GUIDELINES FOR GEOTECHNICAL INVESTIGATION AND REPORTING LOW IMPACT DEVELOPMENT STORMWATER INFILTRATION

Urbanization impacts the water resources of Los Angeles County by decreasing the amount of stormwater that infiltrates into the subsurface and increasing the potential for conveyance of pollutants into watersheds and the flood control system. Low Impact Development (LID) stormwater infiltration is a strategy that is used to mitigate some of these hydrological impacts. The goal of LID stormwater infiltration is to reduce runoff from the site using stormwater quality control measures that retain runoff. The objective of these guidelines is to facilitate stormwater infiltration in areas of Los Angeles County where ground conditions are suitable.

Compliance with the Los Angeles County LID Ordinance (Title 12, Section 12.84) is required before the issuance of a building or grading permit. Public Works prepared an updated *LID Standards Manual* in February 2014 to compile previous documents, update standards, and assist applicants with the development process. The *LID Standards Manual* is available online at the following link: https://goo.gl/OaOQ0l.

The geotechnical guidelines presented herein were incorporated into the *LID Standards Manual* in "Section 4: Site Assessment and Design Considerations" and on the Fact Sheets in Appendix E. They provide technical guidance and specific requirements for geotechnical investigations to evaluate ground conditions for proposed stormwater infiltration sites. All proposed stormwater quality control measure Best Management Practices (BMPs) with an infiltration component require a geotechnical report. These LID stormwater quality control measures include, but are not limited to:

- Bioretention
- Infiltration Galleries
- Permeable Pavement
- Infiltration Basin
- Dry Well
- Bioswales

Geotechnical reports prepared for stormwater infiltration BMPs must address the site requirements discussed in these guidelines. Data and analyses must be provided to substantiate the recommended infiltration rates and groundwater elevations. Geotechnical issues that must be addressed include pollutant and sewage mobilization, slope stability, static and seismic settlement, surcharge on adjacent structures, expansive soil and rock, potential impacts to offsite property, and any other geotechnical hazards. Geotechnical reports will be reviewed by Geotechnical and Materials Engineering Division. Design infiltration rates and recommended areas of infiltration in compliance with these guidelines may be recommended for approval, with or without conditions.

SITE REQUIREMENTS FOR STORMWATER INFILTRATION

1. Subsurface materials shall have a design infiltration rate equal to or greater than 0.3 inch per hour. Procedures for performing in-situ infiltration tests and application of reduction factors are described later in these guidelines.

2. The invert of stormwater infiltration shall be at least 10 feet above the design groundwater elevation. Procedures for determining the design groundwater elevation are described later in these guidelines.

3. Stormwater infiltration shall not be allowed in areas that pose a risk of causing pollutant mobilization, as sites identified on environmental regulatory databases or similar files maintained by local agencies, or on properties with other documented environmental concerns.

4. Stormwater infiltration shall not be allowed in areas that pose a risk of causing sewage effluent mobilization from septic pits, seepage lines, or other sewage disposal systems.

5. Stormwater infiltration shall not be placed on or near slopes that may create the condition or potential for slope instability.

6. Stormwater infiltration shall not be permitted in engineered fill or undocumented fill.

7. Stormwater infiltration shall not increase the potential for static settlement of structures on or adjacent to the site. Laboratory testing should be performed to evaluate the anticipated settlement and hydrocollapse potential of soils 10 feet below the proposed invert of infiltration.

8. Stormwater infiltration shall not increase the potential for static and seismic settlement of structures on or adjacent to the site. Liquefaction potential shall be evaluated considering the design volume of stormwater infiltration.

9. Stormwater infiltration shall not place an increased surcharge on structures or foundations on or adjacent to the site. The pore-water pressure shall not be increased on soil retaining structures on or adjacent to the site.

10. The invert of stormwater infiltration shall be set back at least 15 feet or outside a 1:1 plane drawn up from the bottom of adjacent foundations for granular soils. The geotechnical consultant shall discuss the potential impacts of lateral migration of water based on site-specific conditions.

11. Stormwater infiltration shall be setback at least 10 feet from property lines.

12. Stormwater infiltration shall not be located near utility lines where the introduction of stormwater could cause damage to utilities or settlement of trench backfill.

13. Stormwater infiltration is not allowed within 100 feet of any groundwater production wells used for drinking water.

GEOTECHNICAL INVESTIGATION

A site-specific geotechnical investigation performed for proposed stormwater infiltration quality control measures shall include subsurface exploration, laboratory testing, soil type classification, groundwater investigation, and in-situ infiltration testing. The investigation must be conducted by or under direct supervision of a State of California certified professional geologist, geotechnical engineer, or civil engineer experienced in geotechnical engineering.

Subsurface Exploration

Subsurface exploration shall be performed to characterize the subsurface soil or bedrock, determine groundwater conditions, and evaluate infiltration feasibility. Explorations shall be performed at each proposed LID feature location. A minimum of at least one boring shall be conducted to characterize subsurface conditions prior to infiltration testing.

Continuous methods of exploration (such as cone penetration testing or continuous sampling) are favorable for profiling the soil strata but may not be suited for identifying groundwater levels. Auger exploration is suitable to collect in-situ samples, determine soil classification, and assess existing groundwater conditions.

If groundwater is determined to be at depths shallower than 50 feet, exploration shall extend to a depth no less than 25 feet below the bottom of the proposed LID feature invert depth. If continuous methods of exploration are not feasible, enough exploration shall be performed to sufficiently characterize the soil or bedrock. If refusal is encountered, secondary exploration data from other sources may be used to characterize subsurface conditions and will be evaluated for validity on a case by case basis.

