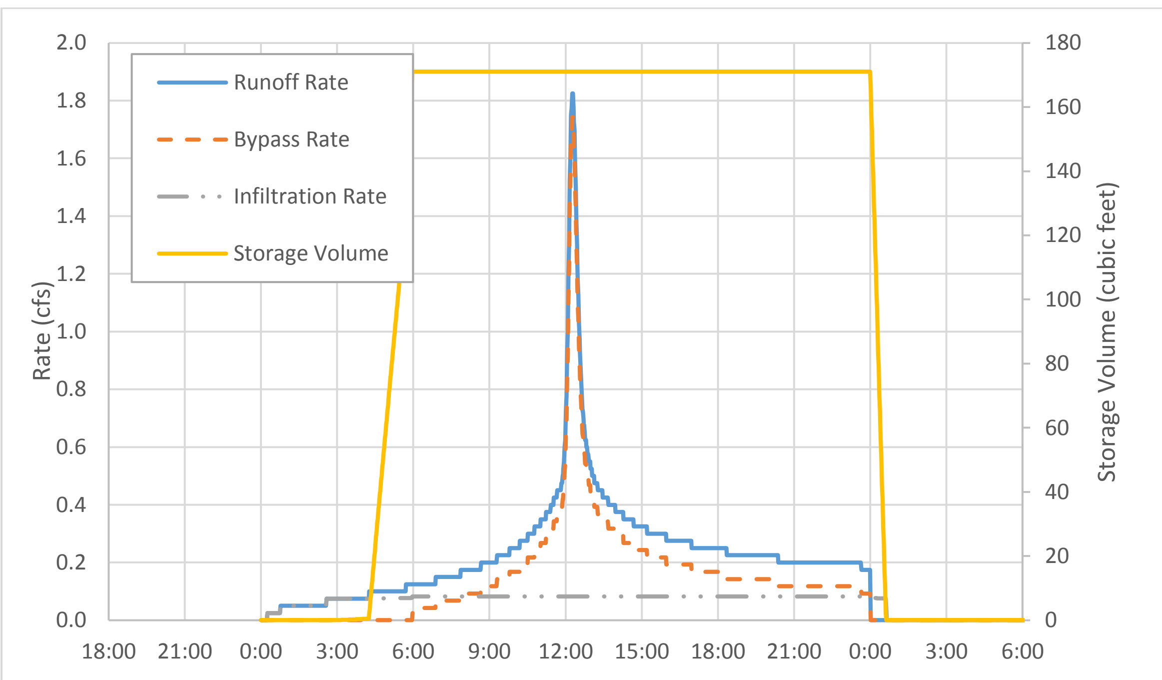



**Figure 16. Scenario 3, Edward 2 Infiltrator.**

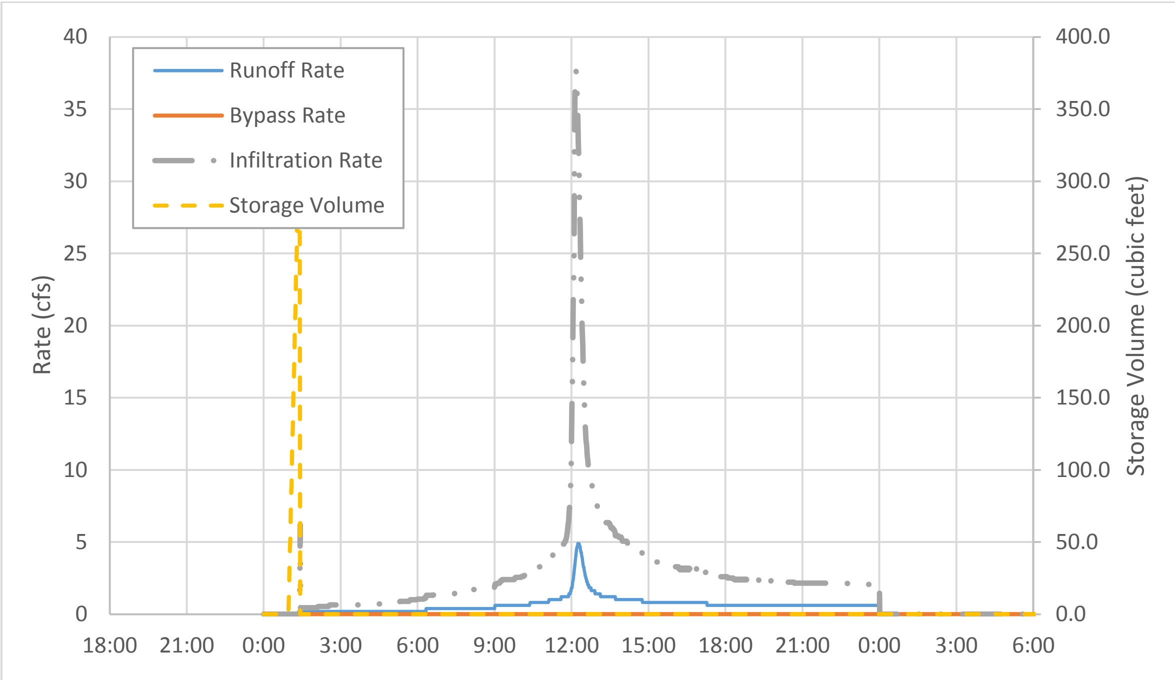
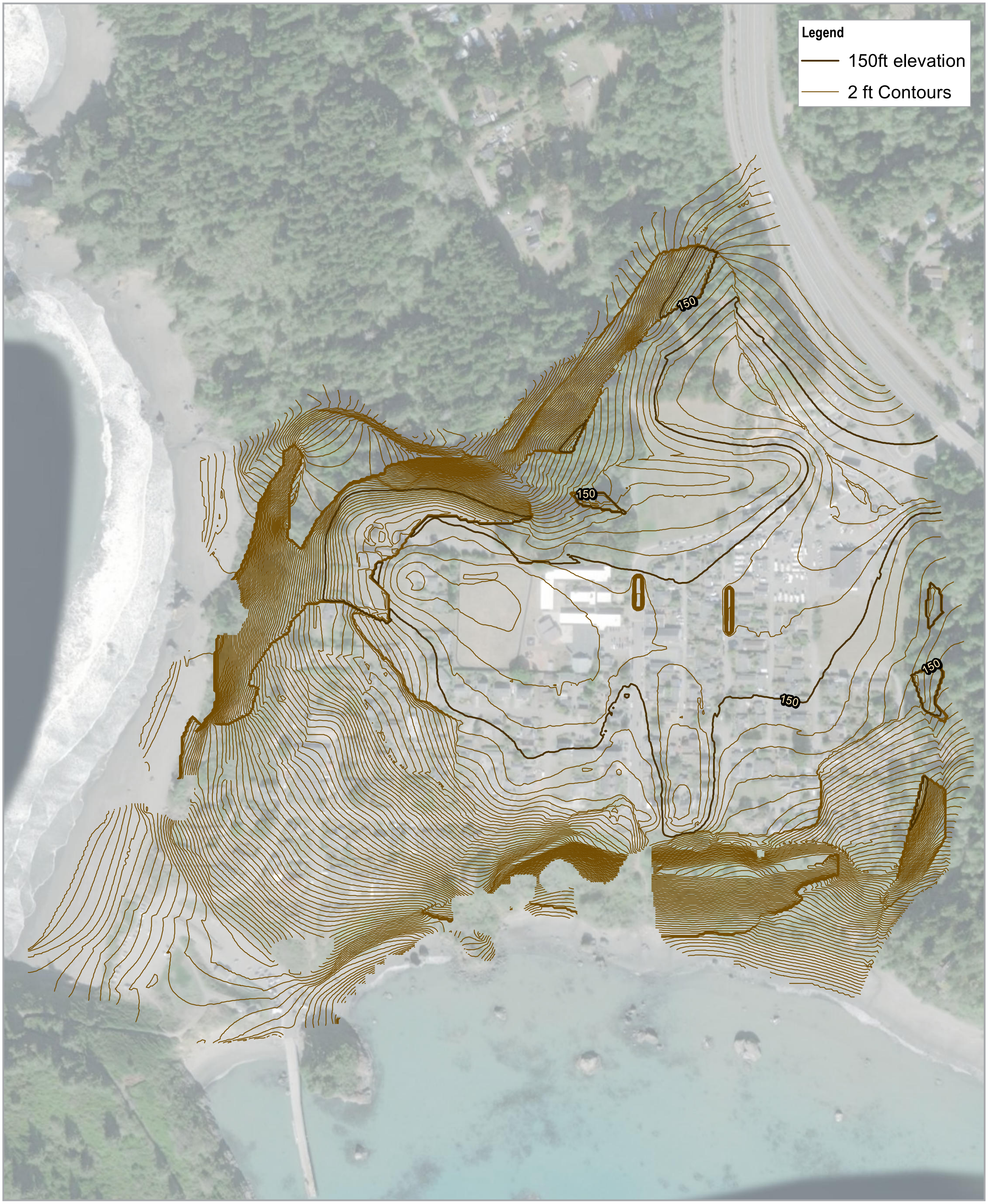



**Figure 17. Scenario 3, Parking Lot Infiltrator.**

# Appendix C: Groundwater Modelling Results




Paper Size ANSI A

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Feet

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

**City of Trinidad**
**ASBS Stormwater Improvement Project**

**Scenario 1**
**Base 2016**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**FIGURE C1**

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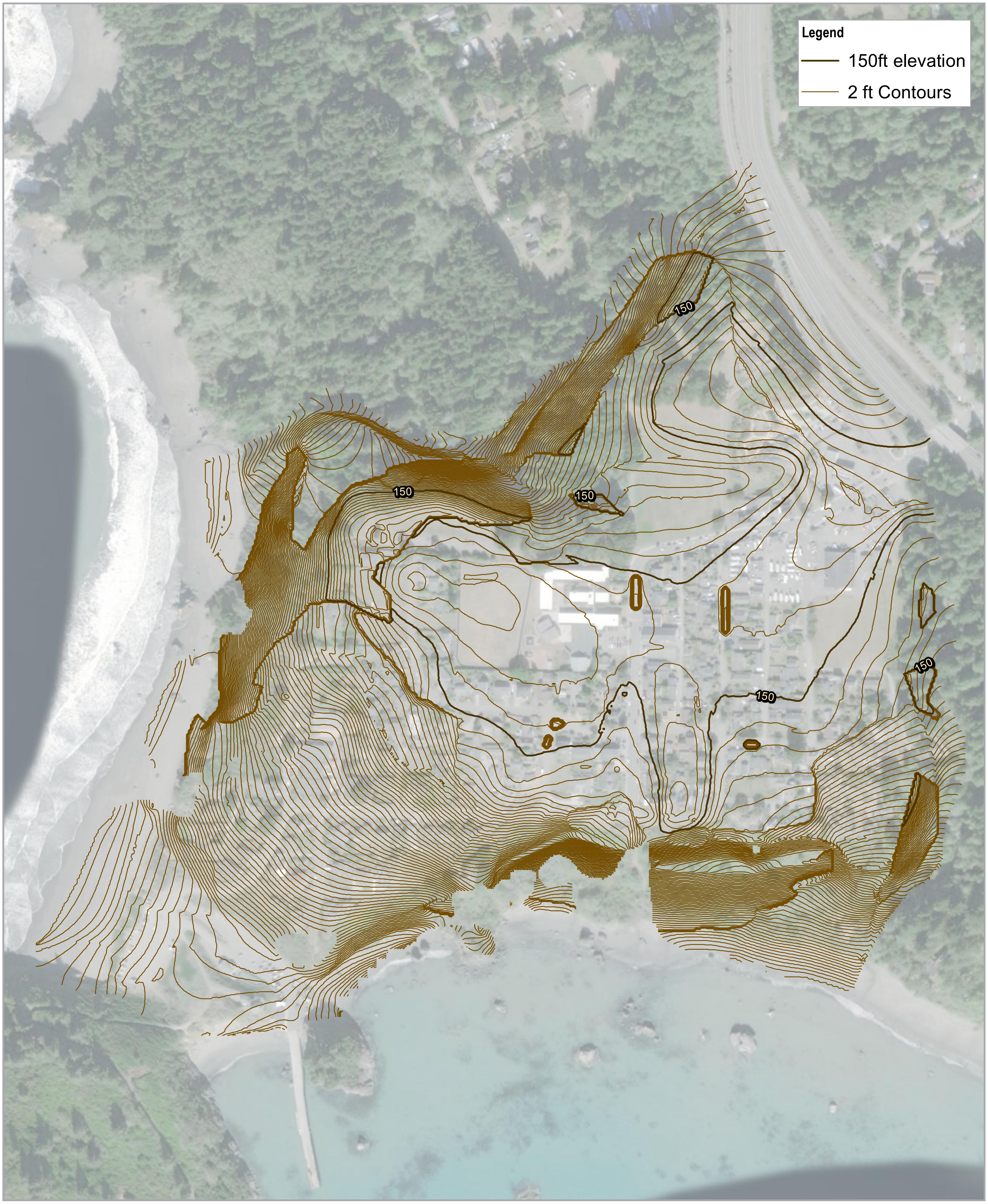
Print date: 22 Jan 2019 - 08:46

Data source: GHD model results, Base 2016, 1/20/2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: jclark2

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Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

GHD

**City of Trinidad**
**ASBS Stormwater Improvement Project**

**Scenario 2**
**Base 2018**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

# FIGURE C2

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Paper Size ANSI A

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Feet

N

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

**City of Trinidad**
**ASBS Stormwater Improvement Project**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**Scenario 2 compared to Scenario 1**

# FIGURE C3

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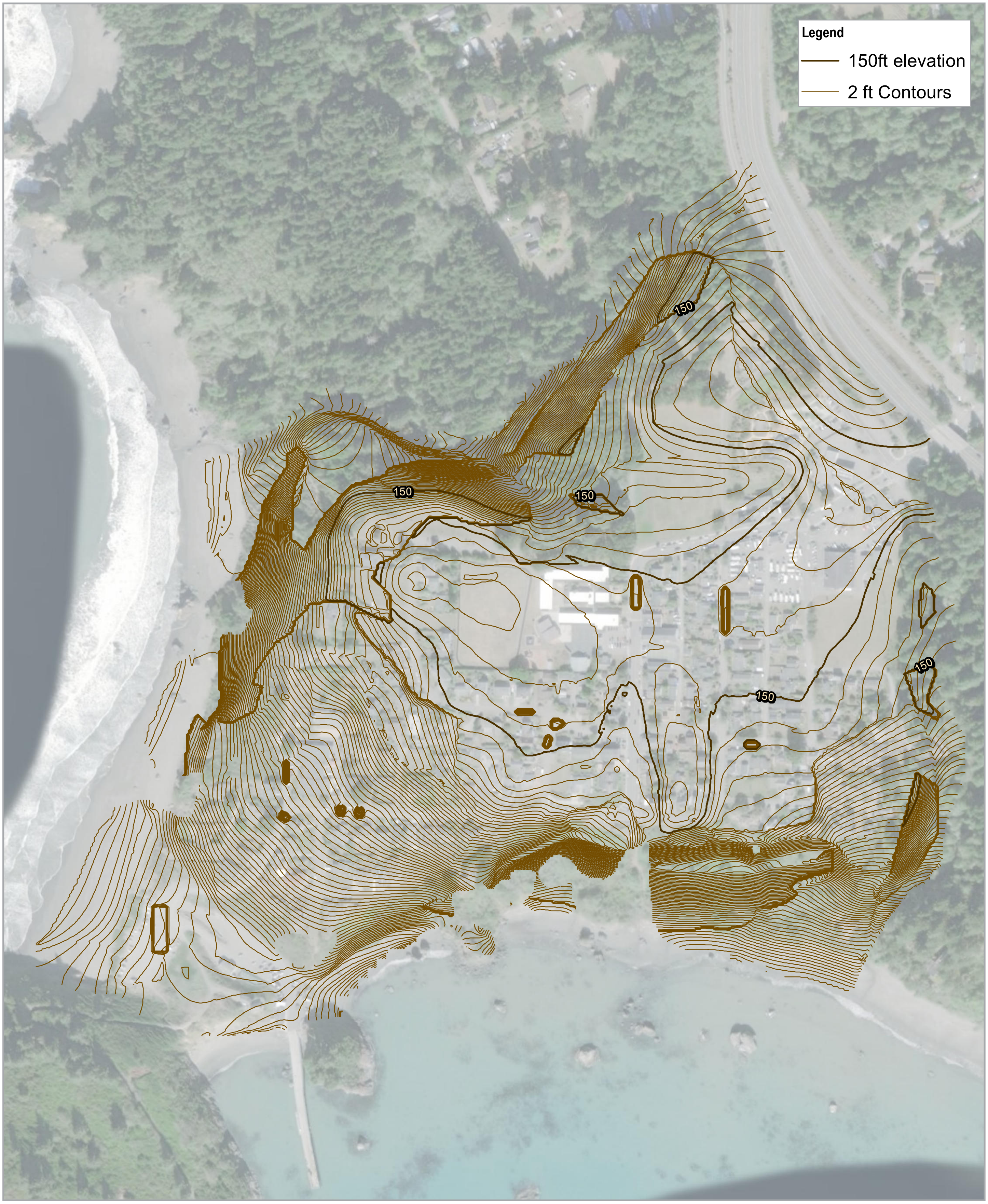


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Feet

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

N

**City of Trinidad**
**ASBS Stormwater Improvement Project**

**Scenario 3**
**Full System Improvements**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**FIGURE C4**

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Paper Size ANSI A

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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 of Trinidad**
**ASBS Stormwater Improvement Project**

| | |
|---|---|
| Project No. | 11136537 |
| Revision No. | - |
| Date | 01/22/2019 |

**Scenario 3 compared to Scenario 1**

**FIGURE C5**

N:\US\Eureka\Projects\111\11136537 Trinidad-OPC Citywide LID Assist\08-GIS\Maps\Deliverables\FinalReport\11136537_C5_Scenario3_v_Scenario1.mxd
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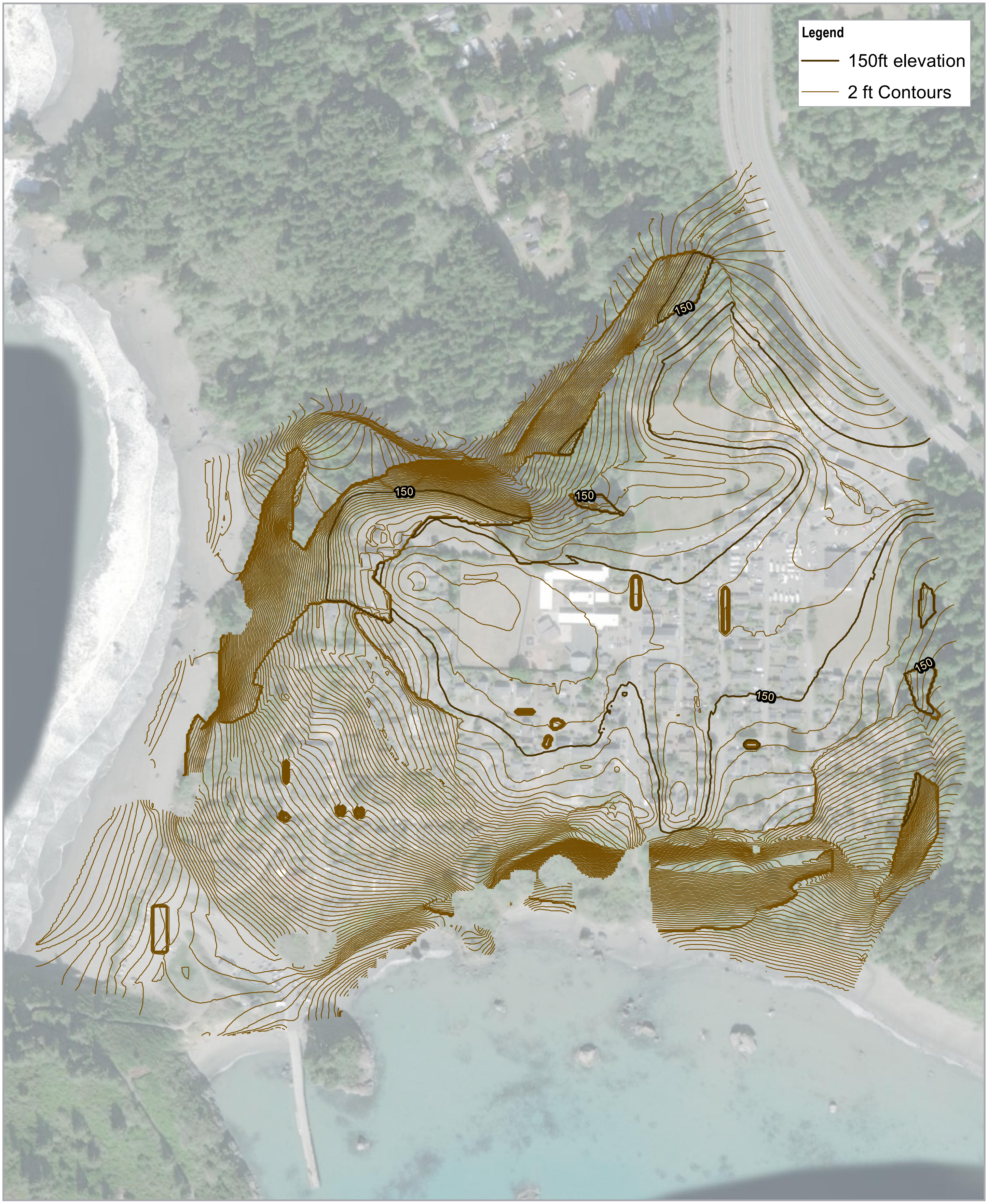
Data source: GHD model results, 1/20/2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: jclark2




Paper Size ANSI A

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Feet

N

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

GHD

**City of Trinidad**
**ASBS Stormwater Improvement Project**

**Scenario 4**
**Buildout**

| | |
|---|---|
| Project No. | **11136537** |
| Revision No. | **-** |
| Date | **01/22/2019** |

**FIGURE C6**

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Paper Size ANSI A

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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

GHD

**City of Trinidad**
**ASBS Stormwater Improvement Project**

Project No. **11136537**
Revision No. **-**
Date **01/22/2019**

**Scenario 4 compared to Scenario 1**

**FIGURE C7**

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Data source: GHD model results, Base 2016, 1/20/2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: jclark2

# Appendix D: Groundwater Monitoring Data


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

Soil Boring

Monitoring Well

Preexisting Monitoring Well

Project Area Boundary

Geophysical Transect
(Seismic Reflection & Electrical Resistivity)

GHD

City of Trinidad
Trinidad ASBS Stormwater Project

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

| | |
|---|---|
| Job Number | 0106311005 |
| Revision | A |
| Date | 15 Oct 2013 |

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

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



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

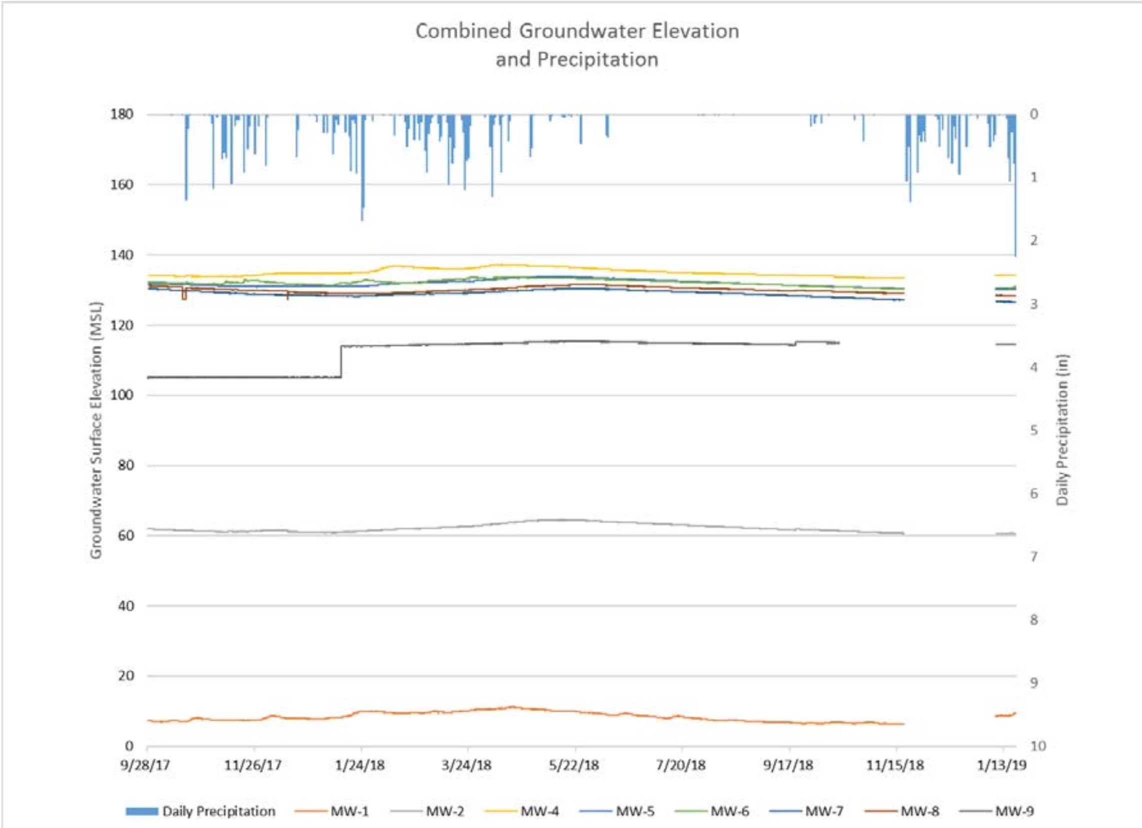



Figure D-1 Combined Groundwater Monitoring Results with Rainfall

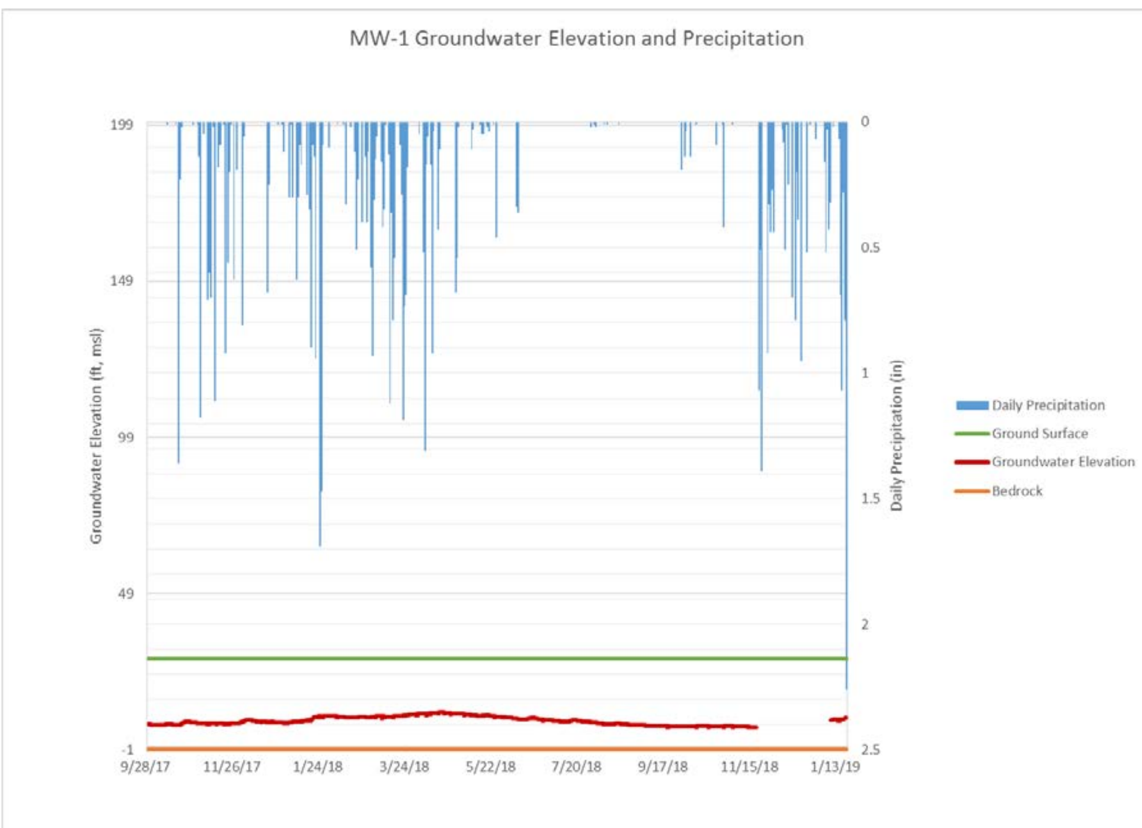
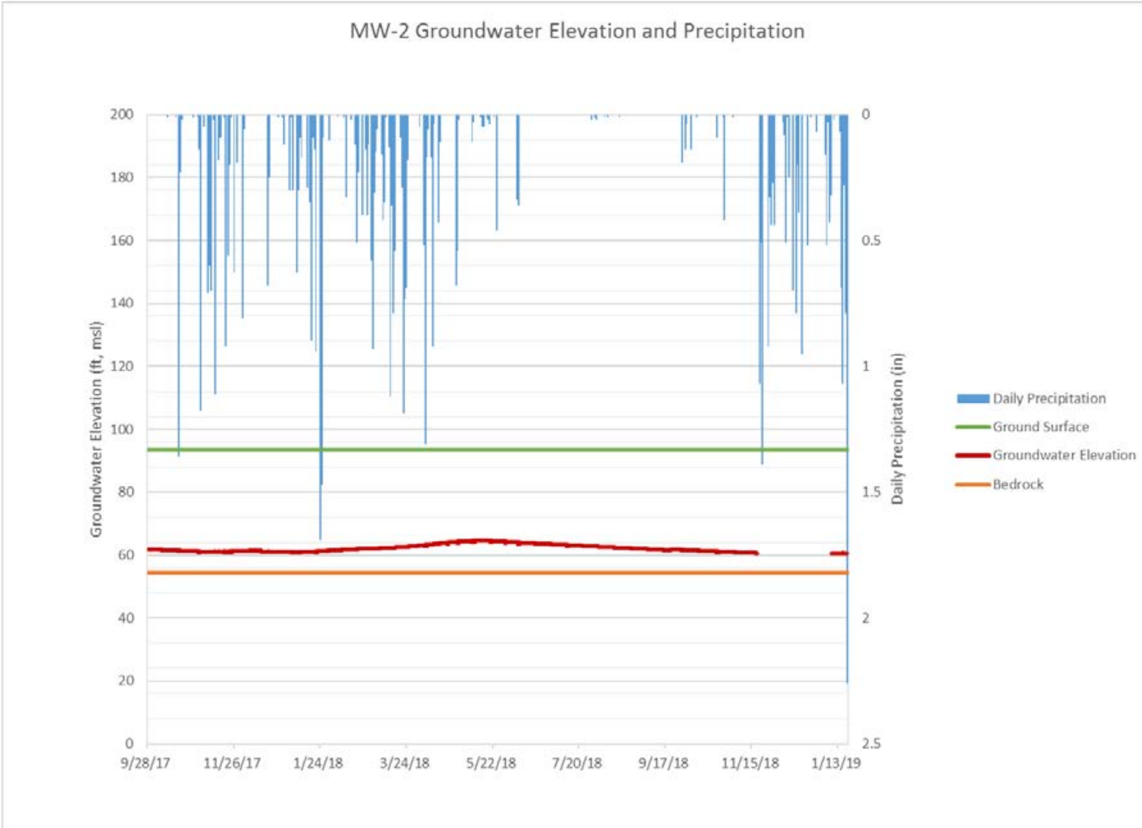



Figure D-2 MW-1 Groundwater Monitoring Results with Rainfall




FigureD-3 MW-2 Groundwater Monitoring Results with Rainfall

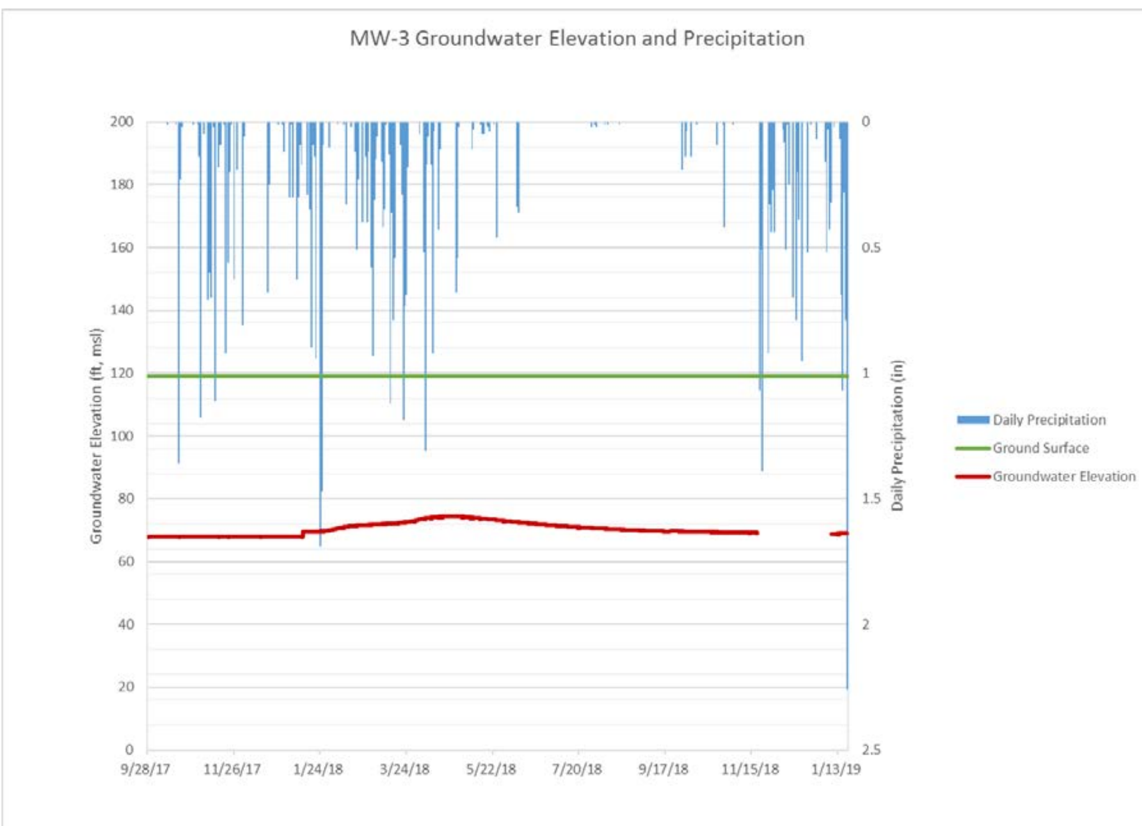



Figure D-4 MW-3 Groundwater Monitoring Results with Rainfall

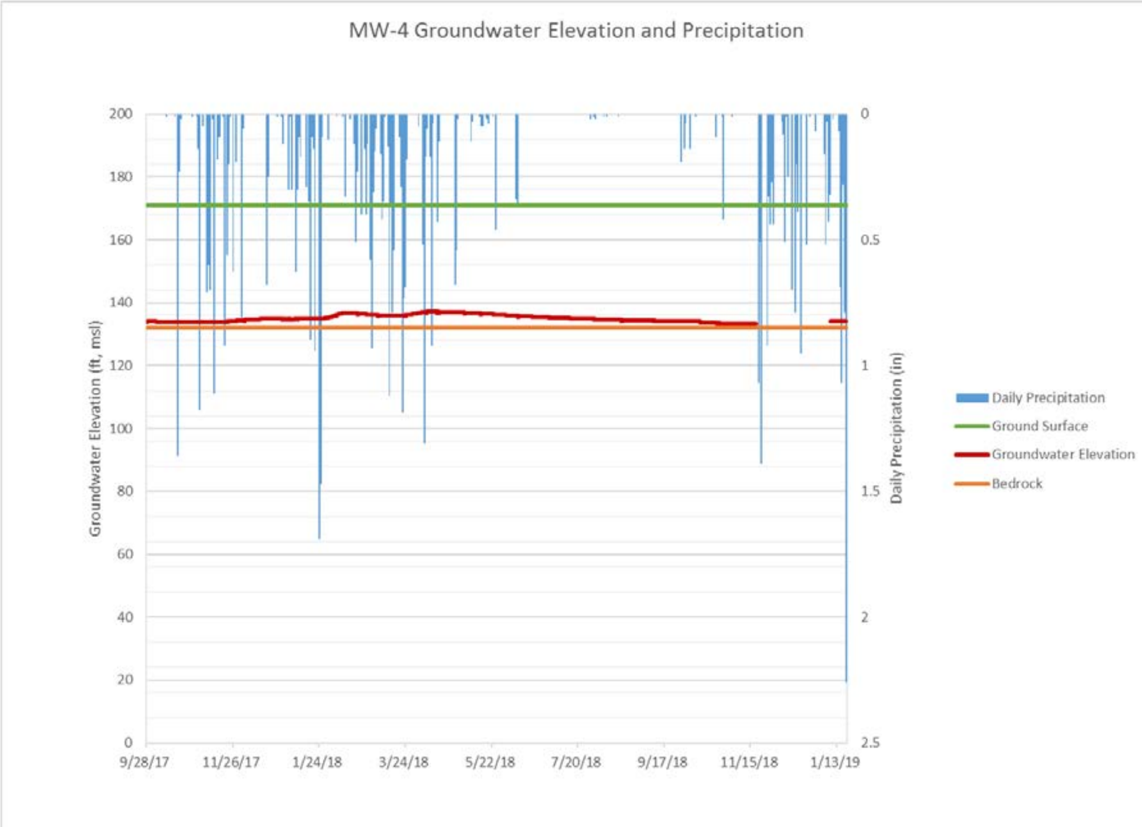



Figure D-5. MW-4 Groundwater Monitoring Results with Rainfall

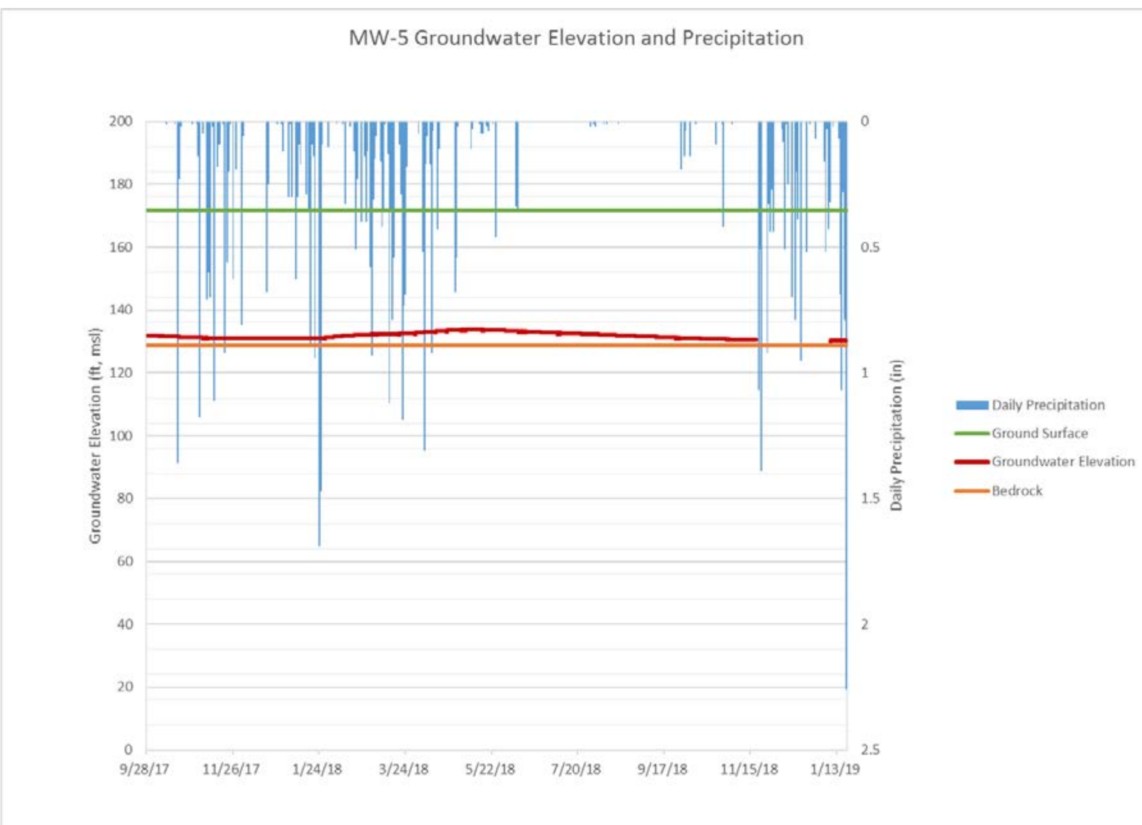



Figure D-6. MW-5 Groundwater Monitoring Results with Rainfall

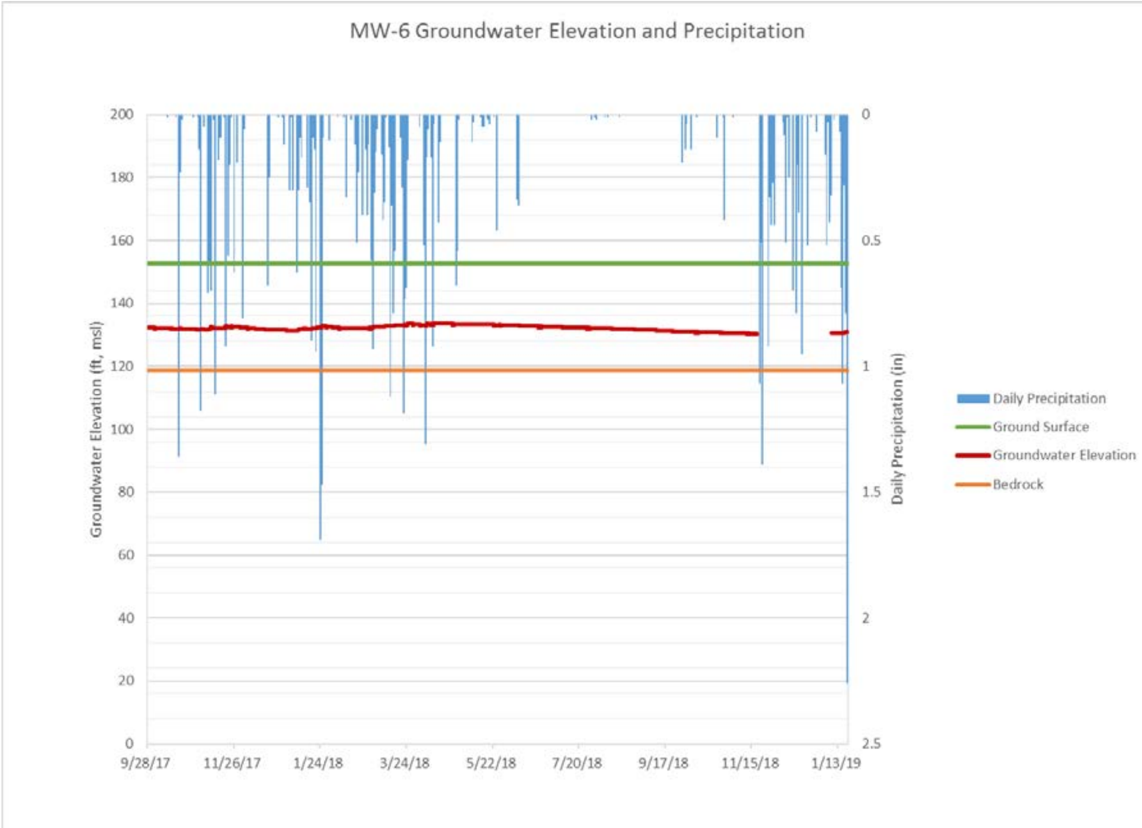



Figure D-7. MW-6 Groundwater Monitoring Results with Rainfall

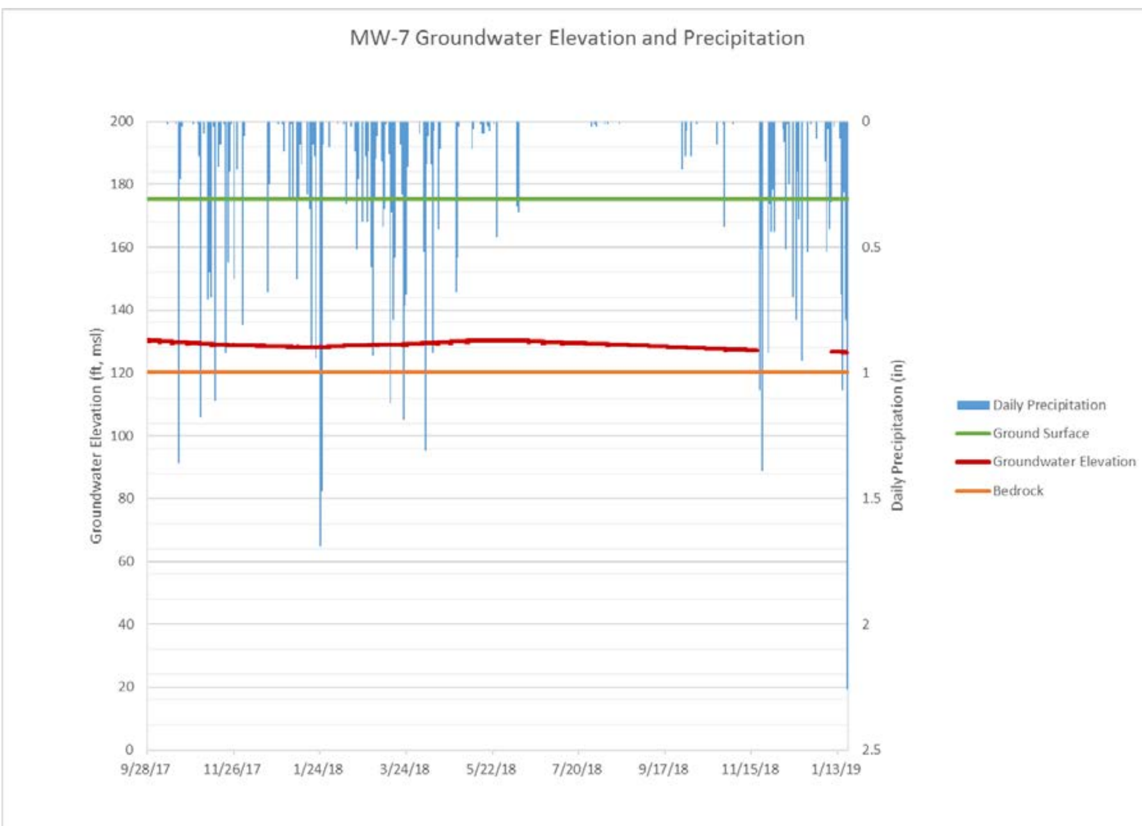



Figure D-8. MW-7 Groundwater Monitoring Results with Rainfall

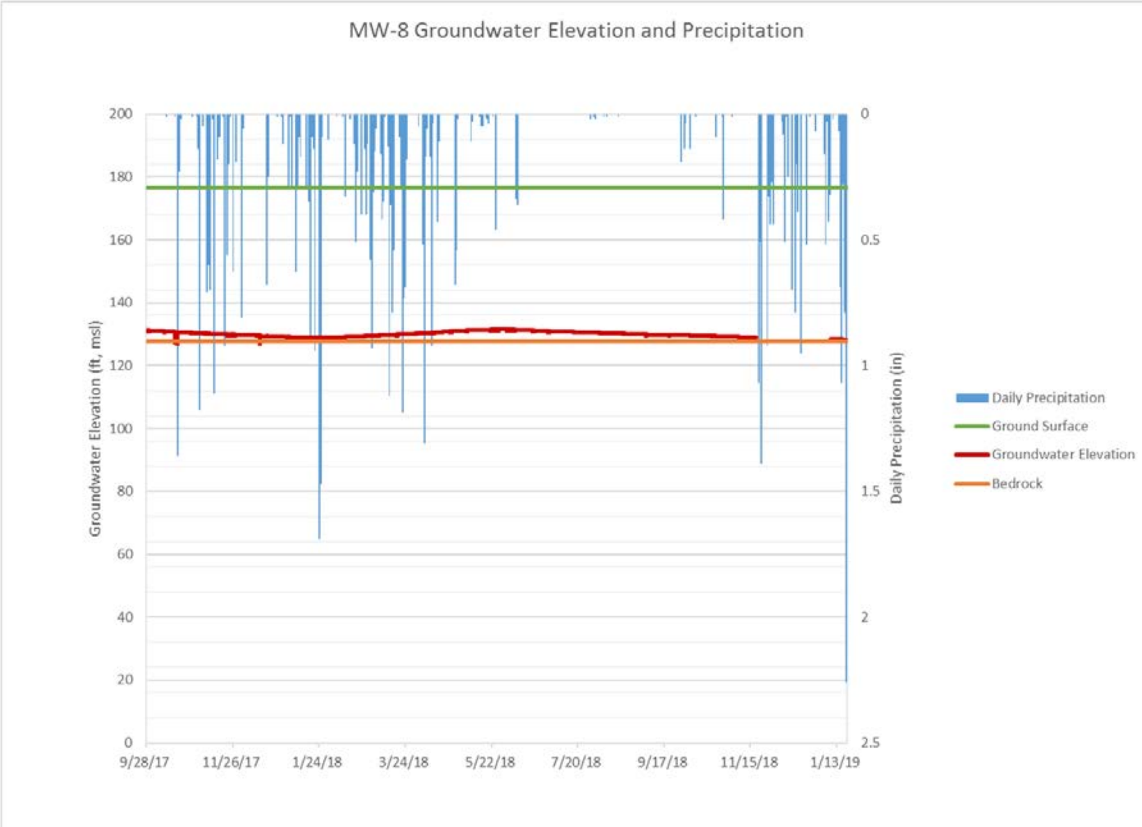



Figure D-9. MW-8 Groundwater Monitoring Results with Rainfall

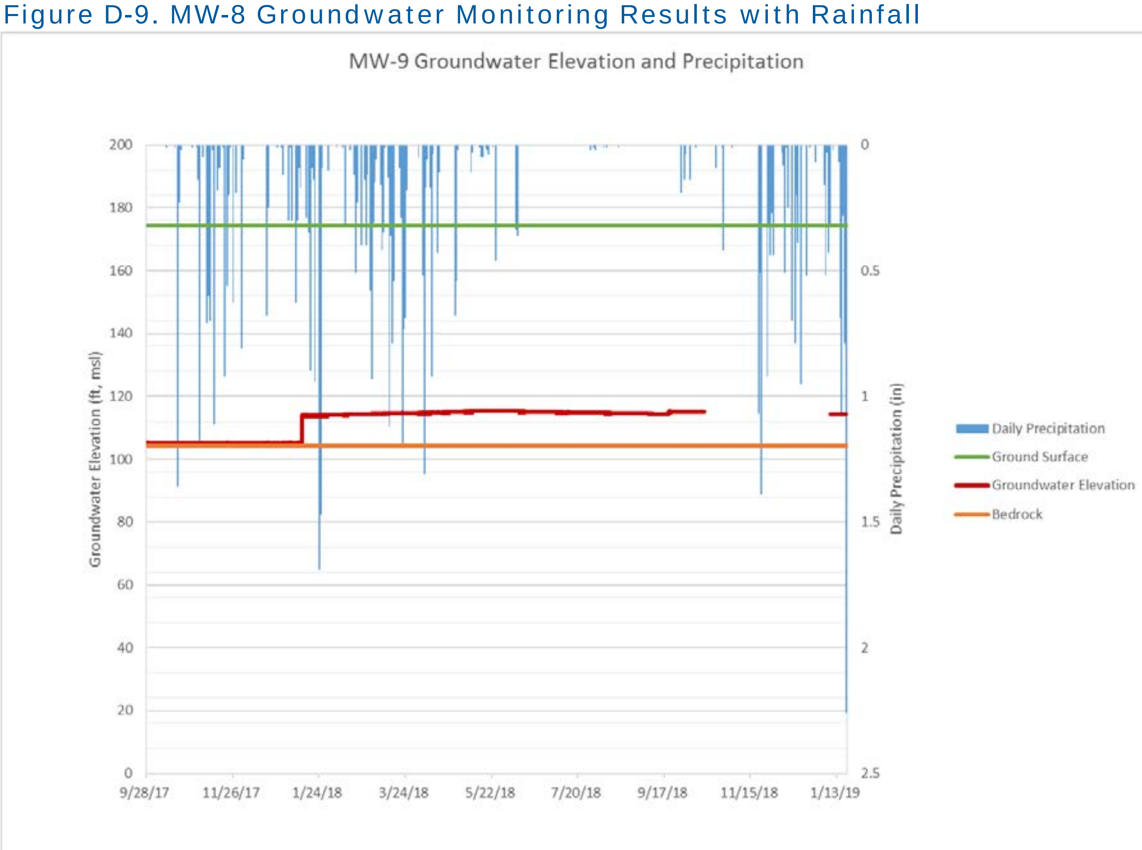



Figure D-10. MW-9 Groundwater Monitoring Results with Rainfall

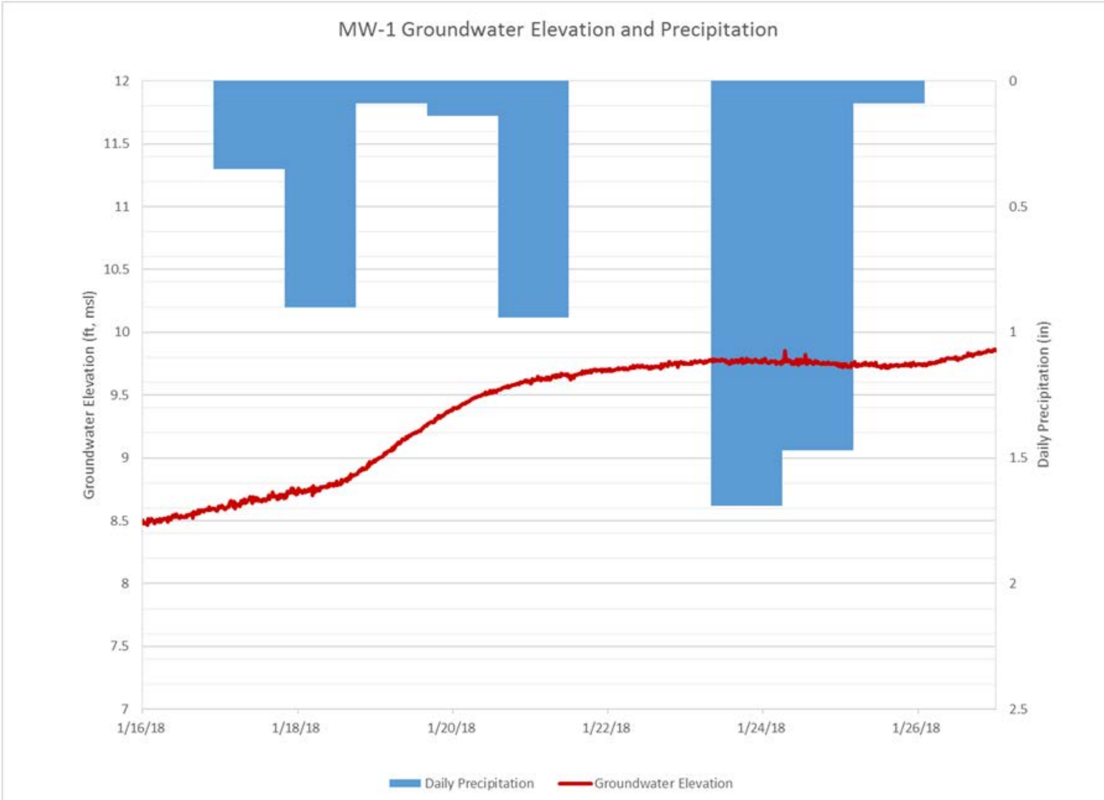



Figure D-11. Groundwater levels during pre-construction precipitation event (1/16/18-1/27/18) at MW-1.

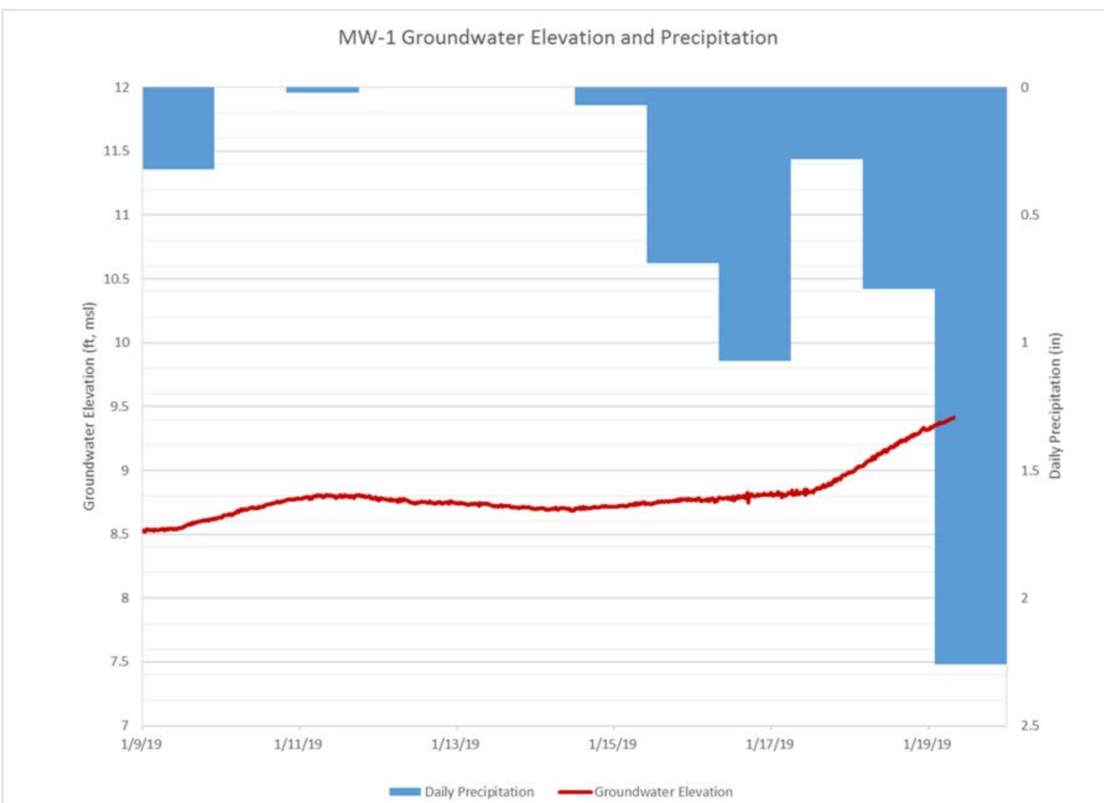



Figure 12. Groundwater levels during post-construction precipitation event (1/9/19-1/20/19) at MW-1.

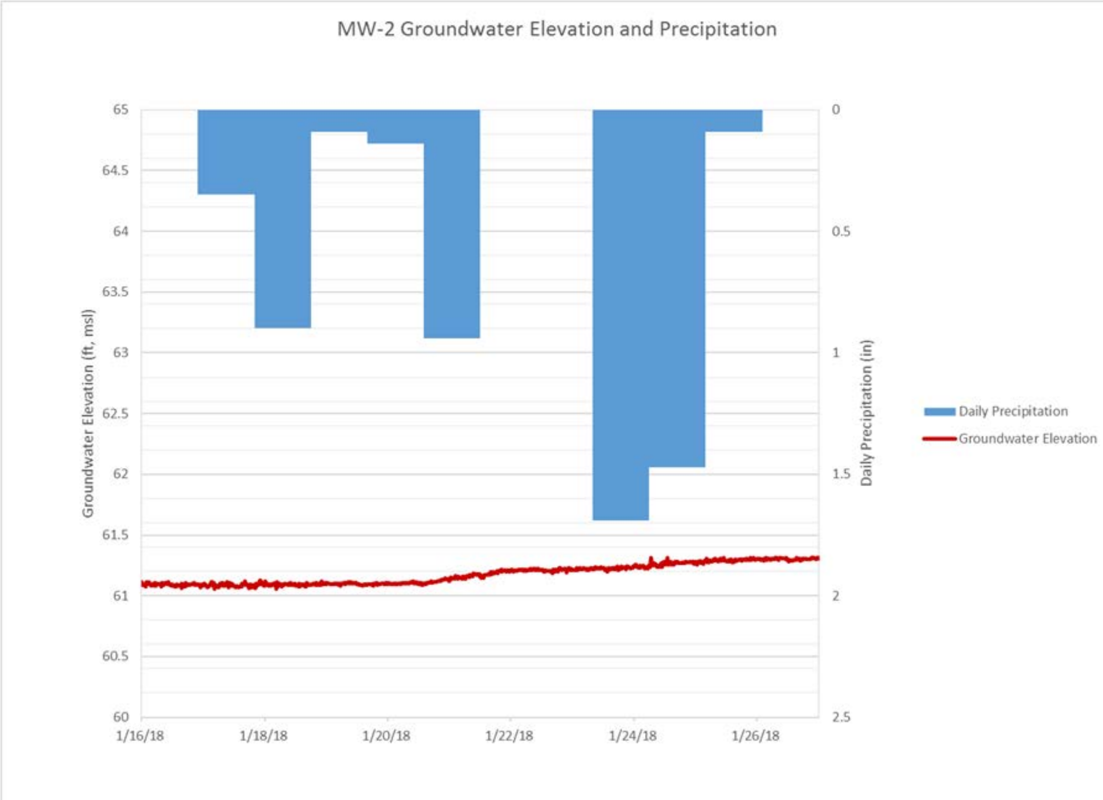



Figure D-13. Groundwater levels during pre-construction precipitation event (1/16/18-1/27/18) at MW-2.

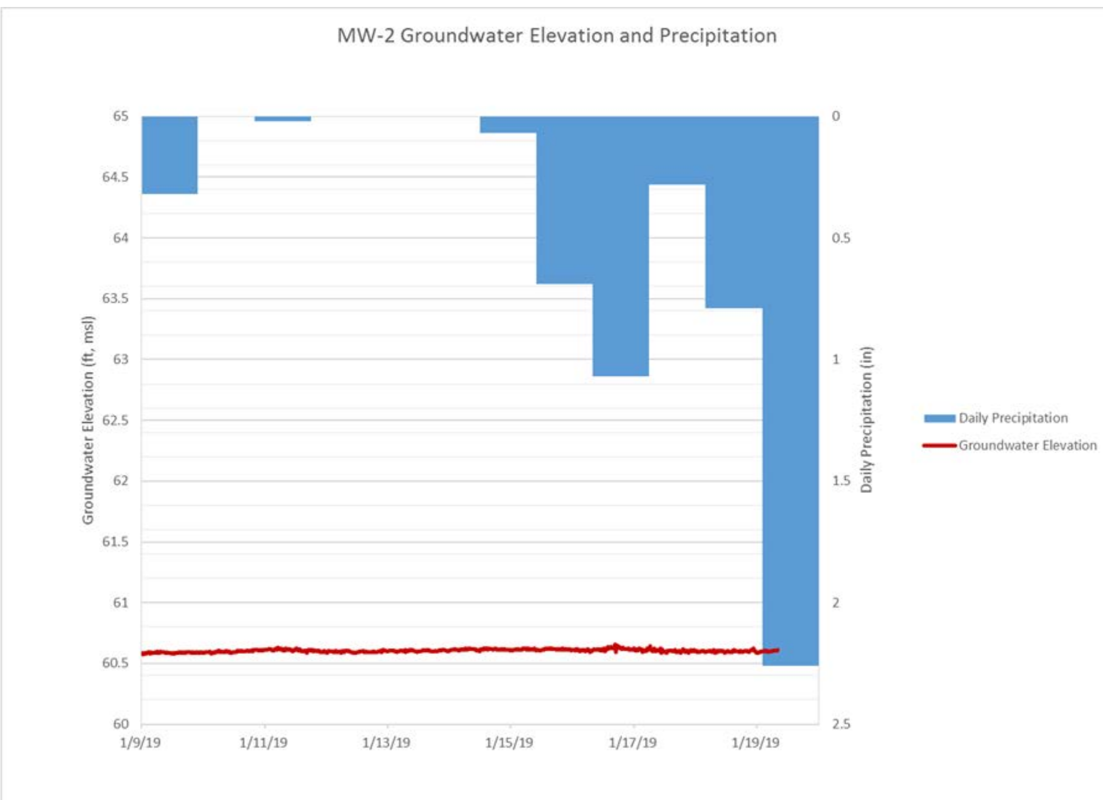



Figure D-14. Groundwater levels during post-construction precipitation event (1/9/19-1/20/19) at MW-2.

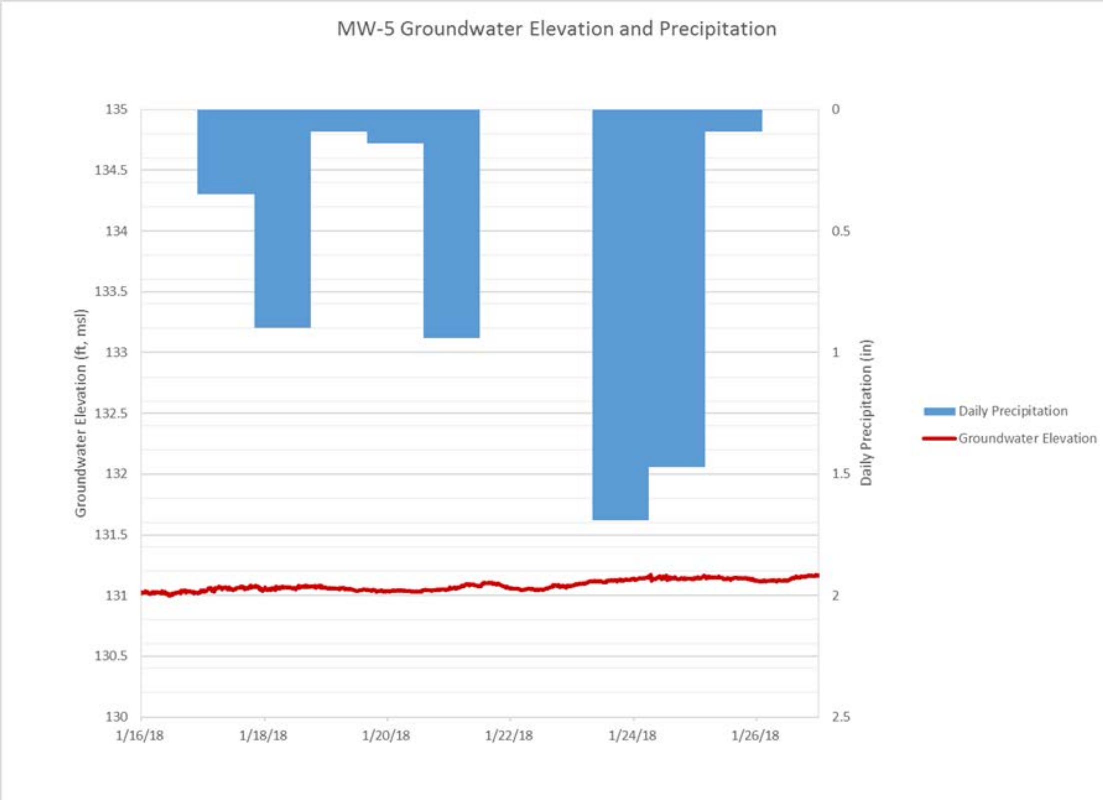



Figure D-15. Groundwater levels during pre-construction precipitation event (1/16/18-1/27/18) at MW-5.

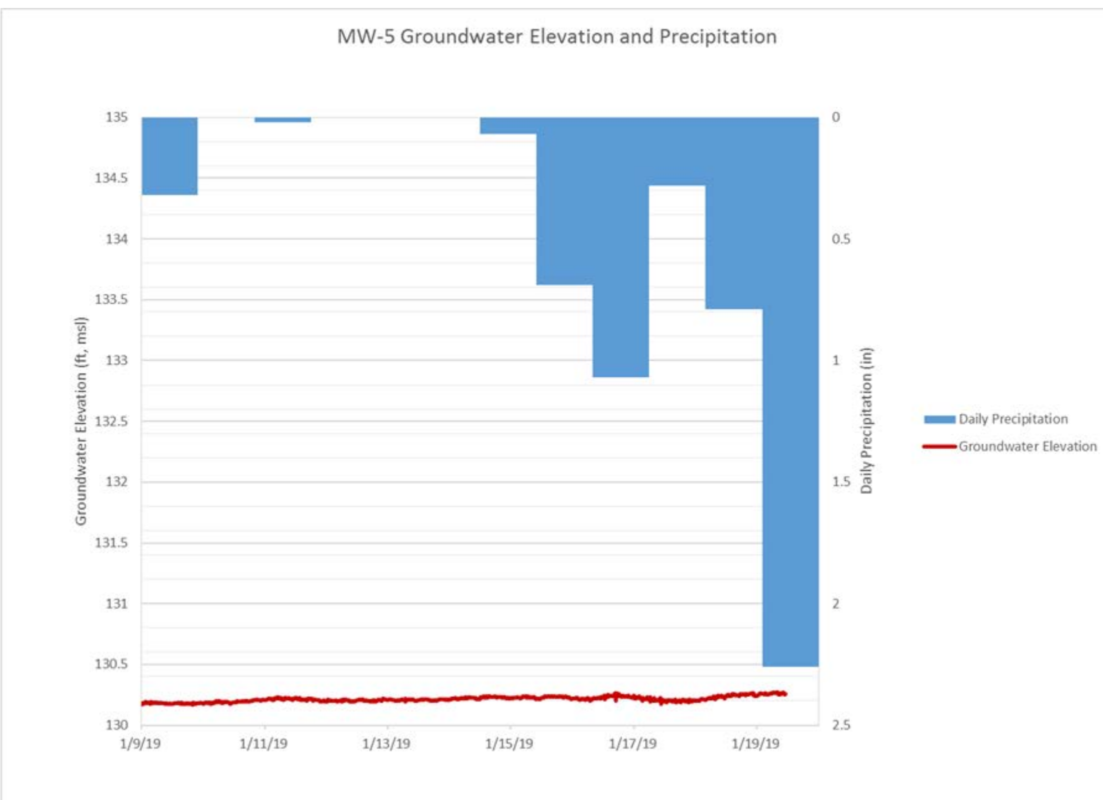



Figure D-16. Groundwater levels during post-construction precipitation event (1/9/19-1/20/19) at MW-5.

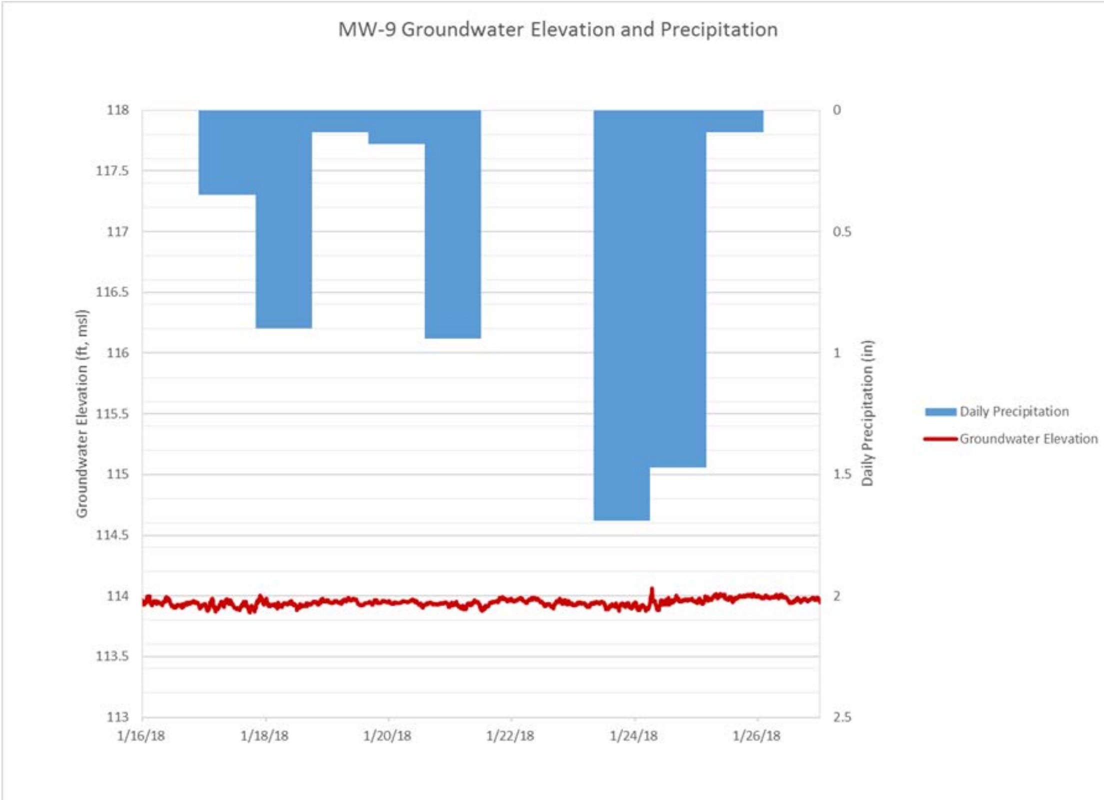



Figure D-17. Groundwater levels during pre-construction precipitation event (1/16/18-1/27/18) at MW-9.

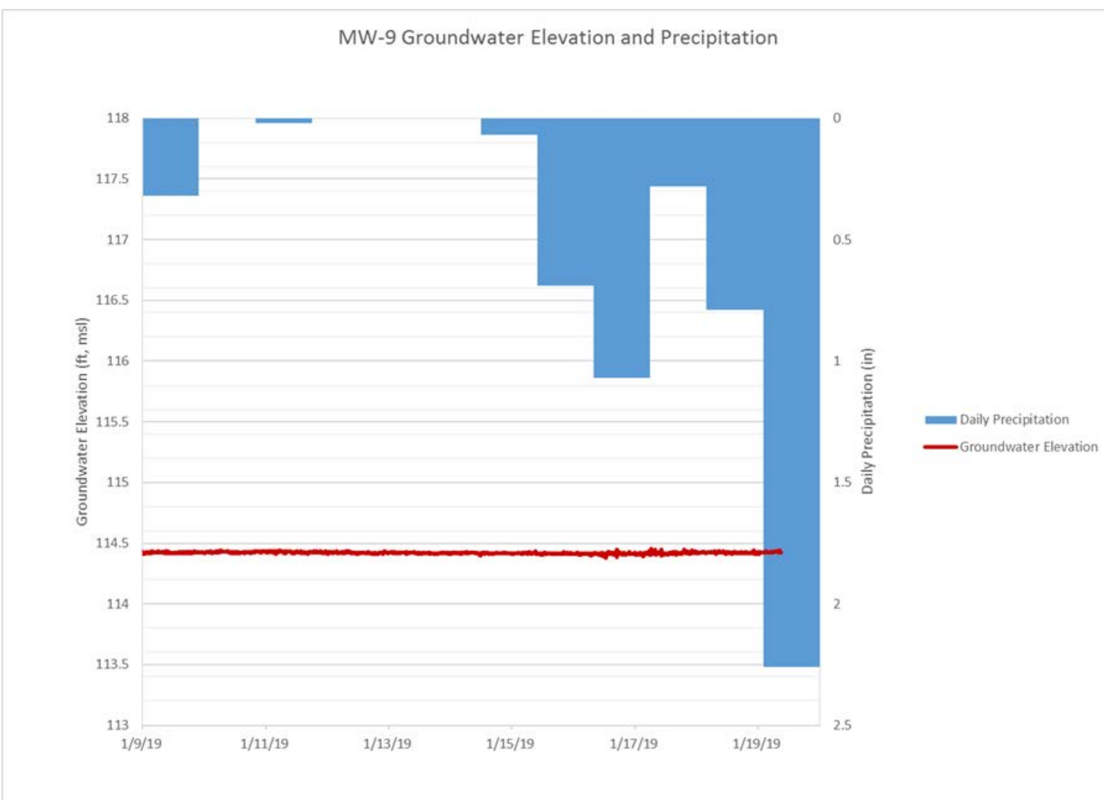



Figure D-18. Groundwater levels during post-construction precipitation event (1/9/19-1/20/19) at MW-9.

# Appendix E: Slope Stability Analysis Memorandum

# Technical Memorandum

January 23, 2019

| | | | |
|---|---|---|---|
| To: | Patrick Sullivan, PE | Ref. No.: | 11136537 |
| From: | Chris Trumbull, PE, GE, D.GE | Tel: | 530-387-5683 |
| CC: | Steve Allen, PE | | |
| **Subject:** | **Trinidad ASBS Stormwater Project – Slope Stability Analysis** | | |

## 1. Introduction

This slope stability analysis was performed to evaluate if the change in groundwater surface due to the implementation of the proposed LID features would adversely affect the bluff stability in the project area.

Slope stability analyses uses factors of safety (FS) to evaluate the potential instability of a slope. The components of a FS the driving forces and moments versus the resisting forces and moments. The moments are determined using the surface geometry, subsurface stratigraphy, soil strength, and groundwater levels.

$$FS = \frac{\sum Resisting\ Moments}{\sum Driving\ Moments}$$

When the driving moments equal the resisting moments, the factor of safety is unity. Unity is considered a metastable condition, where the slope is balanced between stability and movement. A FS less than unity would imply an unstable slope and an FS over unity would imply a stable slope.

## 2. Available Field Investigations

The available field data included:

- Drilling and geophysical data from GHD
- Borings logs from SHN at the lighthouse

## 3. Site and Subsurface Conditions

The site generally consists of marine terrace deposits overlying weathered Franciscan formation siltstone. The terrace deposits consist of sand, silty sand and some gravel. The results of the groundwater modeling effort by GHD were considered.

# 4. Stability Analysis

## 4.1 Approach

Since the bluff at the lighthouse, denoted at Section G-G', was the steepest in the groundwater modeling effort and the stability of this slope has been recently investigated, the topography here was used as the critical ground surface. In addition, the stratigraphy model from Section G-G' from the groundwater modeling effort was used. The FS for the long-term buildout groundwater levels was also determined for comparison to the existing condition.

Slope stability analyses were performed using the GeoStudio 2012 software, version 8.15.3. Spencer's Method of Slices was used, which satisfies force and moment equilibrium. The entry-exit search routing was used.

## 4.2 Material Parameters

Table 4.1 Soil Parameters for Stability Analysis

| Material | $\gamma_T$ (pcf) | $\phi$ (deg) | c (psf) |
|---|---|---|---|
| Terrace Deposits | 115 | 32 | 200 |
| Bedrock | 120 | 38 | 200 |

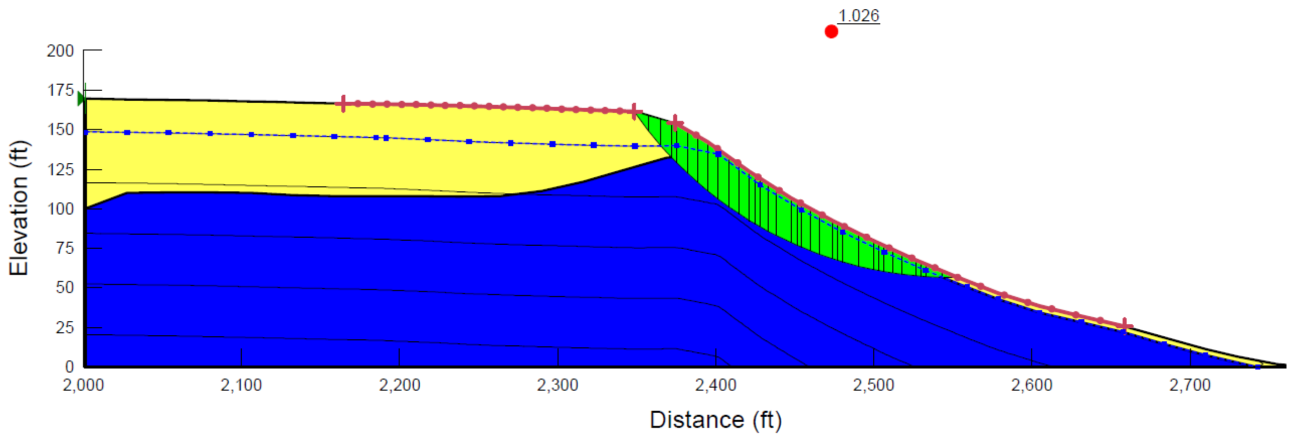
## 4.3 Phreatic Surface

The groundwater surface from the results of the GHD groundwater modeling effort were used for existing and buildout conditions.

## 4.4 Stability Analysis Results

The results of the slope stability analysis for existing conditions indicated that the FS was 1.03. When introducing the increased groundwater surface after full LID buildout, the FS was 1.02. A graphical representation of the results of the existing conditions is presented below; the green hatched area represents the critical failure surface. For sensitivity, the material parameters were increased along with the comparison to existing versus buildout, and a change in FS of -0.01 was also realized.

File Name: Trinidad02a.gsz
Date: 1/23/2019
Name: Bedrock Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 200 psf Phi': 38 °
Name: Marine Terrace Deposits Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 200 psf Phi': 32 °




## 5. Closing

Comparing the existing groundwater level to the buildout resulted in a reduction in FS of 0.01. That difference is small; so small that it would be considered no change. Therefore, the rise in the groundwater levels from TR-Base to Buildout do not adversely affect the slope stability of the bluff at Section G-G'. Since G-G' is expected to be the worst case, the other sections/slopes likely have a similar result.

# Appendix F: Excerpts from the Humboldt LID Stormwater Manual and the City of Santa Rosa LID Technical Design Manual

# APPENDIX 3

## Site Design Measures

# Tree Planting and Preservation

## Description

Trees intercept rain water on their leaves and branches, allowing water to evaporate or run down the branches and trunk where it readily infiltrates into the soil. Tree roots also increase infiltration of the soil. Runoff reduction credits can be applied for newly planted or preserved trees.

At a minimum inspection and maintenance shall include the following:

- Annual inspection prior to the rainy season.
- Annual proper watering and application of mulch.
- Routine pruning and weeding as needed.
- Replacement of trees as needed.

## Technique

At time of planting, newly planted trees must have:

- A trunk measuring at least 1-inch in diameter, 6-inches above the soil line
- A height of at least 6-feet for deciduous trees and 4-feet for evergreen trees.

A minimum of two deciduous trees or one evergreen tree must be planted to use this credit, such that a minimum of 200 square feet of runoff reduction credit is achieved for newly planted trees.

Additionally, to use the runoff reduction credit for existing trees, the canopy area must be:

- Equal to, or greater than 300 square feet of existing tree canopy, such that a minimum of 150 square feet (50% credit for existing canopy) of runoff reduction credit is achieved for existing trees.
- Existing trees must be adequately protected during construction

## Credits

The following tree credits apply:

- New deciduous trees provide a tributary area reduction credit of 100 $ft^2$
- New evergreen trees provide a tributary area reduction credit of 200 $ft^2$
- Existing trees provide a credit equal to half of the existing tree canopy area.

# Rain Barrels and Cisterns

## Description

Rain Barrels and Cisterns are a system that collects and stores storm water runoff from a roof or other impervious surface. These typically have overflow mechanisms or plugs that drain to a vegetated area or to the storm drain system when the barrel is full.

Use of Rain Barrels and Cisterns must comply with local vector control requirements.

## Technique

Show the following on your site plan:

- Impervious area tributary to each Rain Barrel / Cistern
- Location of each Rain Barrel/Cistern

Confirm the Following Standard Specifications have been met:

- Rain Barrels are sited at grade on a sound and level surface at or near the ground.
- Gutters tributary to the Rain Barrels/Cistern are screened with a leaf guard or maximum ½-inch to ¼ inch minimum corrosion resistant metallic hardware fabric.
- Water collected will be used for irrigation purposes only.
- Openings are screened with a corrosion-resistant metallic fine mesh (1/16 inch or smaller) to prevent mosquito harborage.
- Large openings are secured to prevent entry by children.
- Rain Barrels and Cistern are cleaned annually.

## Credits

Runoff reduction credits can be applied for rain barrels or cisterns installed.

- A minimum rain barrel or cistern capacity of 55 gallons must be installed to use this credit

# Rooftop and Impervious Area Disconnection

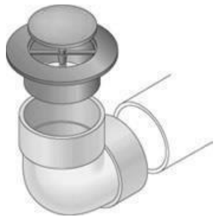
## Description

Disconnection of rooftop and impervious areas from the storm drain system helps reduce runoff and provide pollutant removal as the re-directed water travels over and through vegetation and soil instead of being directly piped and discharged into the storm drain. Roof runoff is directed to spread over a pervious area such as a stream setback and buffers, areas of soil quality improvement, or other appropriate infiltration areas.

The following are examples of ways to implement rooftop disconnection:

**Splash Block**
Splash blocks reduce the velocity and impact of water exiting the roof downspout and direct water to a pervious area.

**Pop-up Drainage Emitter**
Pop-up drainage emitters are useful in conveying storm water from roof downspouts into vegetated areas. Roof runoff is piped then released through a capped device that opens with water pressure, allowing the storm water to flow out of the emitter and into the vegetated area.



## Technique

**On Site Plan Show:**

- Delineate the impervious tributary area draining to the pervious area
- Show how the runoff will be directed to the pervious area

**Confirm that the following specifications will be met:**

- Tributary area (impervious area) does not exceed more than twice the pervious area
- Roof areas collect runoff and route to the suitable pervious area
- Paved areas are sloped to direct runoff to suitable pervious area
- Runoff is dispersed across the pervious area (splash block or pop-up emitter)
- Pervious area has vegetation and soils meeting the requirements of stream setbacks and buffers or areas of soil quality improvement and maintenance

## Credits

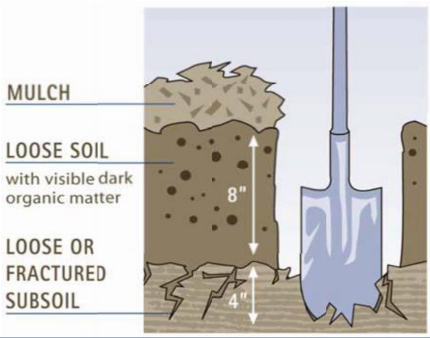
Runoff reduction credits can be applied for the area of rooftop and impervious area disconnection.

- The runoff reduction credits (square feet) will be equal to the area of rooftop and impervious area disconnection and should not exceed more than twice the pervious area receiving runoff.
- A minimum area of 150 square feet of impervious surface tributary area must apply to use this credit.

# Soil Quality Improvement and Maintenance

## Description

In areas subject to grading/clearing not covered by impervious surface, create/amend pervious areas with a 12" layer of topsoil. Soil quality improvement options include the following:




## Technique

**Option 1: Leave native vegetation and soil undisturbed and protect from compaction during construction**

Identify areas of the site that will not be stripped, logged, graded, or driven on, and fence off those areas to prevent impacts during construction. If neither soils nor vegetation are disturbed, these areas do not require amendment.

**Option 2: Amend existing site topsoil or subsoil**

Scarify or till subgrade to 8 inch depth (or to depth needed to achieve a total depth of 12 inches of un- compacted soil after calculated amount of amendment is added). Entire surface should be disturbed by scarification. Amend soil to meet desired organic content.

**Option 3: Stockpile existing topsoil during grading. Replace topsoil before planting.**

Stockpile and cover soil with weed barrier material that sheds moisture yet allows air transmission. Replace stockpiled topsoil prior to planting and ensure that replaced soil plus additional compost as needed will amount to at least 12 inches of depth.

Compost/amendment shall be mature, stable, weed free, and produced by aerobic decomposition of organic matter.

## Credits

Runoff reduction credits can be applied for the area of soil quality improvement.

- The runoff reduction credits (square feet) will be equal to the area of soil quality improvement.
- A minimum area of 150 square feet of soil quality improvement area must apply to use this credit.

# Green Roofs

## Description

A green roof is a multi-layered, vegetated rooftop system design for filtering, absorbing, and retaining stormwater. A green roof captures stormwater within the pore space of the growth medium and then releases the water slowly via evaporation, transpiration, and discharge to the roof drains.

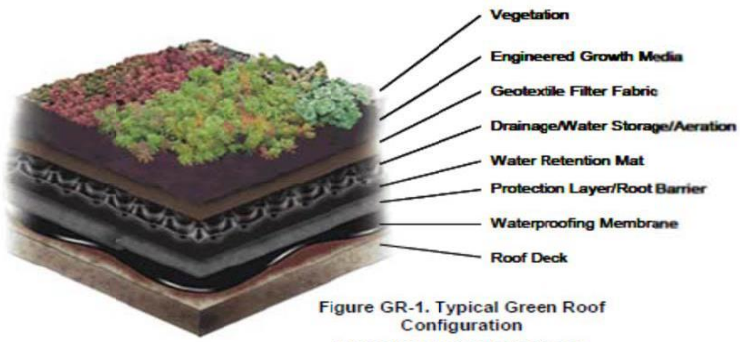



Figure GR-1. Typical Green Roof Configuration

Image source: American Hydrotech, Inc.®, http://www.hydrotechusa.com/. Text detail added.

## Technique

Green roof installation should be considered during building design, as green roofs require special structural reinforcements, irrigation provisions, and leak protection elements. Involve the landscape architect, licensed structural engineer, and mechanical engineer early in the design process with the project architect, since architectural roof style, roof structural requirements, building heating/cooling needs, vegetation selection, and irrigation needs go hand in hand.

Routine inspection of the roof membrane, drainage layer flow paths, and irrigation system is needed. Periodic maintenance and replacement of rooftop vegetation and growth media should be expected during the lifespan of the green roof.

## Credits

Runoff reduction credits can be applied for area of installed green roof.

- A minimum area of 150 square feet of green roof must be installed to use this credit.

# PPPP - Porous Asphalt, Pervious Concrete, Permeable Pavers – (alternative engineered hardscaping surfaces)

## Description

This option can be easy to install and maintain, cost effective, and can add aesthetic value to your project. PPPP may include pervious concrete, porous asphalt, porous pavers, crushed aggregate, open pavers with grass or plantings, open pavers with gravel, or solid pavers.

## Technique

Show on your site plan:

- Location, extent and types of pervious pavements.

Confirm the following standard specifications are met:

- No erodible areas drain on to permeable pavement.
- Subgrade compaction is minimal.
- Reservoir base course is of open-graded crushed stone. Base depth is adequate to retain rainfall (3 inches is adequate) and support design loads (more depth may be required).
- No subdrain is included or, if a subdrain is included, outlet elevation is a minimum of 3 inches above bottom of base course.
- Subgrade is uniform and slopes are not so steep that subgrade is prone to erosion.
- Rigid edge is provided to retain granular pavements and unit pavers.
- Solid unit pavers, if used, are set in sand or gravel with minimum 3 / 8 inch gaps between the pavers.
- Joints are filled with an open-graded aggregate free of fines.
- Pervious concrete or porous asphalt, if used, are installed by industry-certified professionals according to the vendor's recommendations.
- Selection and location of pavements incorporates Americans with Disabilities Act requirements (if applicable), site aesthetics, and uses.

## Credits

Runoff reduction credits can be applied for area of installed porous pavement.

- A minimum area of 150 square feet of pervious pavement must be installed to use this credit.

# Vegetated Swales

## Description

A vegetated swale is a broad, shallow channel with dense vegetation covering the bottom and side slopes. Vegetation in the channel provides filtration and solids removal and reduces flow velocities as stormwater is conveyed through the system. Depending on soil type, some infiltration may also occur, decreasing runoff volume and providing additional filtration.

## Technique

Vegetated swales are suitable for the following conditions:

- Areas with a maximum slope of 5%
- Areas wide enough to provide a bottom width between 2 ft and 10 ft
- Areas wide enough to provide a 3:1 side slope
- Areas long enough to provide at least 100 feet of swale length

Flow depth should be limited to 4 to 6 inches with a maximum velocity of 1 foot per second for water quality treatment. Under higher flow conditions, the maximum velocity should be 3 feet per second to avoid erosion. Swale should discharge to a piped system or can function as a confined channel if sized large enough to do so. If the swale discharges to a slope rather than to a piped system, an energy dissipater should be used at the swale outlet.

## Credits

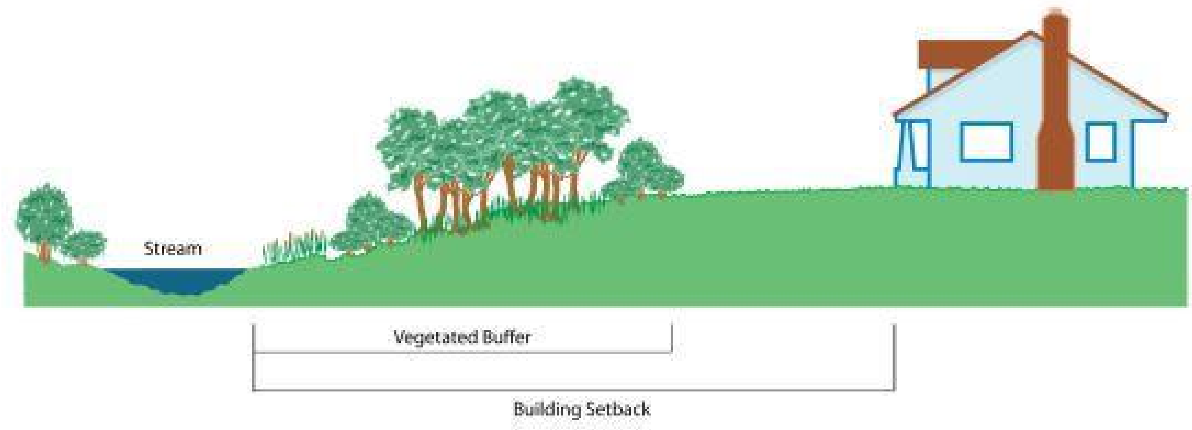
Runoff reduction credits can be applied for area of installed vegetated swale.

- A minimum area of 150 square feet of vegetated swale must be installed to use this credit.

# Stream Setbacks and Buffers

## Description

A stream setback or buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of setbacks and buffers is to physically protect and separate a stream, lake or wetland from future disturbance or encroachment. If properly designed, setbacks and buffers can provide stormwater management and act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats.




## Technique

Stream setbacks and buffers should be considered as part of the initial phases of site design for the project. Provisions should be made to place impervious developments and areas to be impacted or disturbed furthest from the aquatic feature, with a zone of natural, undisturbed vegetation remaining between the stream and the areas impacted by development.

Contact County or City Department with project jurisdiction for stream setback and buffer requirements and design criteria.

## Credits

Runoff reduction credits can be applied for the area of stream setback and buffer.

- The runoff reduction credits (square feet) will be equal to the area of stream setback and buffer.
- A minimum area of 150 square feet or more of stream setback and buffer must apply to use this credit.

# Infiltration Trench

## Description

An infiltration trench is a long, narrow (<25 ft.), rock-filled trench (depth between 3-8 ft.) that receives stormwater runoff and allows it to infiltrate.

Infiltration trenches typically have no outlet. Before entering the trench, runoff should pass through stormwater pretreatment measures, such as pre-settling basins, to remove coarse sediment that can clog the void spaces between the stones and render the trench ineffective. A level spreader may be used to spread concentrated flows.

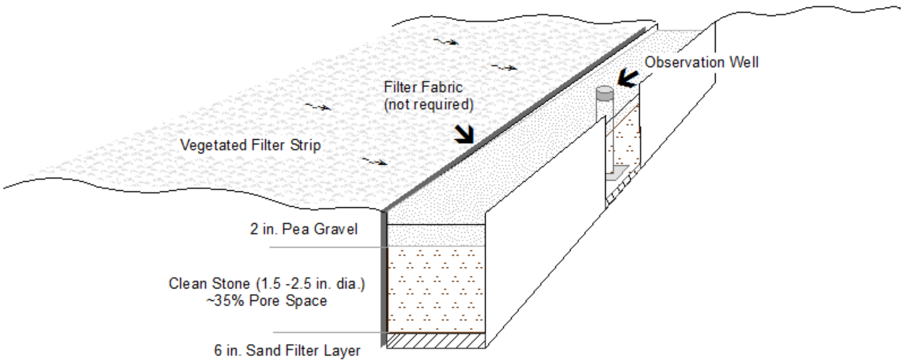
Pretreated runoff is stored in the void spaces and slowly infiltrates through the bottom of the trench into the soil matrix, thus contributing to groundwater recharge. Infiltration trenches should be designed to operate offline, such that only design flows are diverted to the trench and the remainder is bypassed.

⚠ Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and the potential for insufficient infiltration capacity, adequate soil infiltration and BMP siting must be demonstrated, please follow the steps below.

Infiltration trenches are generally between 3 (minimum depth) and 8 feet deep and not more than 25 feet wide. They should:

- Have a level surface and bottom to promote uniform infiltration across the trench;
- The top two inches should be a pea gravel filter layer.
- Trench fill material should be double washed locally available rock with a diameter range of 1.5 to 2.5 inches,
- Below the rock layer is a 6-inch deep sand filter layer. The sides of the trench can be lined with filter fabric to prevent adjacent soils from clogging the rock; and,
- An observation well located at the center of the trench is recommended to monitor water drainage from the system. The well can be a capped 4 to 6-inch diameter PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench
- The infiltration trench should be designed to drain within 72 hours.

# Infiltration Trench




Overflow: Infiltration trenches should be designed such that only design flows are diverted to the trench and the remainder is bypassed.

☐ Utilize the Small Project or Regulated Project (Worksheet 2) Calculators for documenting runoff reduction achieved based on the size of the proposed infiltration facility.

## Requirements for Credit

**On Site Plan Show:**

☐ Delineate the impervious tributary area draining to the infiltration system

☐ Show how the runoff will be directed to the infiltration system

☐ Show the percent and direction of land slope for the site

☐ Show a cross-section of the proposed trench on the plan with dimensions clearly noted

**Confirm that the following specification will be met:**

☐ Infiltration trench must be located at least 5 feet from the parcel property lines.

☐ Infiltration Trench must be located at a minimum of 10 feet (down gradient) from building foundations. Exceptions may be granted if a mounding analysis, conducted as part of a geotechnical report, clearly shows that no potential impact to the structure will result from a closer setback, Appendix 8 Mounding Analysis Procedures.

☐ Infiltration trench must be located 100 feet or greater from water wells, monitoring wells, springs and flowing surface water bodies, and from unstable land masses.

# Infiltration Trench

☐ Infiltration trench must be located 100 feet or greater from the high water mark of vernal pools, wetlands, lakes, ponds, or other surface water bodies.

☐ Infiltration trench must be located 1,200 feet or greater from any public water systems' surface water intake point.

☐ Pretreatment systems, debris/sediment traps and filter strips, are recommended for all facilities and may be required by the jurisdictional entity on facilities that capture runoff from roofs, roads, and parking areas (check with the jurisdictional entity for minimum filter strip widths).

☐ Inspection port is accessible.

☐ Slopes are less than 20% unless constructed to the recommendations in a geotechnical report.

☐ Infiltration trench must be located at least 25 feet from slope break on slopes greater than 30%. A mounding analysis, conducted as part of a geotechnical report, is required for set backs less than 25 feet

☐ The depth to seasonal high groundwater level is greater than 5 feet, measured from the bottom of the trench. If groundwater depth is found to be less than 5 feet, a mounding analysis conducted as part of a geotechnical report will be required. Groundwater level determination shall be made using methods described in Humboldt County's, Wet Weather Testing of Soils, using either soil mottling or direct observation techniques.

☐ Must comply with local vector control requirements.

☐ There shall be no adverse impact to adjacent properties.

☐ No contaminated soils shall be on site.

**Infiltration Rate Requirements**

Infiltration rates of the soils underlying the proposed infiltration system must be documented; the following is the acceptable method and required documentation:

Soil grain analysis using ASTM D 422D, *Standard Test Method for Particle-Size Analysis of Soils,* shall be performed within the boundaries of the proposed infiltration facility and at the bottom elevation/cut (infiltration surface) of the proposed infiltration facility.

☐ Check if particle size analysis results in less than (<) 50% fines – **Stop** - Compliance has been met.

☐ Check if particle size analysis results in greater than (>) 50% fines – Compliance has not been met. Procced to percolation testing requirements, below.

# Infiltration Trench

A percolation test according to the Humboldt County Environmental Health's *Wet Weather Testing of Soils* must be performed if particle size analysis compliance has not been met.

☐ Percolation is equal to or greater than (≥)1 inch per hour. **Stop** – Compliance has been met. Please include all testing results with submission.

☐ Percolation is less than 1-inch per hour – Compliance has not been met. Please, meet with jurisdictional authority for alternative compliance requirements (Mounding Analysis Procedures)

Meeting all of the criteria on this worksheet does not guarantee approval of these devices. Infiltration facilities proposed in areas with high groundwater and in close proximity to waterbodies impaired for pathogens may not be approved regardless of meeting the above requirements.

Alternatively, areas that may not meet the above requirements have the opportunity to request a waiver. However, it must be demonstrated that groundwater surfacing and impacts to structures will not result from the placement of the facility. Please consult with your jurisdictional permitting authority for additional requirements and considerations.

An infiltration trench that is to be designed to address limitations in the down stream conveyance system may be required to submit percolation and groundwater elevation testing reports to the jurisdictional permitting authority for approval.

☐ An operation and maintenance plan must accompany permit submission (does not need to be recorded against the deed).

**Projects that do not meet the above requirements may request a waiver, issued on a case-by-case basis. Please contact jurisdictional entity for the necessary information needed for an alternative compliance waiver.**

**Please include this sheet with application.**

*Link to Environmental Health Department's Wet Weather Testing of Soils:*

*http://www.humboldtgov.org/685/Land-Use-Program*

*OWTS Policy, Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems, June 19, 2012.*

*http://www.swrcb.ca.gov/water_issues/programs/owts/docs/owts_policy.pdf*

# Subsurface Infiltration Devices – Dry Wells, Galleries and Proprietary Systems

## Description

A number of underground infiltration systems, including premanufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Similar to traditional infiltration facilities, these systems are designed to capture, temporarily store, and infiltrate stormwater over several days. Performance of underground infiltration systems varies by manufacturer, system design, and site conditions.

The materials of construction, configuration, and lay-out of underground infiltration systems vary considerably depending on the system manufacturer. Specific design criteria and specifications for these systems can be obtained from system manufacturers or vendors.

## Sizing and Materials

General design requirements common to most of these systems are summarized below and must be followed if used as a site design measure.

☐ Utilize the Regulated Project Calculator (Worksheet 2) for documenting the runoff reduction achieved based on the size of the proposed infiltration facility.

⚠ Due to the potential to contaminate groundwater and/or soils, cause slope instability, impact surrounding structures, and the potential for insufficient infiltration capacity, adequate soil infiltration and BMP siting must be demonstrated, please follow the steps below

However, meeting all of the criteria on this worksheet does not guarantee approval of these devices. Infiltration facilities proposed in areas with high groundwater and in close proximity to waterbodies impaired for pathogens may not be approved regardless of whether all requirements have been met. Please consult with your jurisdictional permitting authority for additional requirements and considerations.

# Subsurface Infiltration Devices – Dry Wells, Galleries and Proprietary Systems

## Requirements For Credit

**On Site Plan Show:**

☐ Delineate the impervious tributary area draining to the infiltration system

☐ Show how the runoff will be directed to the infiltration system

☐ Show the percent and direction of land slope for the site

☐ Show a cross-section of the proposed system on the plan with dimensions called out

**Confirm that the following specification will be met:**

☐ Subsurface infiltration facility must be located at least 5 feet from the parcel property lines

☐ Subsurface infiltration facility must be located at a minimum of 10 feet (down gradient) from building foundations. Exceptions may be granted if a mounding analysis, conducted as part of a geotechnical report, clearly shows that no potential impact to the structure will result from a closer setback (Appendix 8. Mounding Analysis Procedure).

☐ Subsurface infiltration facility must be located 100 feet or greater from water wells, monitoring wells, springs and flowing surface water bodies, and from unstable land masses.

☐ Subsurface infiltration facility must be located 100 feet or greater from the high water mark of vernal pools, wetlands, lakes, ponds, or other surface water bodies.

☐ Subsurface infiltration facility must be located 1,200 feet or greater from any public water systems' surface water intake point.

☐ Subsurface infiltration facility must be located at least 25 feet from slope break on slopes greater than 30%. A mounding analysis, conducted as part of a geotechnical report, is required for set backs less than 25 feet.

☐ Pretreatment systems, debris/sediment traps and filter strips, are recommended for all facilities and may be required by the jurisdictional entity on facilities that capture runoff from roofs, roads, and parking areas (check with the jurisdictional entity for minimum filter strip widths).

☐ Inspection port is accessible.

☐ Slopes are less than 20% unless a geotechnical report is prepared

# Subsurface Infiltration Devices – Dry Wells, Galleries and Proprietary Systems

☐ The depth to seasonal high groundwater level is greater than 5 feet, measured from the bottom of the trench. If groundwater depth is found to be less than 5 feet, a mounding analysis will be required. Groundwater level determination shall be made using methods described in Humboldt County's, Wet Weather Testing of Soils, using either soil mottling or direct observation techniques.

☐ No adverse impact to adjacent property

☐ No contaminated soils shall be on site

☐ Overflow: subsurface infiltration facilities shall be designed to operate offline, such that only design flows are diverted to the facility and the remainder is bypassed

**Infiltration Rate Requirements**

Infiltration rates of the soils underlying the proposed infiltration system must be documented; the following outlines the method for determining infiltration rate compliance.

Soil grain analysis using ASTM D 422D, *Standard Test Method for Particle-Size Analysis of Soils,* shall be performed within the boundaries of the proposed infiltration facility and at the bottom elevation/cut (infiltration surface) of the proposed infiltration facility.

☐ Check box if particle size analysis results in <u>less than</u> (<) 50% fines. **Stop** - Compliance has been met.

☐ Check box if particle size analysis results in <u>greater than</u> (>) 50% fines. <u>Compliance has not been met</u>. Please, procced to percolation testing requirements, below.

A percolation test according to the Humboldt County Environmental Health's *Wet Weather Testing of Soils,* must be performed if particle size analysis compliance has not been met.

☐ Percolation is equal to or greater than (≥) 1-inch per hour. **Stop** - Compliance has been met. Please include all testing results with submission.

☐ Percolation is less than 1-inch per hour – <u>Compliance has not been met.</u> Please meet with jurisdictional authority for alternative compliance requirements.

Meeting all of the criteria on this worksheet does not guarantee approval of these devices. Infiltration facilities proposed in areas with high groundwater and in close proximity to waterbodies impaired for pathogens may not be approved regardless of meeting the above requirements.

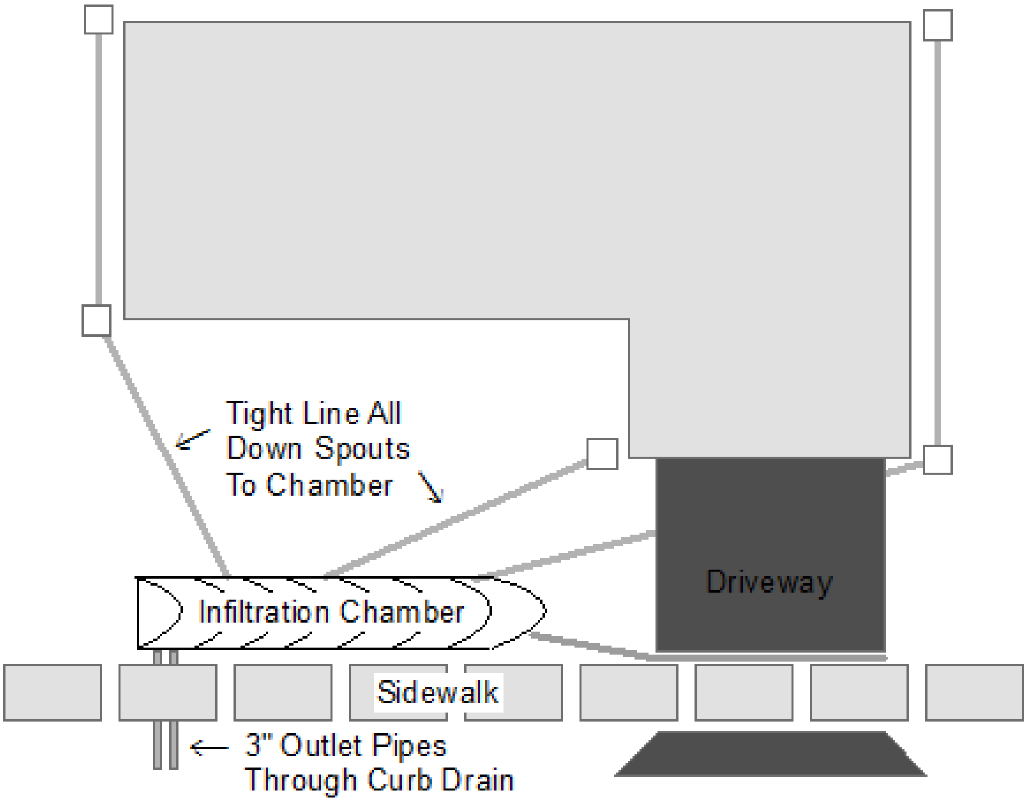
Alternatively, areas that may not meet the above requirements have the opportunity to request a waiver. However, it must be demonstrated that groundwater surfacing and impacts to structures will not result from the placement of the facility. Please consult with your jurisdictional permitting authority for additional requirements and considerations.

# Subsurface Infiltration Devices – Dry Wells, Galleries and Proprietary Systems

An infiltration trench that is to be designed to address limitations in the down stream conveyance system may be required to submit percolation and groundwater elevation testing reports to the jurisdictional permitting authority for approval.

☐ An operation and maintenance plan must accompany permit submission (does not need to be recorded against the deed). Operation and Maintenance Plans that are specific to proprietary units and are produced by manufacturer are acceptable. Runoff reduction credits will be proportional to the volume of available storage in infiltration device.

**Example Schematic**




## References

*Link to Environmental Health Department's Wet Weather Testing of Soils:*

*http://www.humboldtgov.org/685/land-use-program*

*OWTS Policy, Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems, June 19, 2012.*

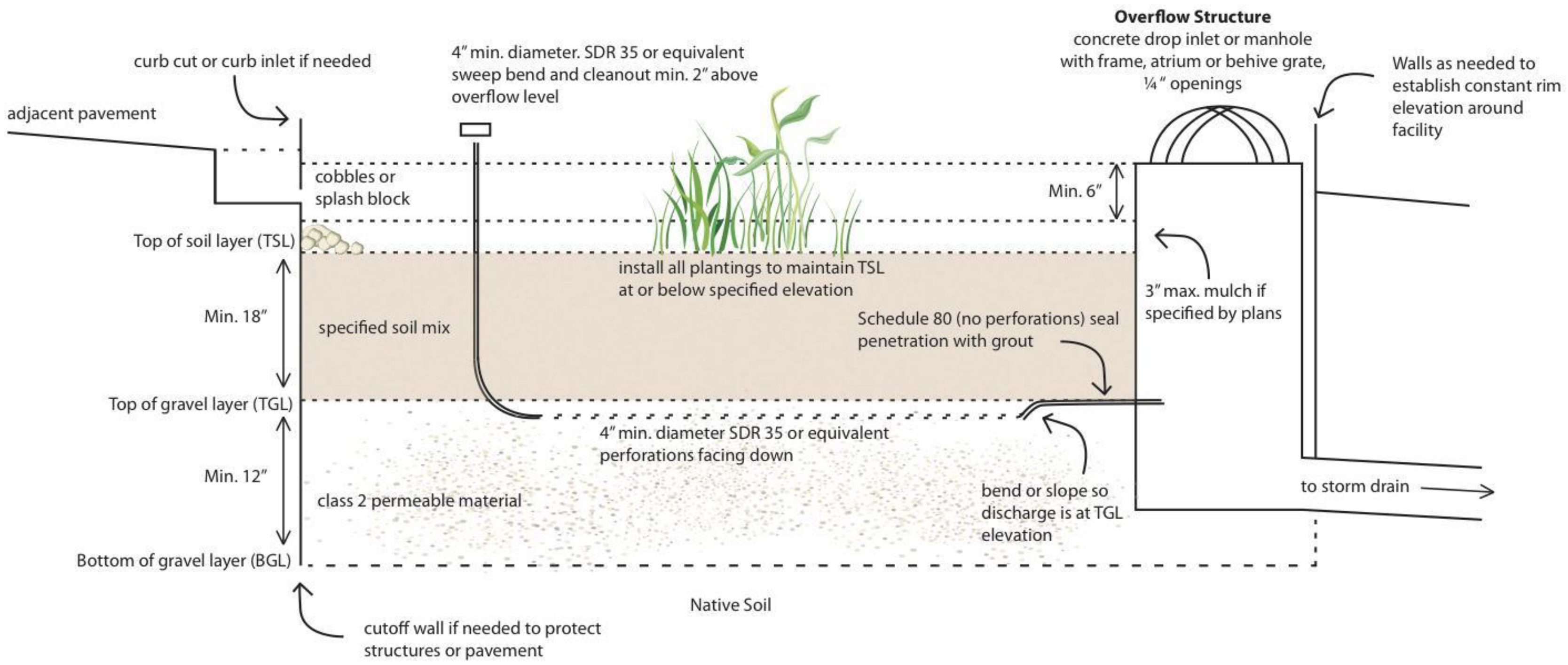
*http://www.swrcb.ca.gov/water_issues/programs/owts/docs/owts_policy.pdf*

# APPENDIX 4

## Bioretention Specifications and Checklist

# Bioretention Facility

not to scale




**Allowed variations for special site conditions:**

- Facilities located within 10 feet of structures or other potential geotechnical hazards may incorporate an impervious cutoff wall

- Facilities with documented high concentrations of pollutants in underlying soil or groundwater, facilities where infiltration could contribute to a geotechnical hazard, and facilities located on elevated plazas or other structures may incorporate an impervious liner between the native soil and the BGL and locate the underdrain discharge at the BGL (flow-through planter configuration)

- Facilities located in areas of high groundwater, highly infiltrative soils, or where connection of the underdrain to a surface drain or subsurface storm drain are infeasible may omit the underdrain

**Notes:**

- No liner, no filter fabric, no landscape cloth.

- Maintain BGL, TGL, TSL throughout facility area at elevations to be specified in plan.

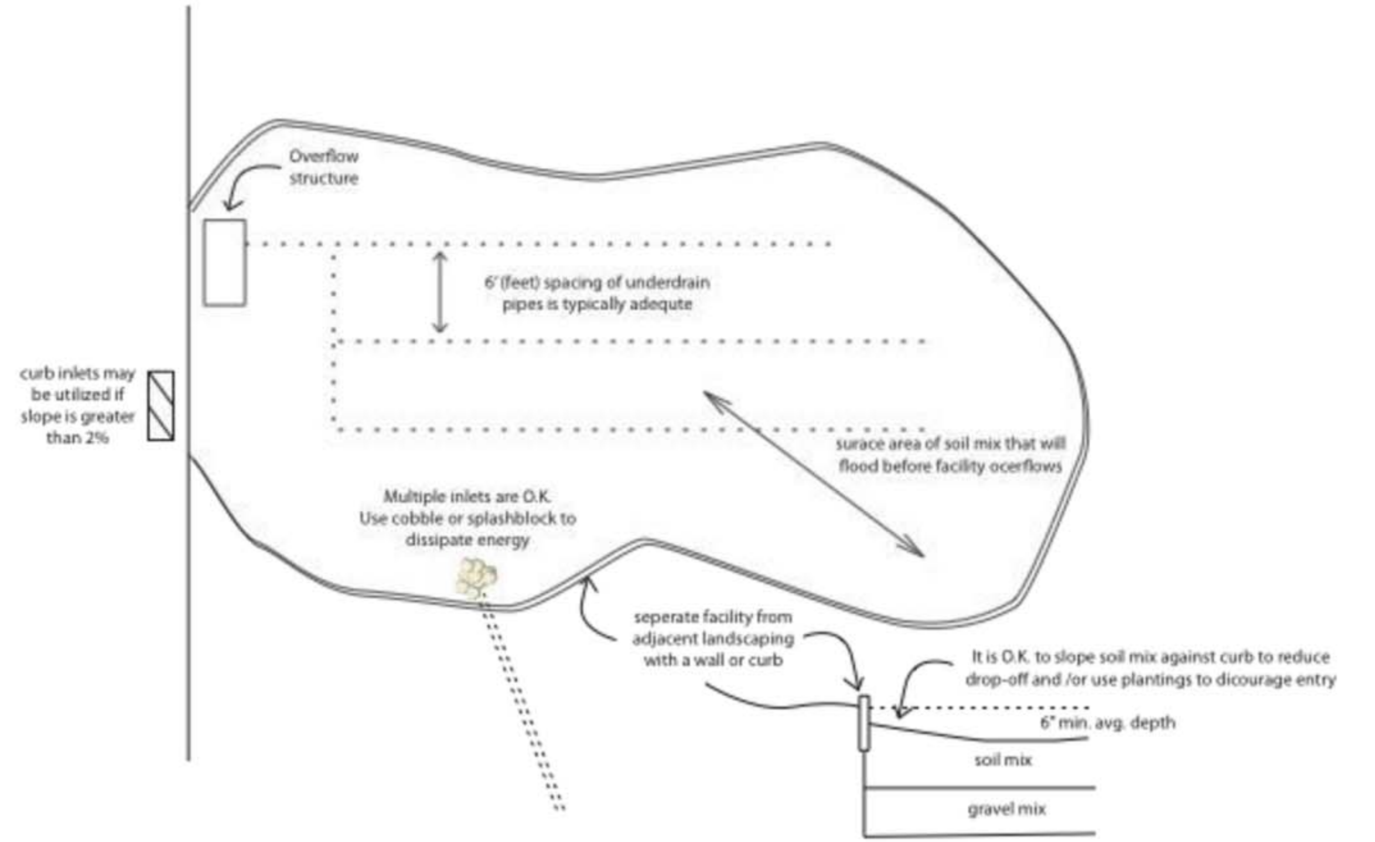
- Class 7 permeable layer may extend below and underneath drop inlet.

- Elevation or underdrain discharge is at top of gravel layer.

- See Section 6.3 for instructions on facility sizing and additional specifications

# Bioretention Facility - Overview

not to scale




**Note:**

Show all elevations of curb, pavement, inlet, top of soil layer (TSL), top of gravel layer (TGL), and bottom of gravel layer (BGL) at all inlets and outlets and at key points along edge of facility.

# Soil/Compost and Gravel Specifications for Bioretention Facility

Compost shall be a well-decomposed, stable, weed-free organic matter source derived from waste materials including yard debris, wood wastes or other organic materials not including manure or biosolids, and shall meet the standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

**Compost Quality Analysis:**

Before delivery of the soil, the supplier shall submit a copy of the lab analysis performed by a laboratory that is enrolled in the USCC's Compost Analysis Proficiency (CAP) program and using approved Test Methods for the Evaluation of Composting and Compost (TMECC). The lab report shall verify that the compost parameters are within the limits specified below.

| **Parameter** | **Range** | **Reported as (units)** |
|---|---|---|
| Organic Matter Content | 35-75 | %, dry weight basis |
| Carbon to Nitrogen Ratio | 15:1 to 25:1 | ratio |
| Maturity<br>(Seed Emergence and Seedling Vigor) | >80 | average % of control |
| Stability ($CO_2$ Evolution Rate) | <8 | mg $C0_2$-C/g unit OM/day |
| Soluble Salts (Salinity) | <6.0 | mmhos/cm |
| pH | 6.5 - 8.0<br>May vary with plant species | units |
| Heavy Metals Content | PASS | PASS/FAIL: US EPA Class A standard, 40 CFR § 503.13, tables 1 and 3. |
| **Pathogens** | | |
| Fecal coliform | PASS | PASS/FAIL: US EPA Class A standard, 40 CFR § 503.32(a) levels |
| Salmonella | PASS | PASS/FAIL: US EPA Class A standard, 40 CFR § 503.32(a) levels |
| **Nutrient Content (provide analysis, including):** | | |
| Total Nitrogen (N) | ≥0.9 | % |
| Boron (Total B) | <80 | ppm |
| Calcium (Ca) | For information only | % |
| Sodium (Na) | For information only | % |
| Magnesium (Mg) | For information only | % |
| Sulfur (S) | For information only | % |

## Soil/Compost and Gravel Specifications for Bioretention Facility

**Gravel Layer**

The gravel layer used in the bioretention facility must consist of *Class 2 Permeable Material* as specified in the State of California's Business, Transportation and Housing Agency, Department of Transportation; Standard Specifications 2010, manual (http://www.dot.ca.gov/hq/esc/oe/construction_contract_standards/std_specs/2010_StdSpecs/2010_StdSpec s.pdf).

The specific section, Subsurface Drains, Sec. 68, of the manual is used because it offers specific specifications for subsurface drains. In addition to the standardized permeable layer, a membrane layer of pea gravel or other intermediate-sized material is recommended at the top of the gravel layer to prevent fines from the soil/compost layer from moving downward into the gravel layer.

**68-2.02F (1) General**
Permeable material for use in backfilling trenches under, around, and over underdrains must consist of hard, durable, clean sand, gravel, or crushed stone and must be free from organic material, clay balls, or other deleterious substances.

Permeable material must have a durability index of not less than 40.

**68-2.02F (3) Class 2 Permeable Material**
The percentage composition by weight of Class 2 permeable material in place must comply with the grading requirements shown in the following table:

**Class 2 Permeable Material* Grading Requirements**

| Sieve sizes | Percentage passing |
|---|---|
| 1" | 100 |
| 3/4" | 90–100 |
| 3/8" | 40–100 |
| No. 4 | 25–40 |
| No. 8 | 18–33 |
| No. 30 | 5–15 |
| No. 50 | 0–7 |
| No. 200 | 0–3 |

*Class 2 permeable material must have a sand equivalent value of not less than 75.

## Bioretention Facility Construction Checklist

| | |
|---|---|
| | **Layout** (to be confirmed prior to beginning excavation permit approval stage) |
| ☐ | Square footage of the facility meets or exceeds minimum shown in Stormwater Control Plan |
| ☐ | Site grading and grade breaks are consistent with the boundaries of the tributary Drainage Management Area(s) (DMAs) shown in the Stormwater Control Plan |
| ☐ | Inlet elevation of the facility is low enough to receive drainage from the entire tributary DMA |
| ☐ | Locations and elevations of overland flow or piping, including roof leaders, from impervious areas to the facility have been laid out and any conflicts resolved |
| ☐ | Rim elevation of the facility is laid out to be level all the way around, or elevations are consistent with a detailed cross-section showing location and height of interior dams |
| ☐ | Locations for vaults, utility boxes, and light standards have been identified so that they will not conflict with the facility |
| ☐ | Facility is protected as needed from construction-phase runoff and sediment |

| | |
|---|---|
| | **Excavation** (to be confirmed prior to backfilling or pipe installation) |
| ☐ | Excavation conducted with materials and techniques to minimize compaction of soils within the facility area |
| ☐ | Excavation is to accurate area and depth |
| ☐ | Slopes or side walls protect from sloughing of native soils into the facility |
| ☐ | Moisture barrier, if specified, has been added to protect adjacent pavement or structures. |
| ☐ | Native soils at bottom of excavation are ripped or loosened to promote infiltration |

| | |
|---|---|
| | **Overflow or Surface Connection to Storm Drainage** (to be confirmed prior to backfilling with any materials) |
| ☐ | Grating excludes mulch and litter (beehive or atrium-style grates recommended) |
| ☐ | Overflow is connected to storm drain via appropriately sized |
| ☐ | No knockouts or side inlets are in overflow riser |
| ☐ | Overflow is at specified elevation |
| ☐ | Overflow location selected to minimize surface flow velocity (near, but offset from, inlet recommended) |
| ☐ | Grating excludes mulch and litter (beehive or atrium-style grates recommended) |
| ☐ | Overflow is connected to storm drain via appropriately sized |

# Bioretention Facility Construction Checklist

## Underground connection to storm drain/outlet orifice

- ☐ Perforated pipe underdrain (PVC SDR 35 or approved equivalent) is installed with holes facing down
- ☐ Perforated pipe is connected to storm drain at specified elevation (typ. bottom of soil elevation)
- ☐ Cleanouts are in accessible locations and connected via sweep

## Drain Rock/Subdrain (to be confirmed prior to installation of soil mix)

- ☐ Rock is installed as specified, 12" min. depth. Class 2 permeable, Caltrans specification 68- 2.02F(3) recommended
- ☐ Rock is smoothed to a consistent top elevation. Depth and top elevation are as shown in plans
- ☐ Slopes or side walls protect from sloughing of native soils into the facility
- ☐ No filter fabric is placed between the subdrain and soil mix layers

## Soil Mix

- ☐ Soil mix is as specified.
- ☐ Mix installed in lifts not exceeding 12"
- ☐ Mix is not compacted during installation but may be thoroughly wetted to encourage consolidation
- ☐ Mix is smoothed to a consistent top elevation. Depth of mix (18" min.) and top elevation are as shown in plans, accounting for depth of mulch to follow and required reservoir depth

## Irrigation

- ☐ Irrigation system is installed so it can be controlled separately from other landscaped areas
- ☐ Smart irrigation controllers and drip emitters are recommended and may be required by local code or ordinance.
- ☐ Spray heads, if any, are positioned to avoid direct spray into outlet structures

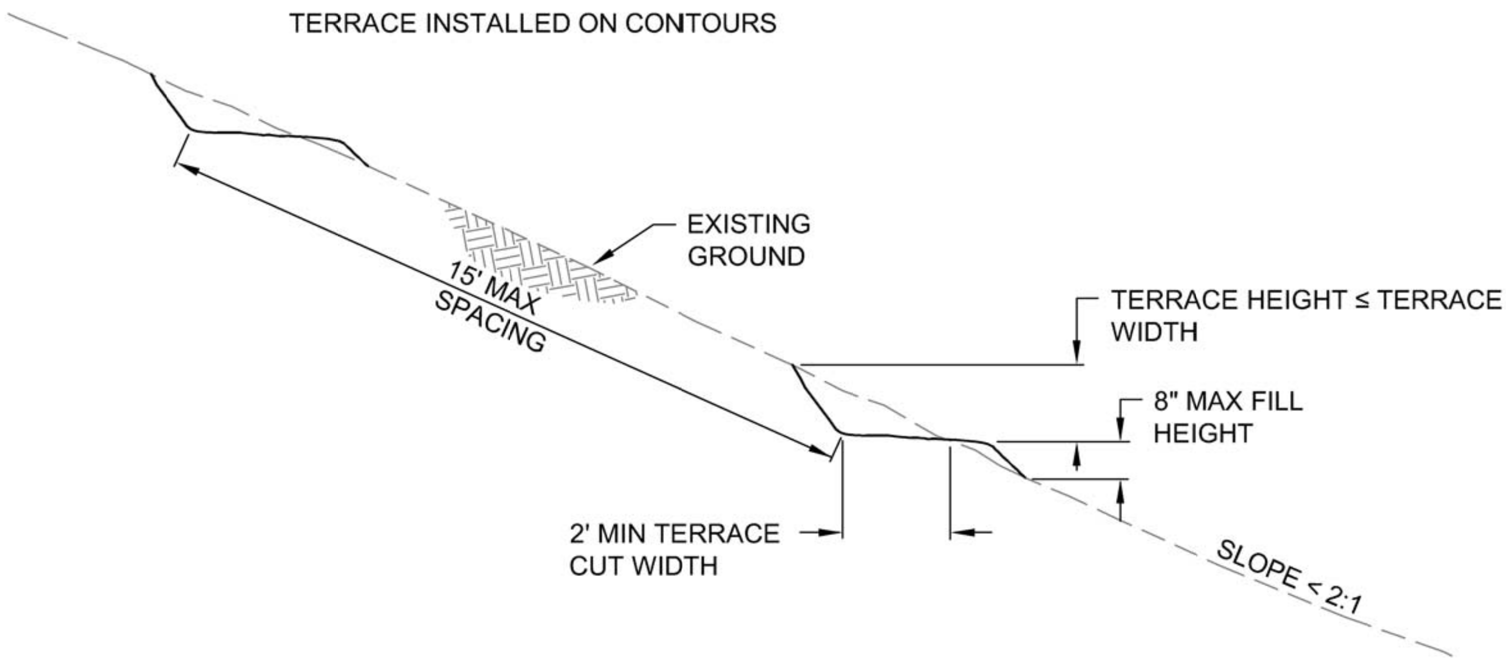
# Bioretention Facility Construction Checklist

## Planting

- ☐ Plants are installed consistent with approved planting plan, consistent with site water allowance
- ☐ Any trees and large shrubs are staked securely
- ☐ No fertilizer is added; compost tea may be used
- ☐ No native soil or clayey material are imported into the facility with plantings
- ☐ 1"-2" mulch may be applied following planting; mulch selected to avoid floating
- ☐ Final elevation of soil mix maintained following planting
- ☐ Curb openings are free of obstructions

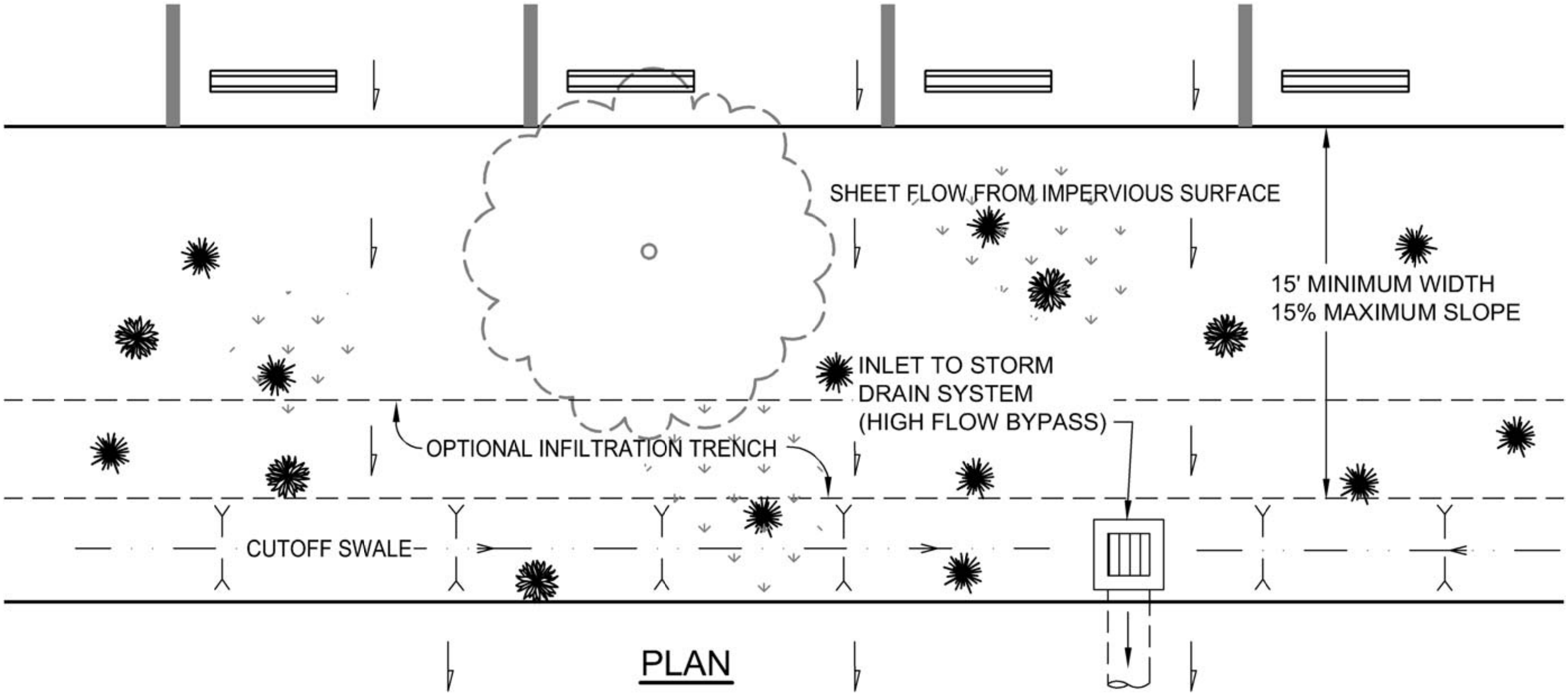
## Final Engineering Inspection

- ☐ Drainage Management Area(s) are free of construction sediment and landscaped areas are stabilized
- ☐ Inlets are installed to provide smooth entry of runoff from adjoining pavement, have sufficient reveal (drop from the adjoining pavement to the top of the mulch or soil mix, and are not blocked
- ☐ Inflows from roof leaders and pipes are connected and operable
- ☐ Temporary flow diversions are removed
- ☐ Rock or other energy dissipation at piped or surface inlets is adequate
- ☐ Overflow outlets are configured to allow the facility to flood and fill to near rim before overflow
- ☐ Plantings are healthy and becoming established
- ☐ Irrigation is operable
- ☐ Facility drains rapidly; no surface ponding is evident
- ☐ Any accumulated construction debris, trash, or sediment is removed from facility
- ☐ Permanent signage is installed and is visible to site users and maintenance personnel

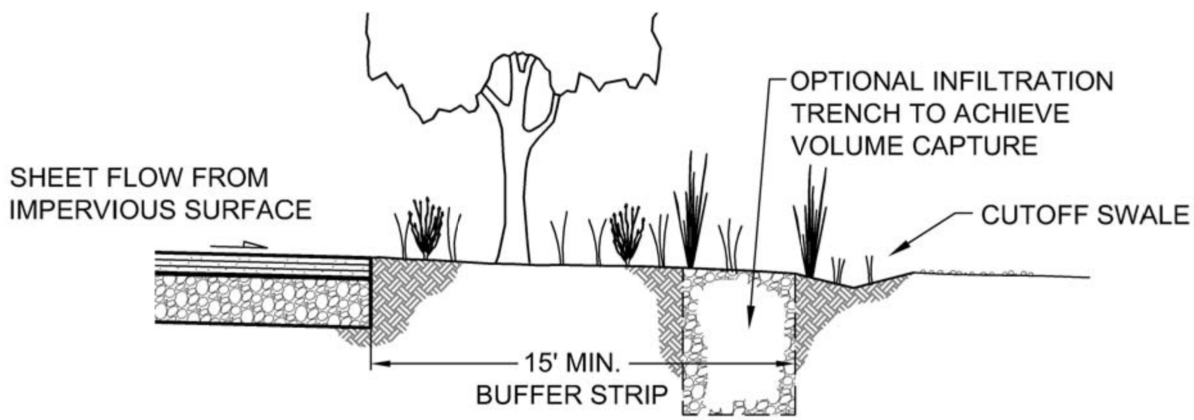



Not to Scale

| | |
|---|---|
| RUNOFF REDUCTION MEASURE<br>BOVINE TERRACE | |
| SCALE: *NONE* | DATE: *04/06/17* |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 1 | RRM–01 |



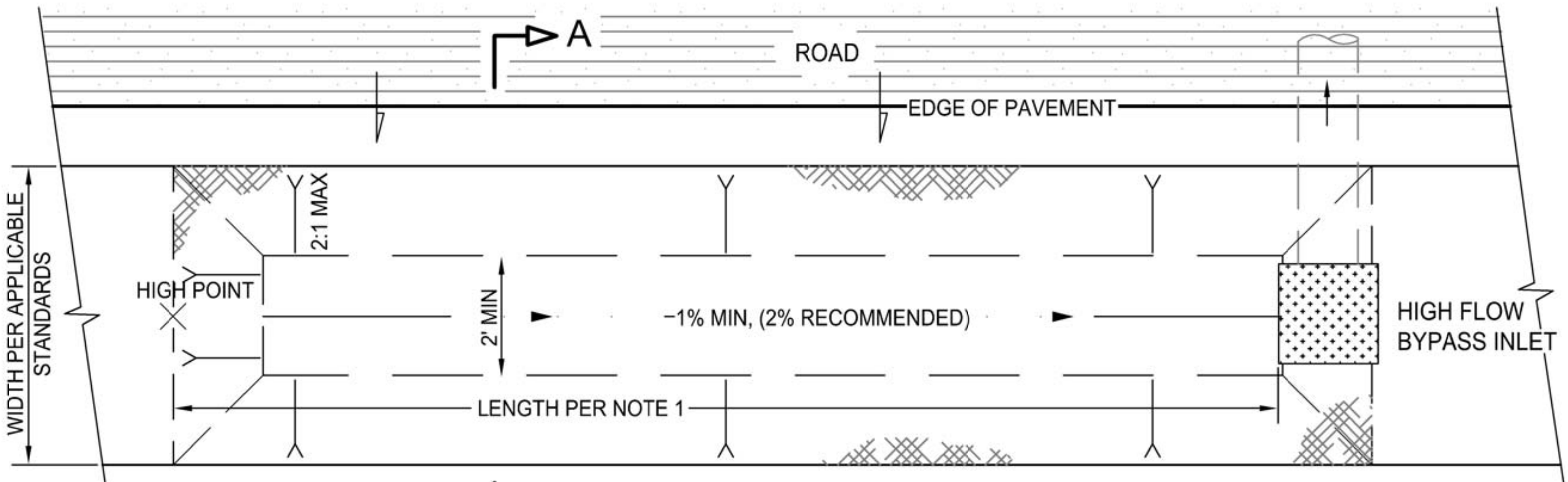

PLAN




TYPICAL SECTION

Not to Scale

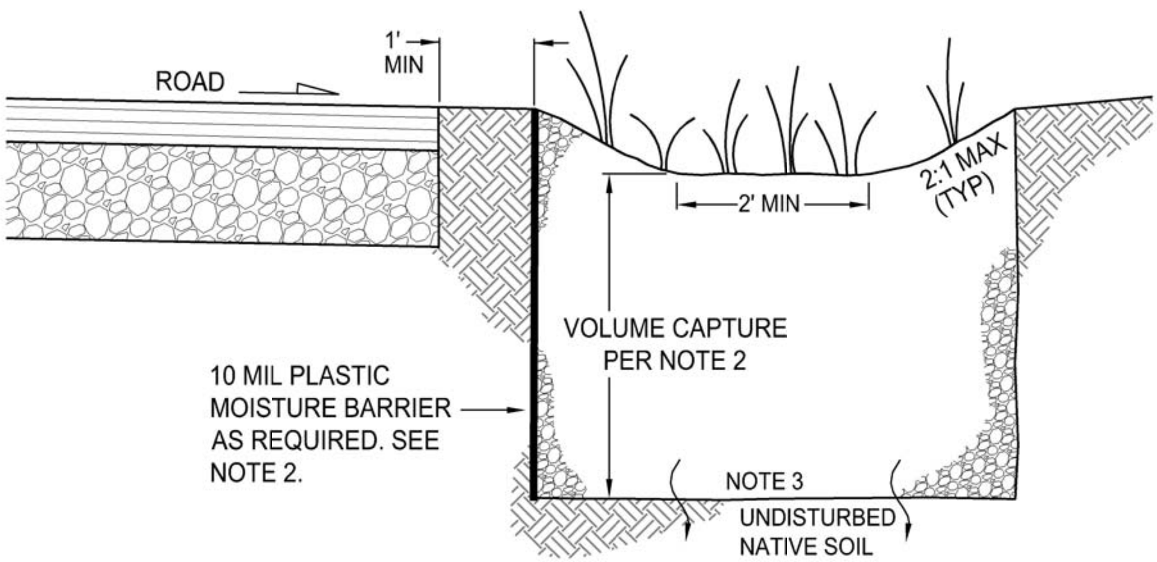
| RUNOFF REDUCTION MEASURE<br>VEGETATED BUFFER STRIP | | |
|---|---|---|
| SCALE: *NONE* | | DATE: *03/28/17* |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 1 | RRM–02 |




PLAN

NOTES:

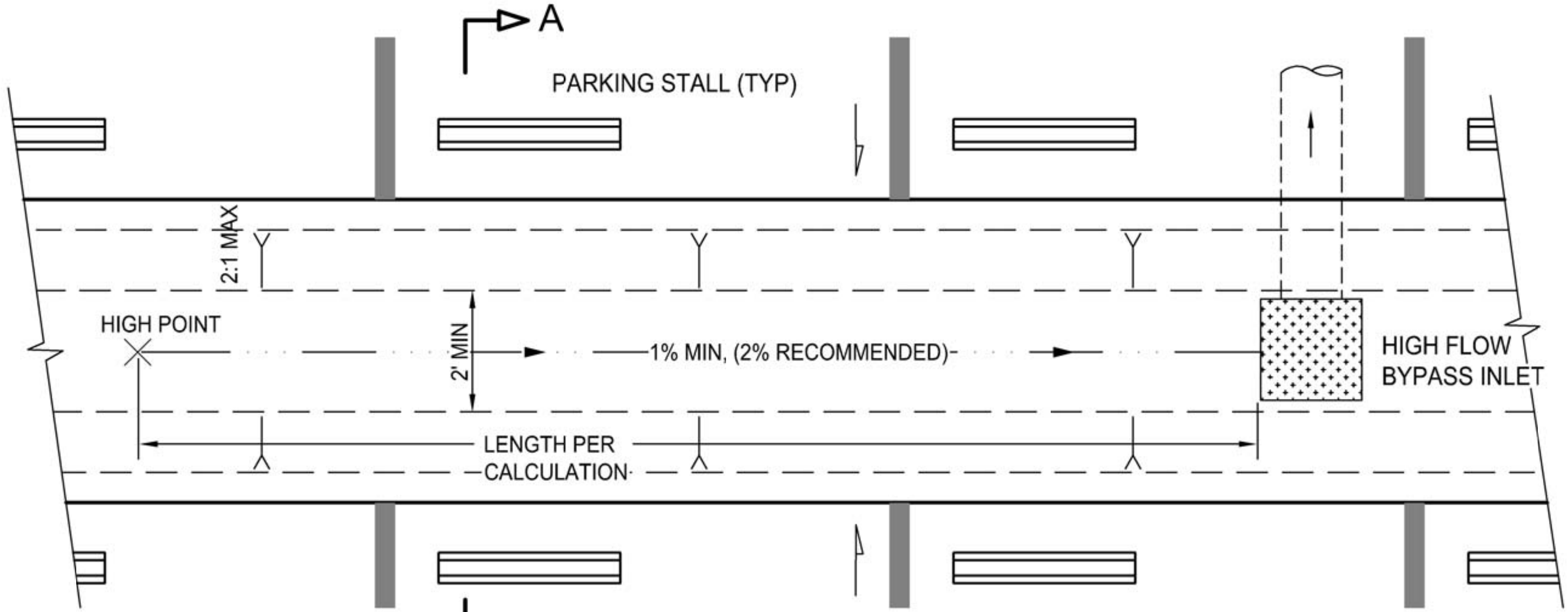
1. IF SWALE PROVIDES TREATMENT, LENGTH SHALL BE DESIGNED TO PROVIDE 12 MINUTES OF CONTACT TIME IF FLOW ENTERS UNIFORMLY ALONG LENGTH. LENGTH SHALL PROVIDE 5 MINUTES OF CONTACT TIME IF 90% OR MORE OF THE FLOW ENTERS AT THE UPSTREAM END.
2. SOIL TO BE SPECIFIED BY DESIGN ENGINEER TO MEET VOLUME CAPTURE AND GOVERNING AGENCY REQUIREMENTS. IF NON-STRUCTURAL SOIL IS SELECTED A CUTOFF WALL IS REQUIRED IN PLACE OF A MOISTURE BARRIER.
3. SWALE MUST CONVEY HIGH FLOWS PER GOVERNING AGENCY DESIGN STANDARDS.




SECTION A-A

Not to Scale

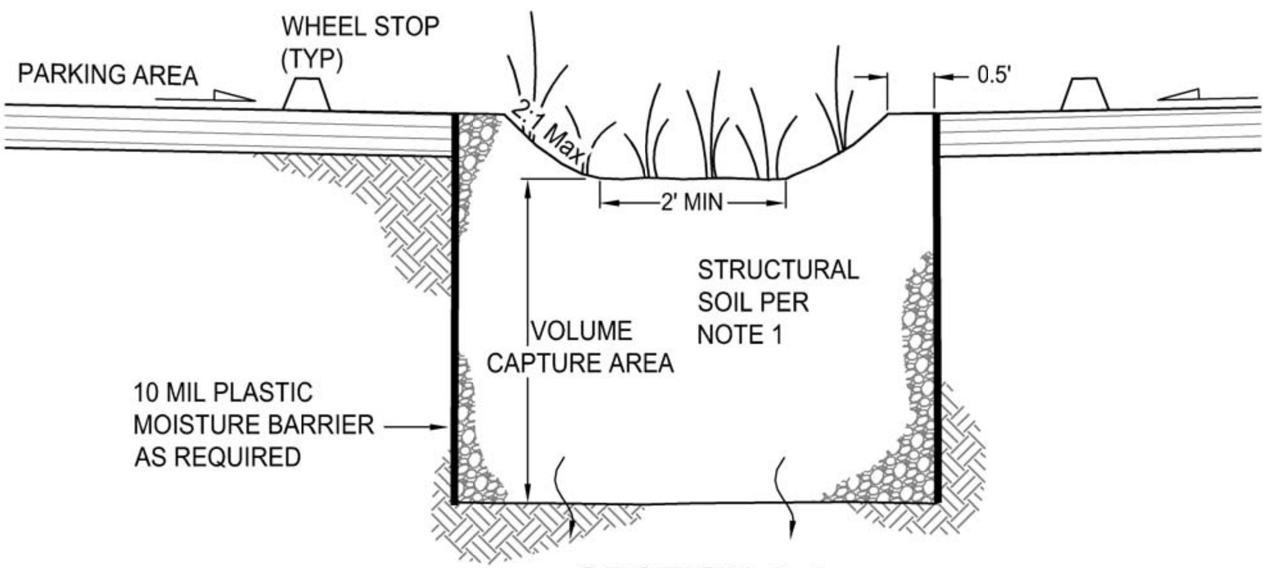
| PRIORITY 1 ROADSIDE BIORETENTION - NO CURB AND GUTTER | | |
|---|---|---|
| SCALE: NONE | | DATE: 03/29/17 |
| DWN. DIT CHK. HM | | P1–02 |




PLAN

NOTES:

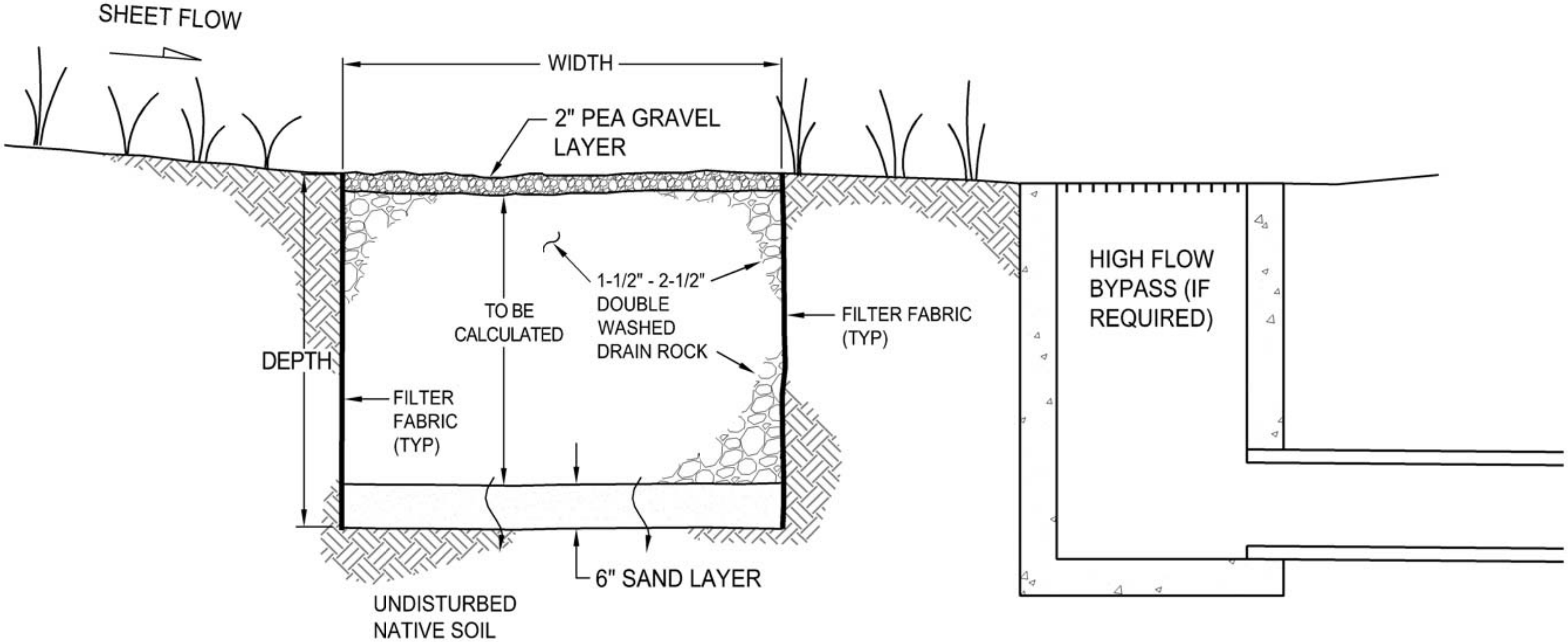
1. STRUCTURAL SOIL UNLESS OTHERWISE APPROVED BY GEOTECHNICAL ENGINEER AND ACCEPTED BY GOVERNING AGENCY.
2. SWALE MUST CONVEY FLOOD DESIGN FLOWS PER GOVERNING AGENCY DESIGN STANDARDS.
3. PARKING ISLAND WIDTH PER APPLICABLE GOVERNING AGENCY STANDARDS.




SECTION A-A

Not to Scale

| PRIORITY 1<br>SWALE WITH BIORETENTION | | |
|---|---|---|
| SCALE: NONE | | DATE: 04/06/17 |
| DWN. DIT<br>CHK. HM | SHEET 1 of 1 | P1–06 |



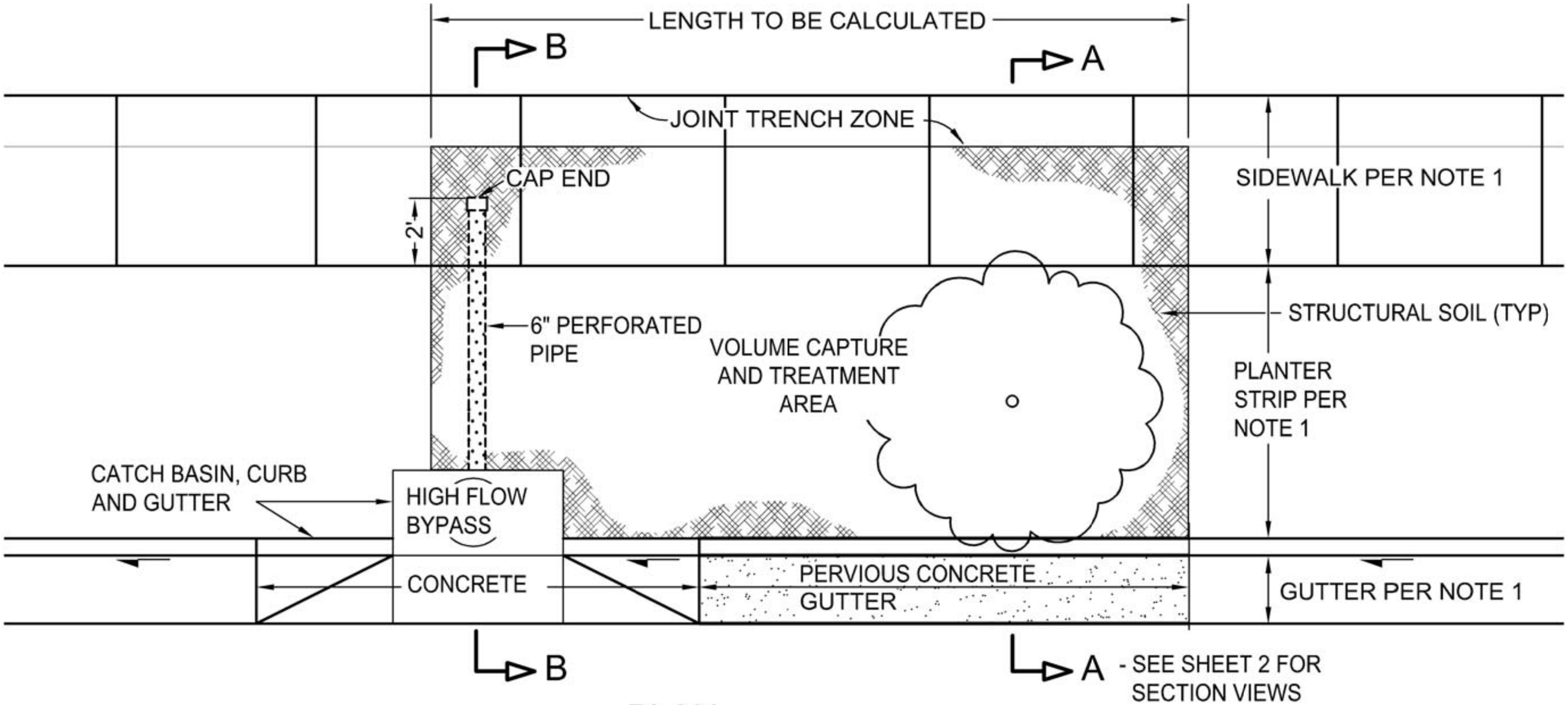

NOTES:

1. DEPTH SHALL NOT EXCEED WIDTH OR LENGTH.
2. TO BE USED AS PART OF A TREATMENT TRAIN.
3. ALL SURFACE WATER MUST DRAIN WITHIN 72 HOURS.

Not to Scale

PRIORITY 3
INFILTRATION TRENCH

| SCALE: NONE | DATE: 04/06/17 |
|---|---|
| DWN. DIT<br>CHK. HM | P1–07 |



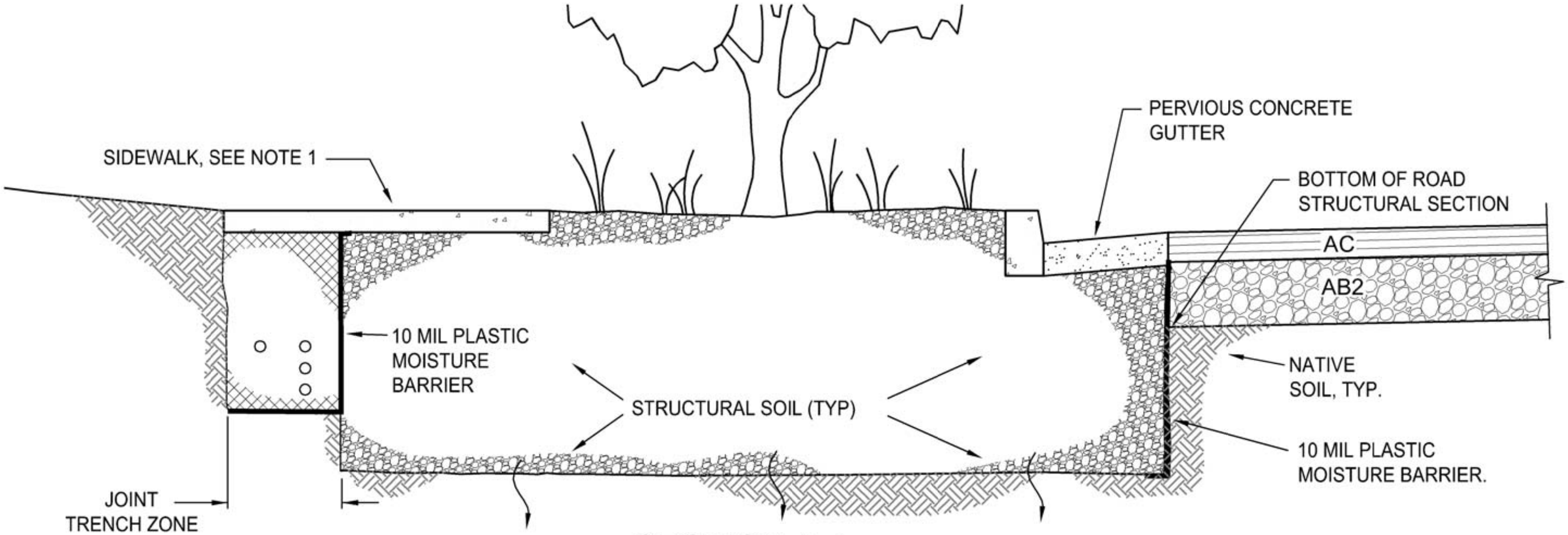

PLAN

NOTES:

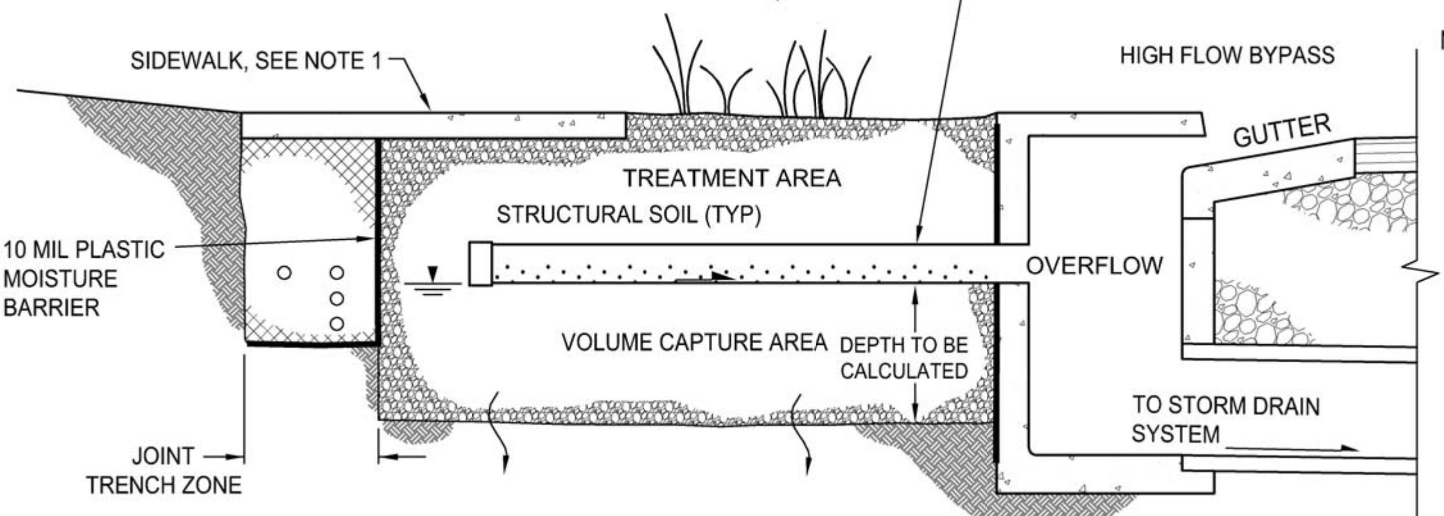
1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).

Not to Scale

| PRIORITY 2 ROADSIDE BIORETENTION - FLUSH DESIGN | | |
|---|---|---|
| SCALE: *NONE* | | DATE: *04/06/17* |
| DWN. *DIT* CHK. *HM* | SHEET 1 of 2 | P2–02 |




SECTION A-A



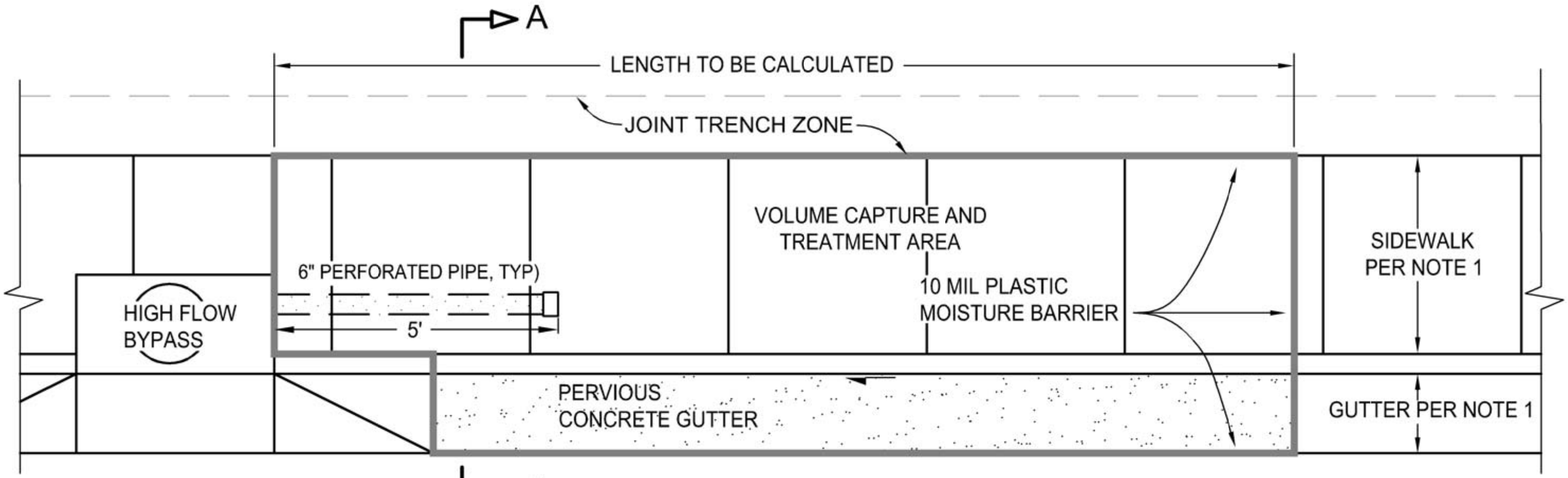

SECTION B-B

NOTES:

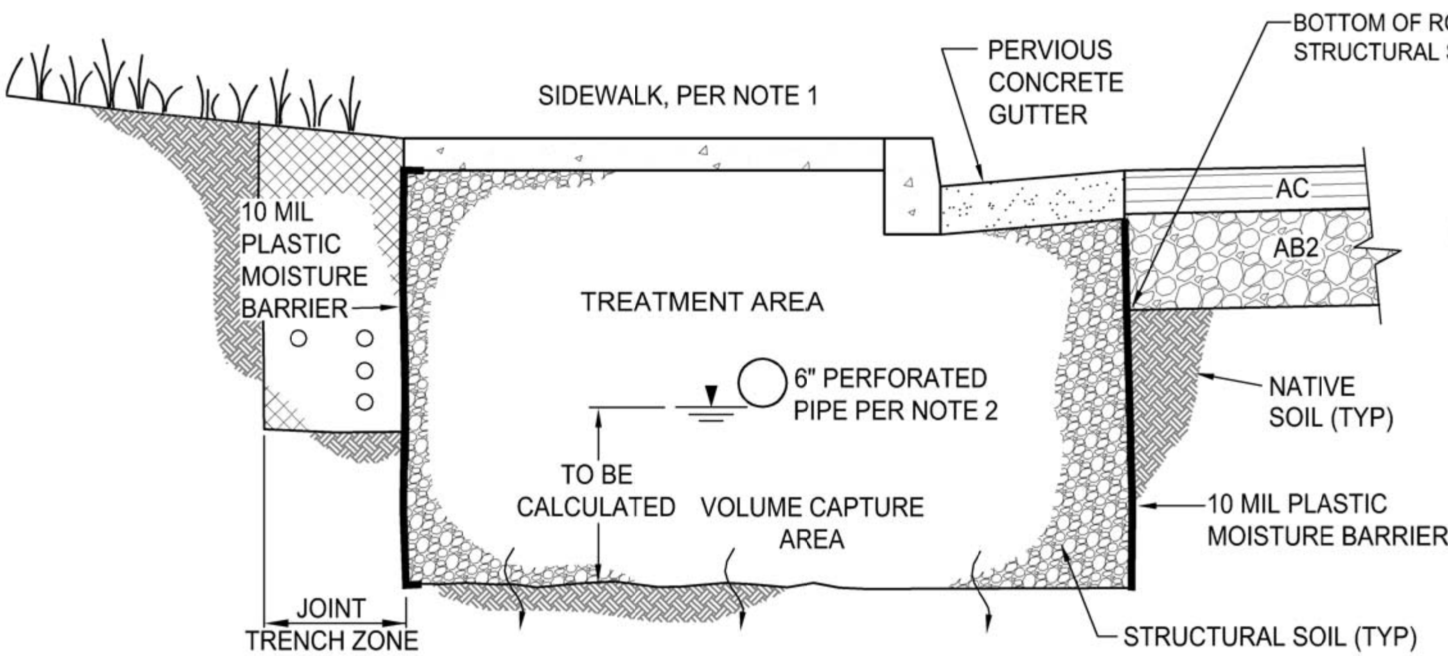
1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. TOP OF 6" PERFORATED PIPE TO BE SET 6" BELOW BOTTOM OF ROAD STRUCTURAL SECTION, MIN.

Not to Scale

| PRIORITY 2<br>ROADSIDE BIORETENTION<br>- FLUSH DESIGN | | |
|---|---|---|
| SCALE: *NONE* | DATE: *04/06/17* | |
| DWN. *DIT*<br>CHK. *HM* | SHEET 2 of 2 | P2–02 |




PLAN



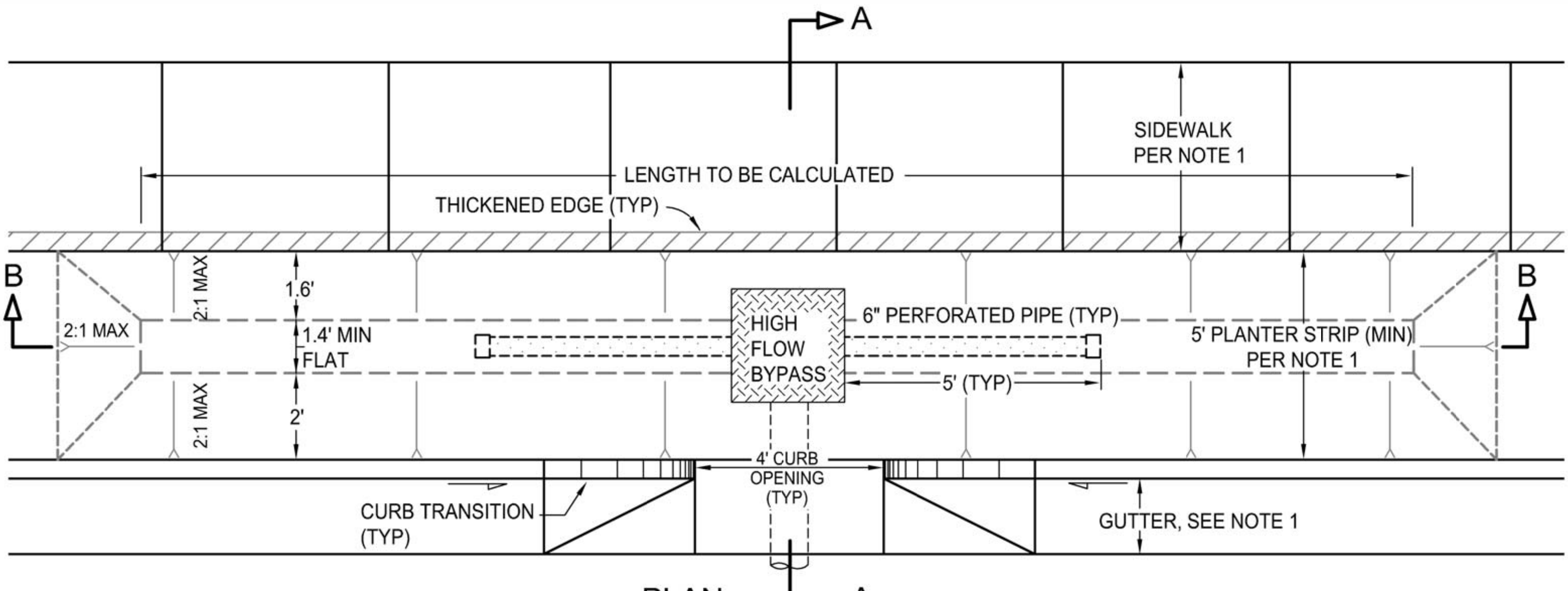

SECTION A-A

NOTE:

1. SIDEWALK AND CURB AND GUTTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. TOP OF 6" PERFORATED PIPE TO BE SET 6" BELOW BOTTOM OF ROAD STRUCTURAL SECTION, MIN.

| PRIORITY 2<br>ROADSIDE BIORETENTION<br>- CONTIGUOUS SIDEWALK | | |
|---|---|---|
| SCALE: NONE | | DATE: 04/06/17 |
| DWN. DIT<br>CHK. HM | SHEET 1 of 1 | P2–03 |

Not to Scale

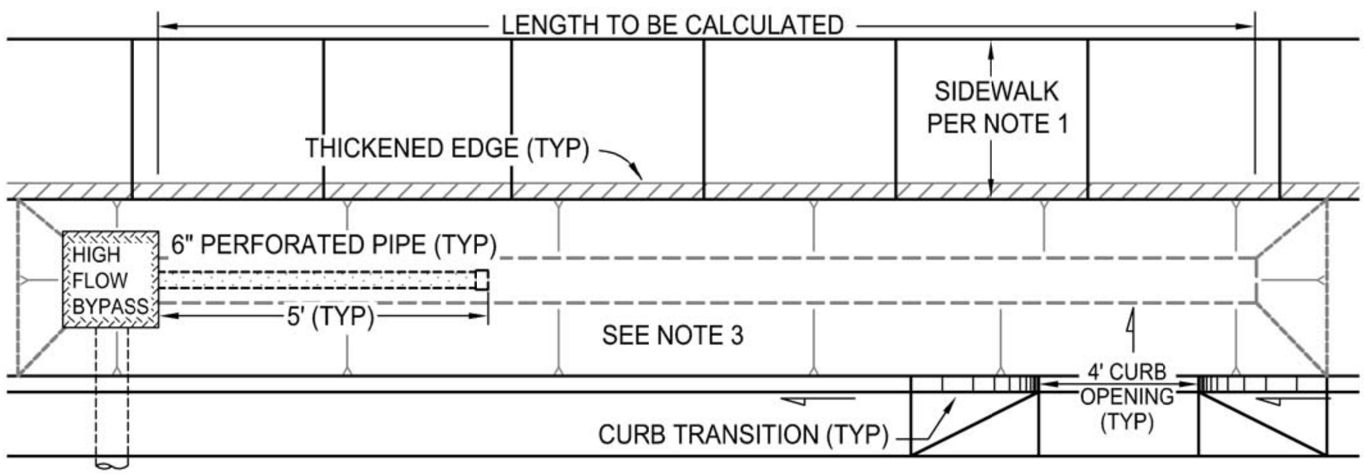



PLAN

TYPE A - CURB OPENING AT LOW POINT

NOTE:

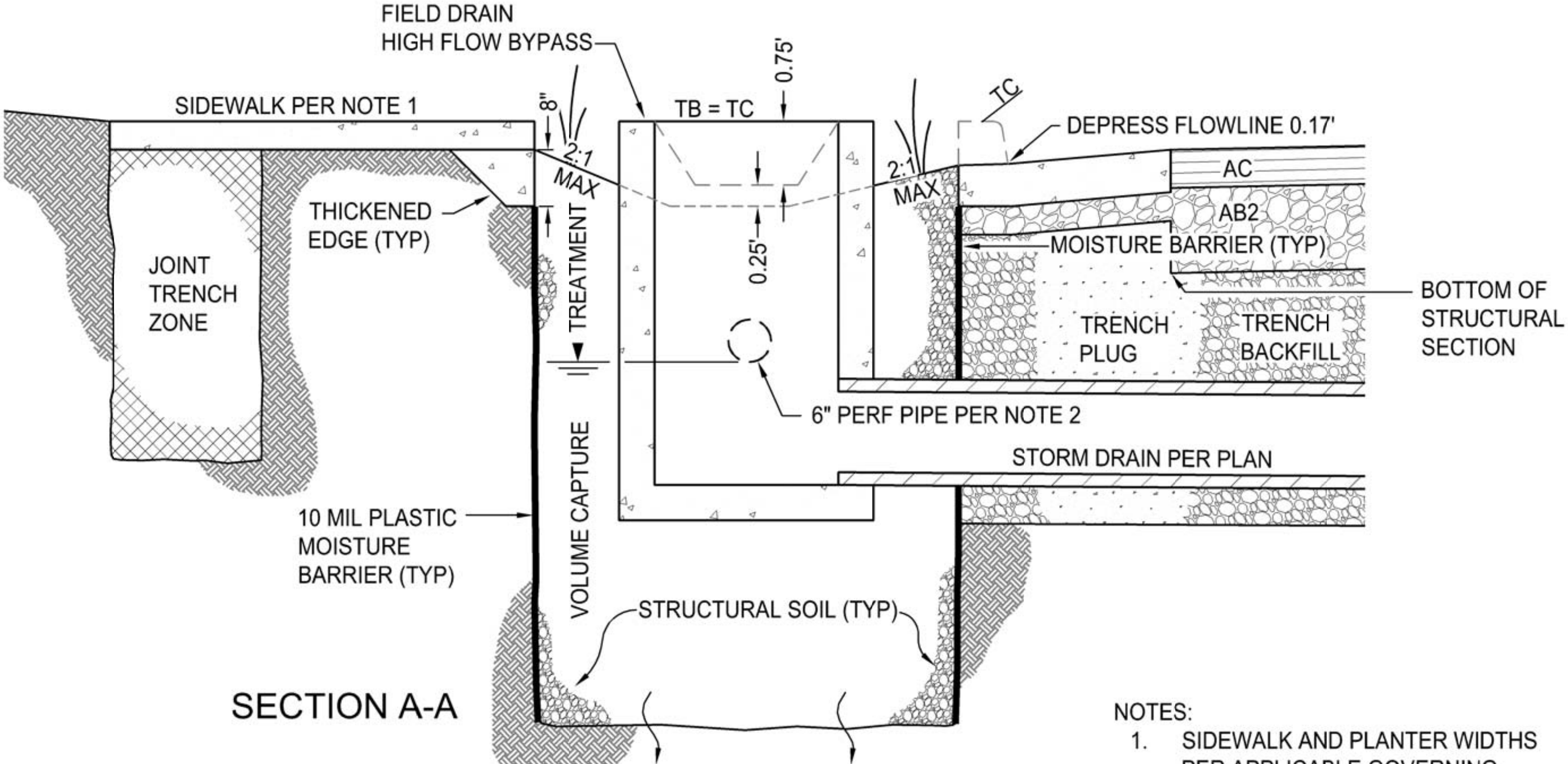
1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE MUNICIPAL STANDARDS (TYP).
2. TOP OF 6" PERFORATED PIPE TO BE SET 6" BELOW ROAD STRUCTURAL SECTION, MIN.
3. TYPE A MINIMUM DIMENSIONS AND GRADES APPLY TO TYPE B.




TYPE B -CURB OPENING ALONG A SLOPE

Not to Scale

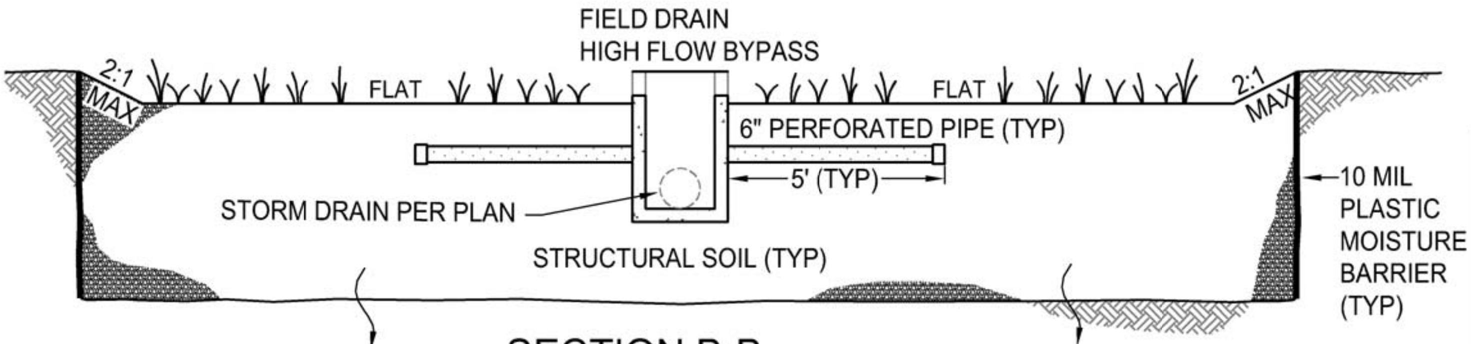
| PRIORITY 2<br>ROADSIDE BIORETENTION<br>- CURB OPENING | | |
|---|---|---|
| SCALE: *NONE* | DATE: *04/06/17* | |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 2 | P2–04 |




SECTION A-A

NOTES:

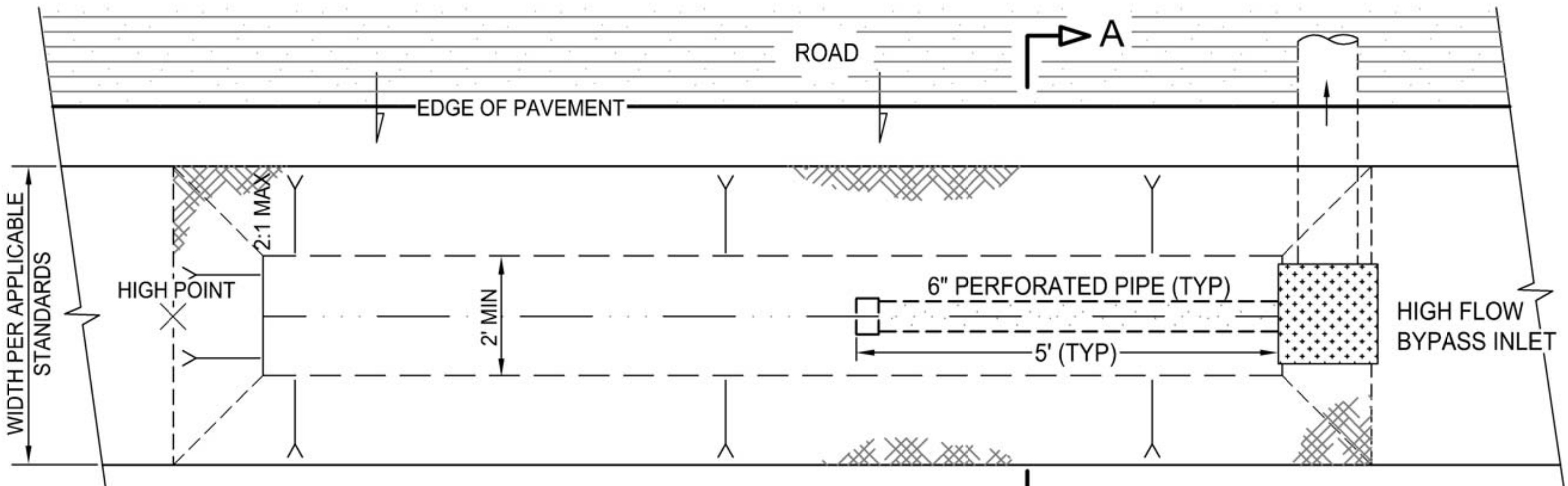
1. SIDEWALK AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. TOP OF 6" PERFORATED PIPE TO BE SET 6" BELOW BOTTOM OF ROAD STRUCTURAL SECTION.



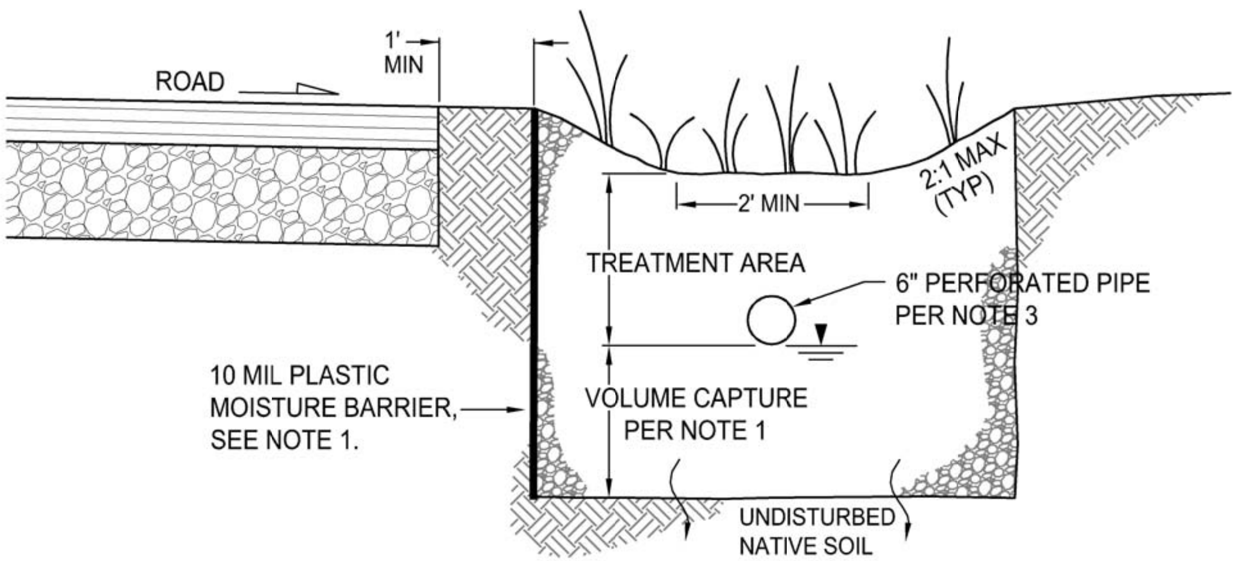

SECTION B-B

Not to Scale

| PRIORITY 2 ROADSIDE BIORETENTION - CURB OPENING SECTION A-A & B-B | |
|---|---|
| SCALE: *NONE* | DATE: *04/06/17* |
| DWN. *DIT* CHK. *HM* SHEET 2 of 2 | P2–04 |




PLAN




SECTION A-A

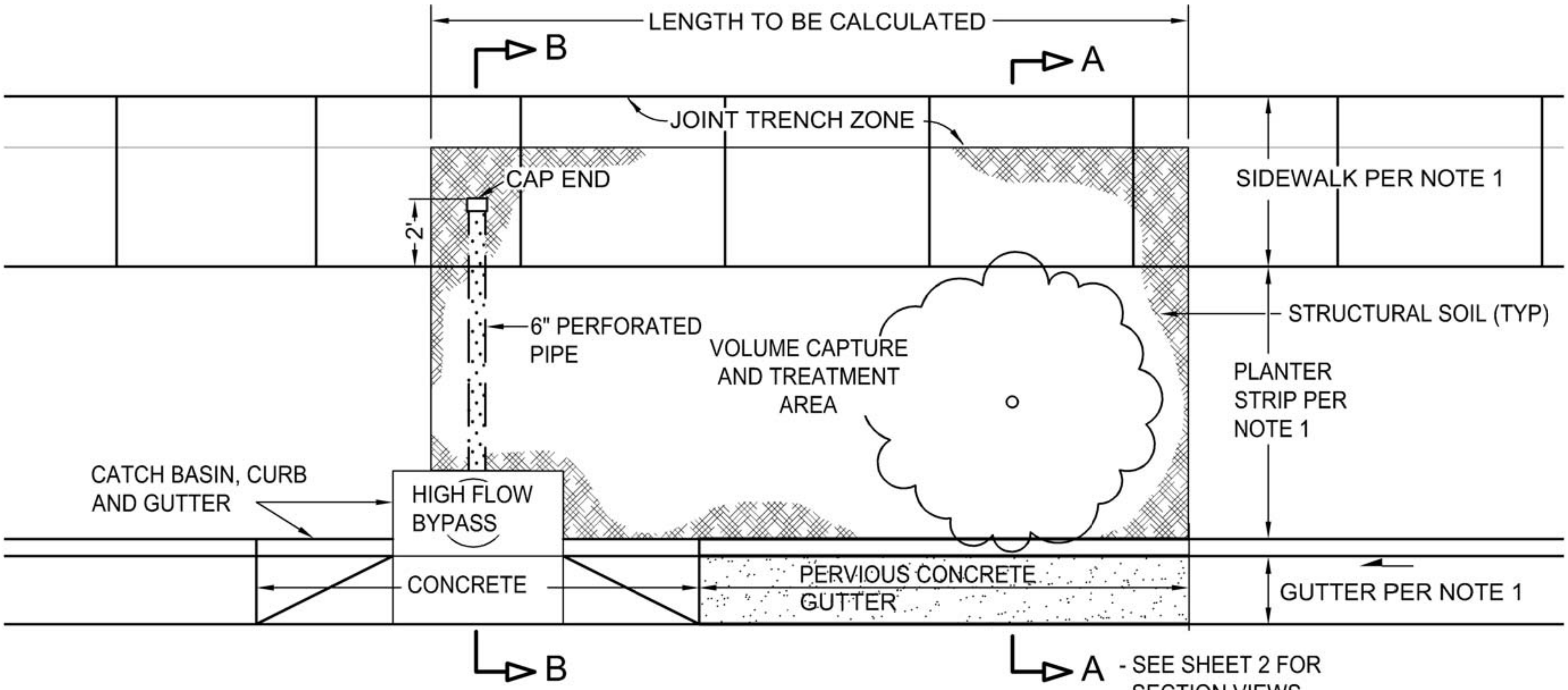
NOTES:

1. SOIL TO BE SPECIFIED BY DESIGN ENGINEER TO PROVIDE VOLUME CAPTURE AND MEET GOVERNING AGENCY REQUIREMENTS. IF NON STRUCTURAL SOIL IS SELECTED A CUTOFF WALL IS REQUIRED IN PLACE OF A MOISTURE BARRIER.
2. SWALE MUST CONVEY DESIGN FLOWS PER GOVERNING AGENCY DESIGN STANDARDS.
3. TOP OF 6" PERFORATED PIPE TO BE SET 6" BELOW BOTTOM OF ROAD STRUCTURAL SECTION.

SIMILAR TO P1-02
WITH A PERFORATED
DRAIN PIPE

Not to Scale

| PRIORITY 2<br>ROADSIDE BIORETENTION<br>- NO CURB AND GUTTER | | |
|---|---|---|
| SCALE: NONE | | DATE: 04/06/17 |
| DWN. DIT<br>CHK. HM | | P2–05 |




PLAN

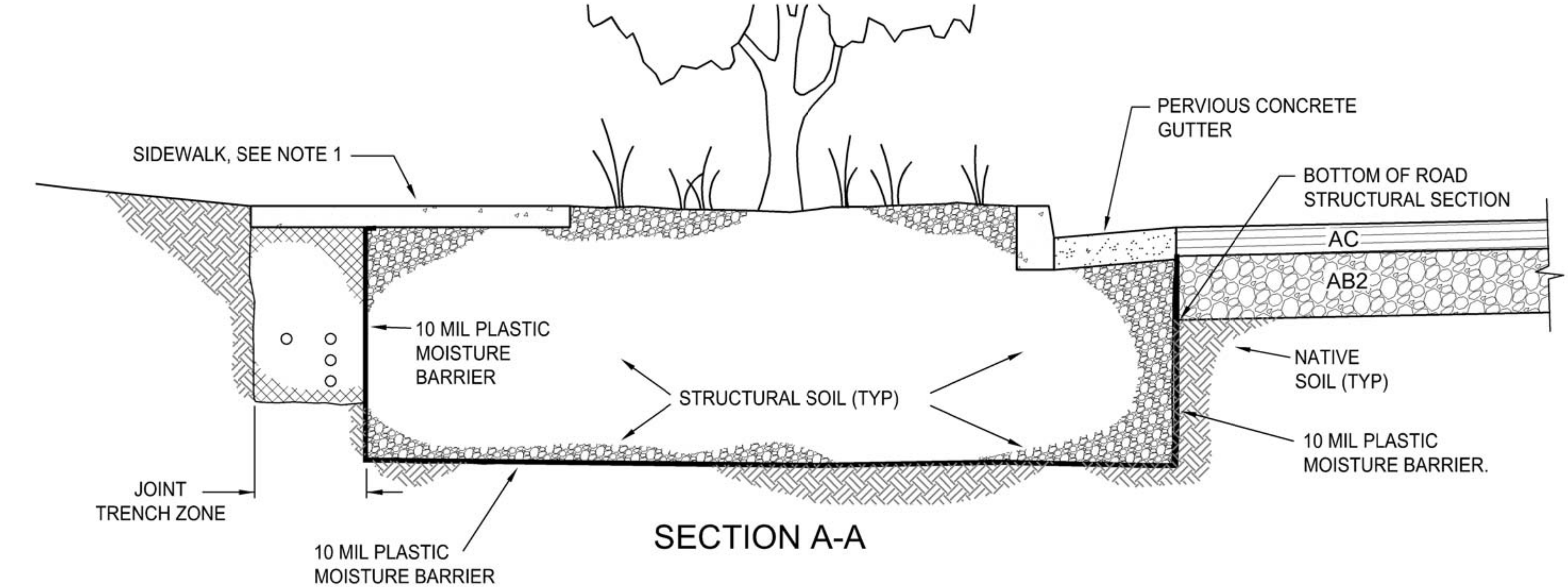
SIMILAR TO P2-02 WITH A MOISTURE BARRIER LINER, NO INFILTRATION.

NOTES:

1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).

Not to Scale

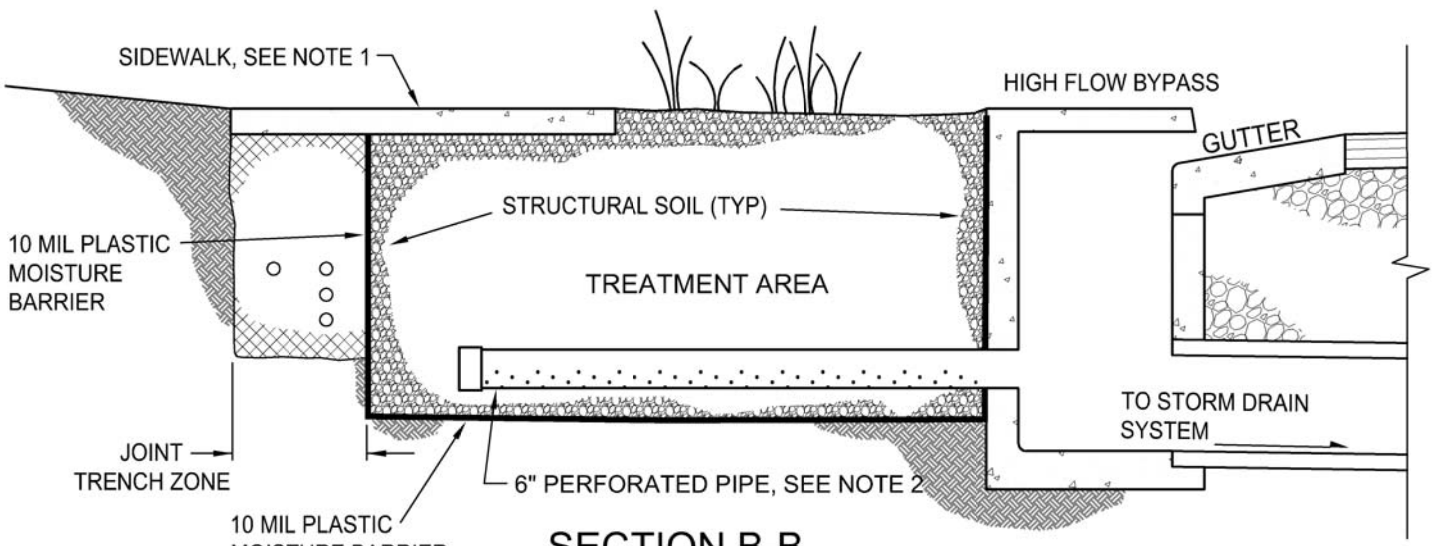
| PRIORITY 3 ROADSIDE BIORETENTION - FLUSH DESIGN | | |
|---|---|---|
| SCALE: NONE | | DATE: 04/06/17 |
| DWN. DIT CHK. HM | SHEET 1 of 2 | P3–02 |




SECTION A-A

NOTES:

1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. 6" PERFORATED PIPE TO BE SET IN BOTTOM OF TREATMENT AREA.

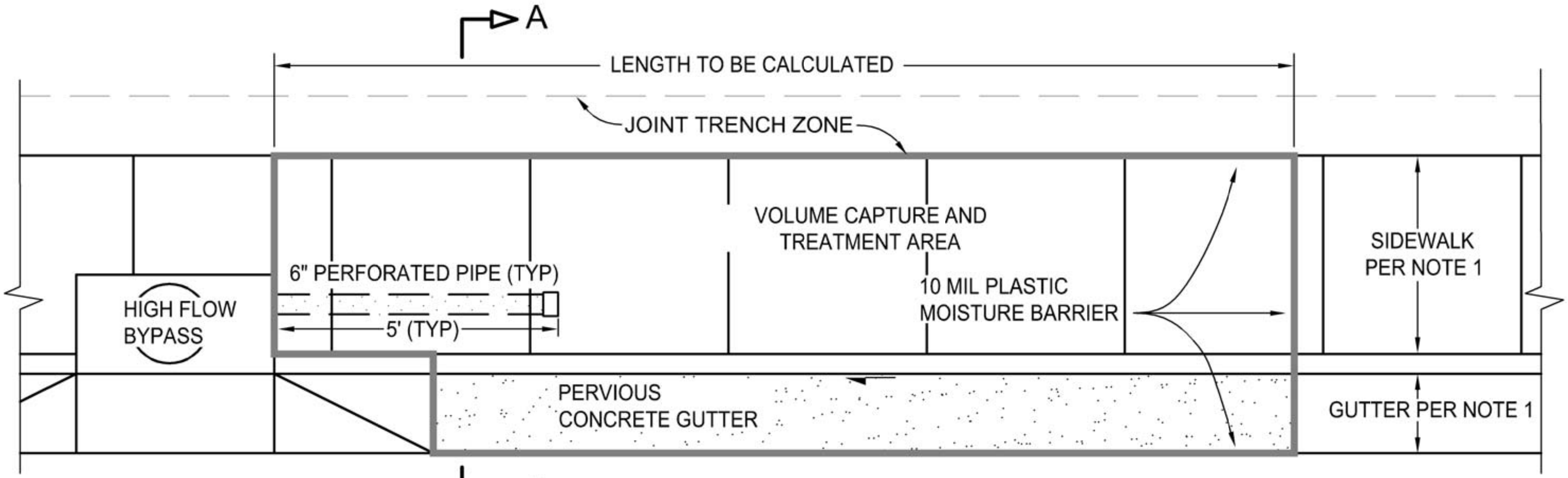



SECTION B-B

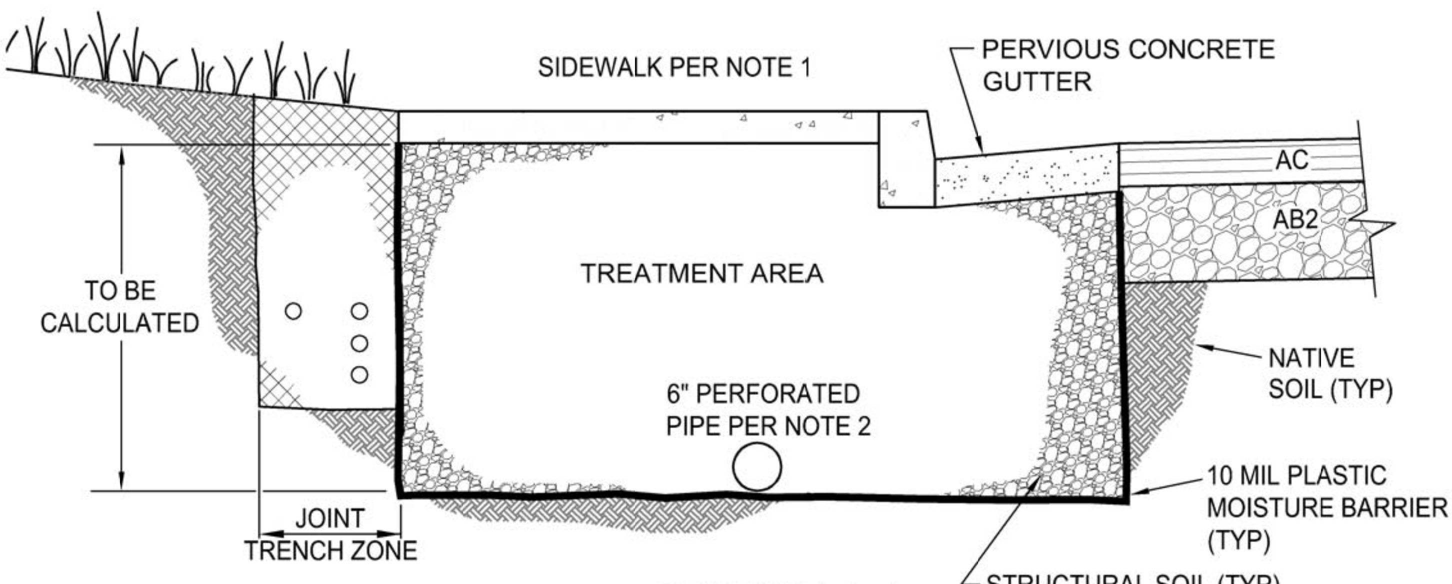
SIMILAR TO P2-02 WITH A MOISTURE BARRIER LINER, NO INFILTRATION.

Not to Scale

| PRIORITY 3 ROADSIDE BIORETENTION FLUSH DESIGN | | |
|---|---|---|
| SCALE: NONE | DATE: 04/06/17 | |
| DWN. DIT CHK. HM | SHEET 2 of 2 | P3–02 |




PLAN




SECTION A-A

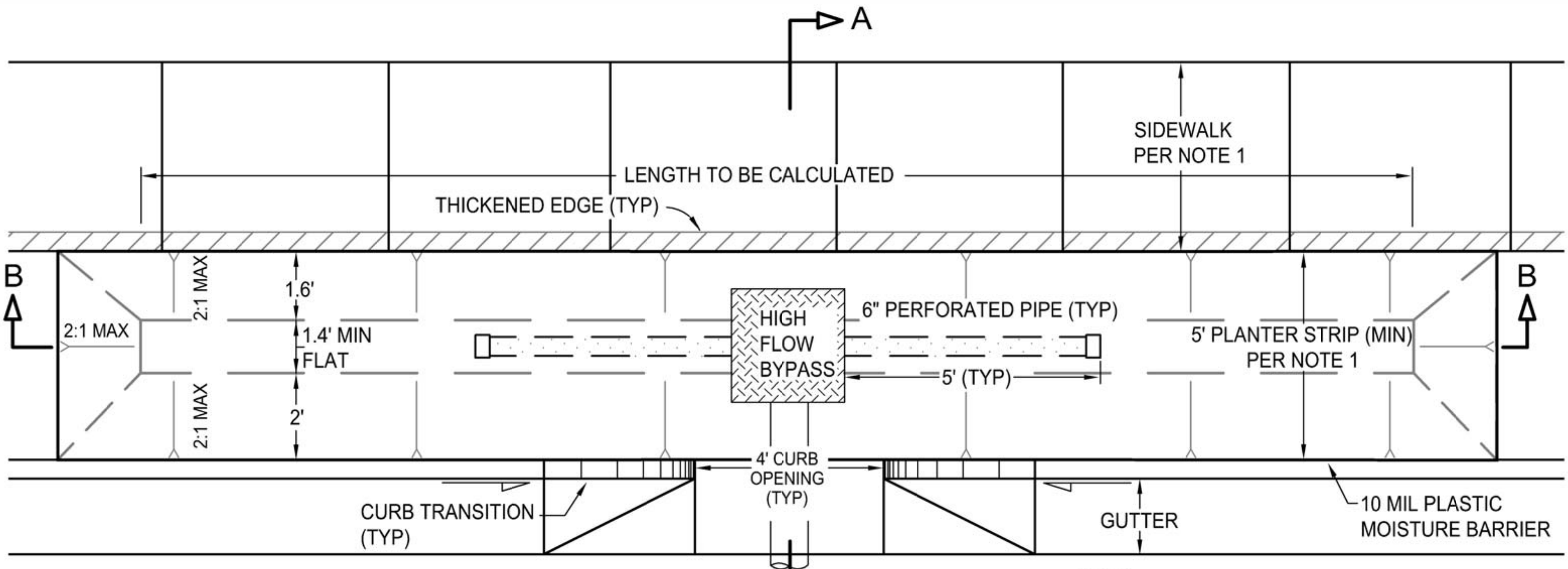
Not to Scale

NOTE:

1. SIDEWALK AND CURB AND GUTTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. 6" PERFORATED PIPE TO BE SET IN BOTTOM OF TREATMENT AREA.

SIMILAR TO P2-03 WITH A MOISTURE BARRIER LINER, NO INFILTRATION.

| | | |
|---|---|---|
| PRIORITY 3<br>ROADSIDE BIORETENTION<br>- CONTIGUOUS SIDEWALK | | |
| SCALE: *NONE* | DATE: *04/06/17* | |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 1 | P3–03 |

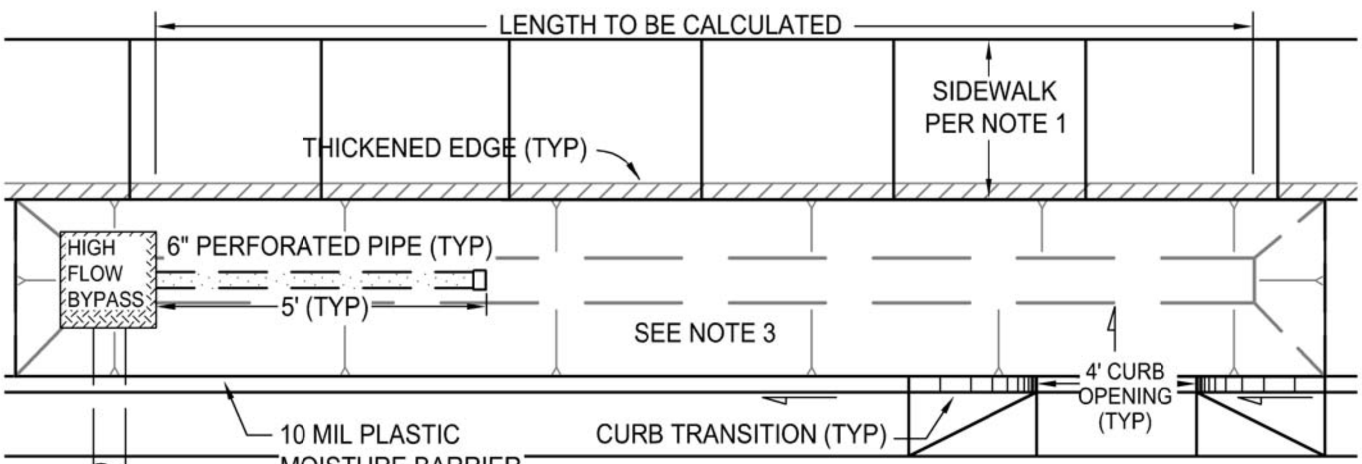



PLAN

TYPE A - CURB OPENING AT LOW POINT

NOTE:

1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. 6" PERFORATED PIPE TO BE SET IN BOTTOM OF TREATMENT AREA.
3. TYPE A MINIMUM DIMENSIONS AND GRADES APPLY TO TYPE B.

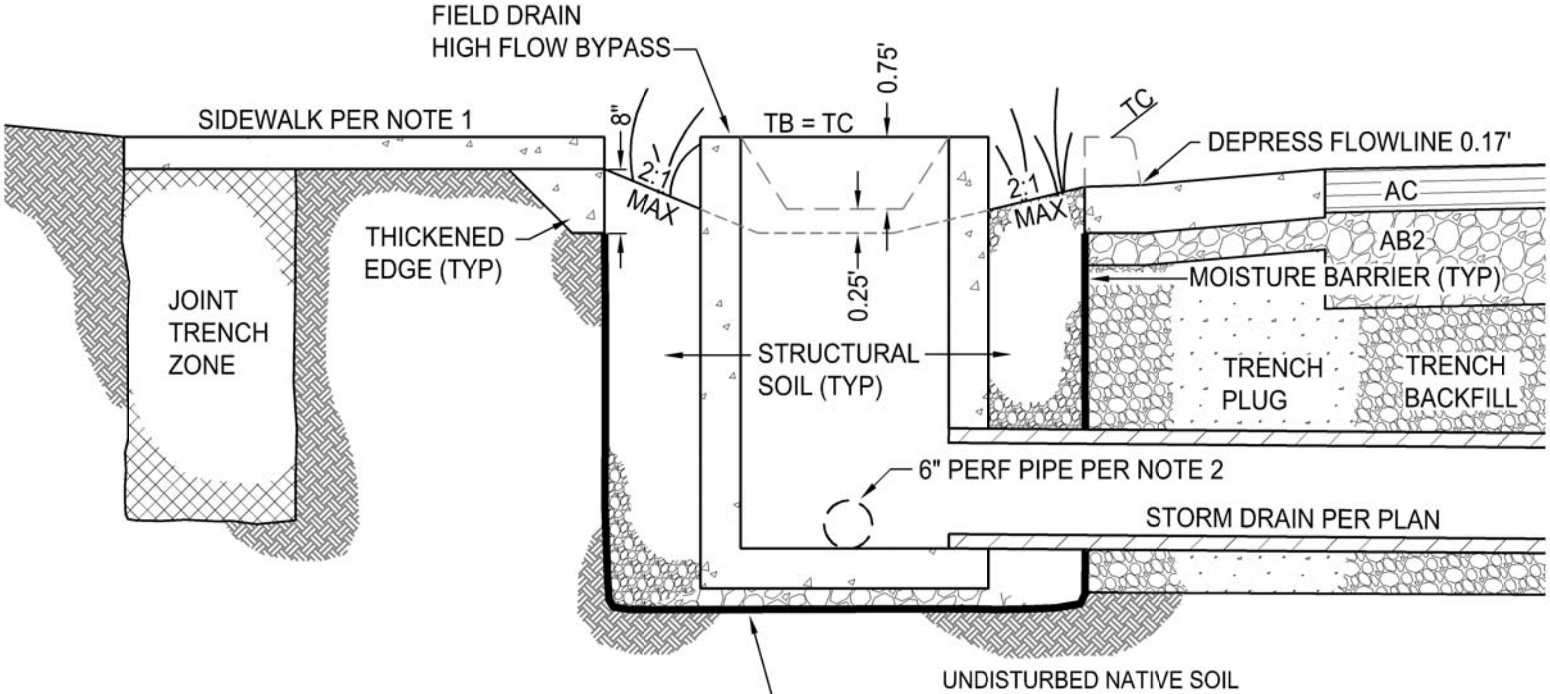



TYPE B -CURB OPENING ALONG A SLOPE

SIMILAR TO P2-04 WITH A MOISTURE BARRIER LINER, NO INFILTRATION.

Not to Scale

| PRIORITY 3<br>ROADSIDE BIORETENTION<br>- CURB OPENING | | |
|---|---|---|
| SCALE: *NONE* | | DATE: *04/06/17* |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 2 | P3–04 |

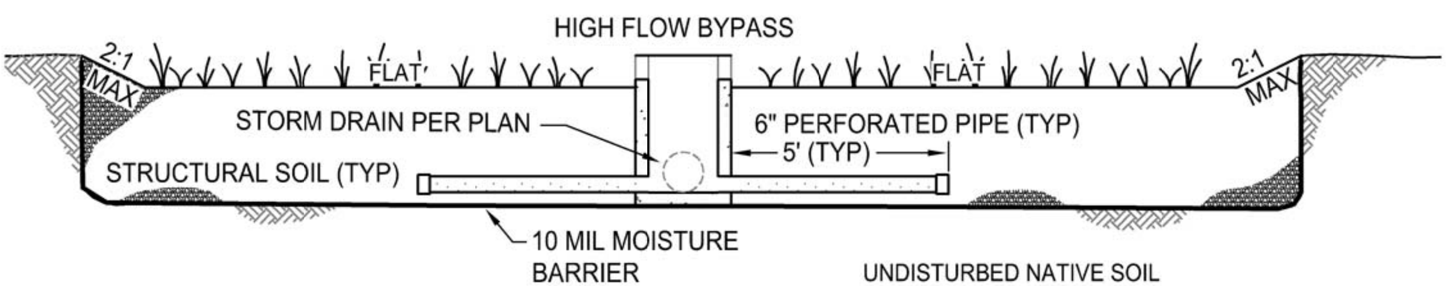



SECTION A-A

NOTES:

1. SIDEWALK, GUTTER AND PLANTER WIDTHS PER APPLICABLE GOVERNING AGENCY STANDARDS (TYP).
2. 6" PERFORATED PIPE TO BE SET IN BOTTOM OF TREATMENT AREA.

SIMILAR TO P2-04 WITH A MOISTURE BARRIER LINER, NO INFILTRATION.

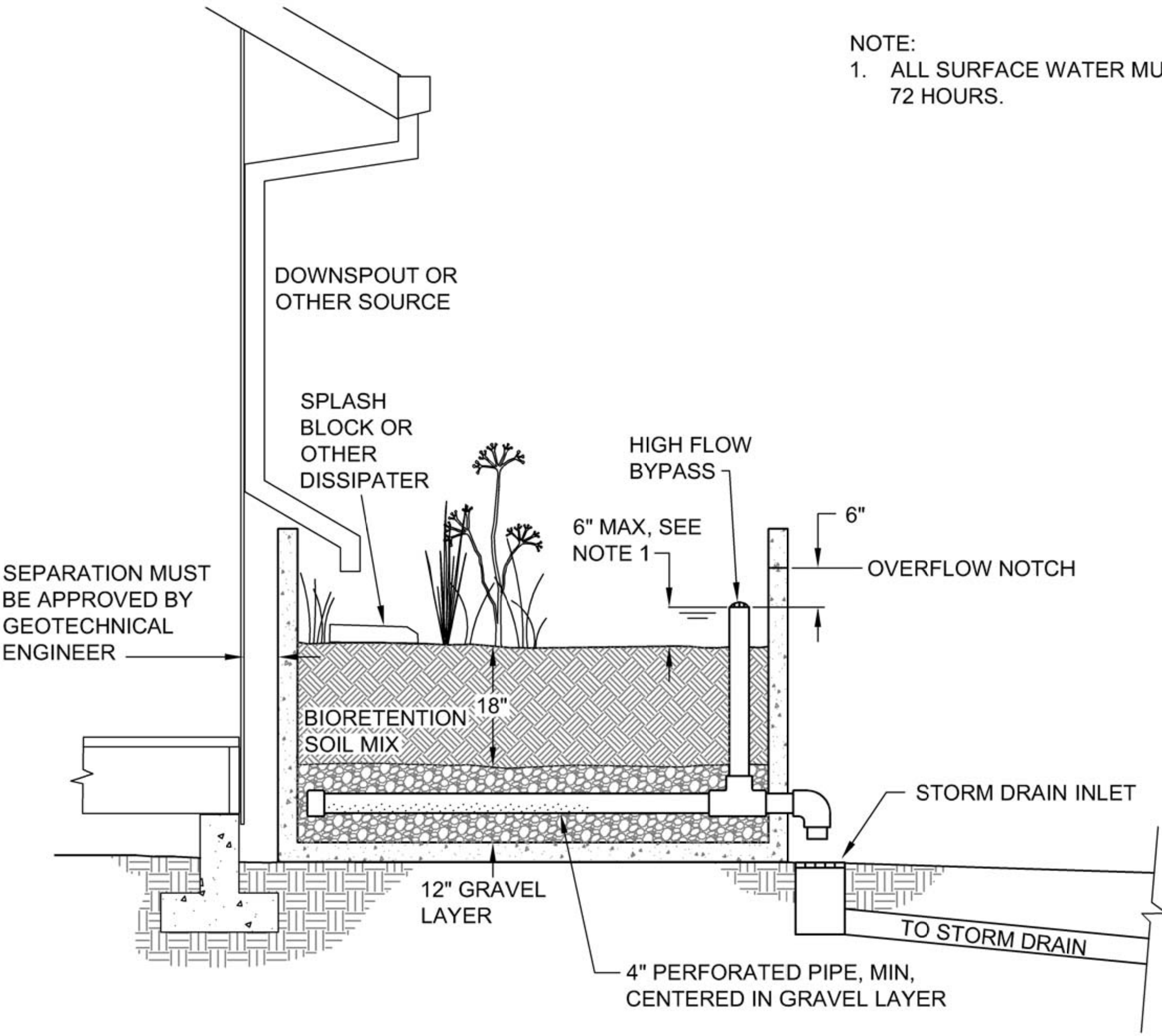



SECTION B-B

Not to Scale

| PRIORITY 3 ROADSIDE BIORETENTION - CURB OPENING SECTION A-A & B-B | | |
|---|---|---|
| SCALE: NONE | | DATE: 04/06/17 |
| DWN. DIT<br>CHK. HM | SHEET 2 of 2 | P3–04 |

NOTE:
1. ALL SURFACE WATER MUST DRAIN WITHIN 72 HOURS.




Not to Scale

| PRIORITY 3<br>FLOW THROUGH PLANTER | | |
|---|---|---|
| SCALE: *NONE* | | DATE: *04/06/17* |
| DWN. *DIT*<br>CHK. *HM* | SHEET 1 of 1 | P3–05 |