Laboratory Testing

Tests shall be performed on samples collected throughout the proposed infiltration zone and below the proposed invert of stormwater infiltration. Sieve analysis, hydrometer, plasticity index, density, and moisture content tests provide indicators of infiltration potential. A discussion shall be provided on how these parameters will affect the proposed stormwater quality control measure BMP.

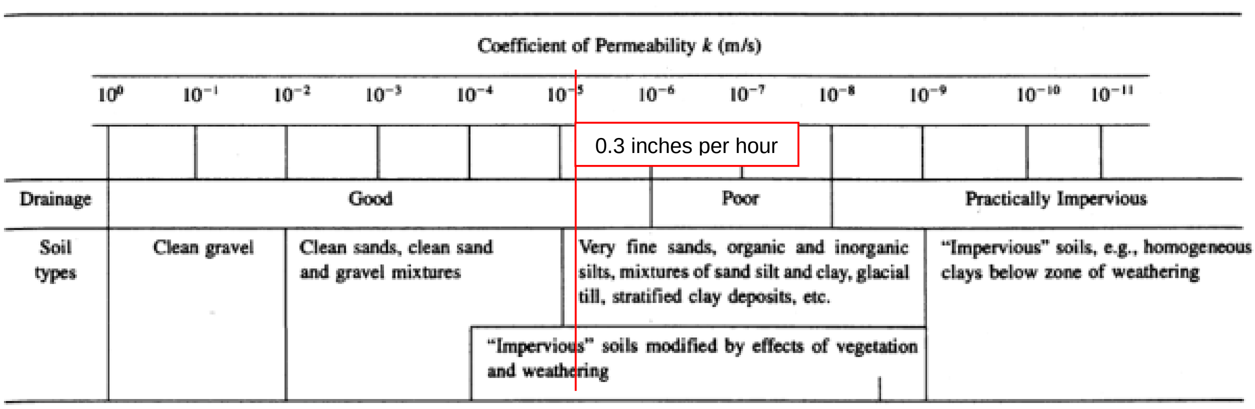
Laboratory testing should be performed to evaluate the potential for settlement and ground subsidence to occur resulting from the operation of the proposed stormwater infiltration device. At a minimum, 10 feet of soil below the proposed invert of infiltration should be tested for consolidation and hydrocollapse. Mitigation measures shall be provided if the potential for hydrocollapse is apparent.

<u>Soil Type Classification</u>

Soil type is one of the best indicators to determine if a proposed site is suitable for infiltration. Classification of soils at and below the proposed invert of infiltration shall be made in accordance with Unified Soil Classification System (USCS). The USCS is defined by the American Society for Testing and Materials (ASTM) International Standard D2487.

<u>Coefficient of Permeability</u>

The coefficient of permeability is a soil index property understood to be closely related to the infiltration potential of soils. The figure included herein presents typical coefficients of permeability for different soil types. It is provided as a general reference. The coefficient of permeability is not an infiltration rate.



Permeability and Drainage Characteristics of Soils from Terzaghi and Peck (1996)

<u>Groundwater Investigation</u>

Geotechnical reports shall address and discuss regional, site-specific, historic high and seasonal high, and current groundwater elevations, and any potential impacts it may have on the design and performance of proposed stormwater infiltration BMPs. Available resources for groundwater evaluation may include, but is not limited to, the following:

- California State Water Resources Control Board:
  https://geotracker.waterboards.ca.gov/
- California Department of Water Resources:
  https://water.ca.gov/
- California DWR – Sustainable Groundwater Management Program
  https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
- Los Angeles County Public Works:
  https://dpw.lacounty.gov/general/wells/
- Water Replenishment District of Southern California:
  https://www.wrd.org/content/regional-groundwater-monitoring-reports

The geotechnical report must specify, reference, and present all data that was considered in their evaluation of groundwater conditions.

Site-specific exploration must extend to depths deep enough to evaluate and determine an adequate design groundwater elevation. If existing site-specific groundwater data is not available, borings shall extend a minimum of 50 feet below ground surface or 25 feet below the proposed LID invert depth, whichever is deepest. The design groundwater elevation must be at least 10 feet above the highest groundwater elevation determined in the groundwater evaluation and shall be evaluated on a case-by-case basis dependent on site-specific conditions.

INFILTRATION TESTING REQUIREMENTS

Infiltration Test Locations

Infiltration tests shall be performed at the location of proposed LID features. The depth of the test shall be at or slightly below the proposed invert depth. The type of test shall be determined by the geotechnical consultant and must closely resemble the performance of the proposed LID features. For example, results from a shallow pit test should not be used to design deep drywells; results from tests performed in a boring at depth should not be used to design LID features that infiltrate water near the ground surface.

However, this may be difficult to achieve for sites with limited access due to terrain (e.g. large tracts in hilly areas) where locations of the proposed LID features may not be reachable prior to site grading. For each LID feature, the engineer should identify the type(s) of subsurface material that the water will infiltrate into based on the site exploration data, then determine accessible locations where similar subsurface material(s) is present so that infiltration testing can be performed there. Materials are considered similar if the composition, lithology, and density are reasonably close. This determination must be supported by sufficient subsurface data and laboratory testing.

If the infiltration tests are not performed at or near the proposed LID features, the engineer should sample and test the material to demonstrate that infiltration is feasible and design the LID features based on the minimum design infiltration rate of 0.3 inch per hour for the preliminary design. Additional testing will be required during the site grading stage to verify the design infiltration rate for each proposed LID feature.

Infiltration Test Methods

At least one infiltration test shall be performed at each LID location. The geotechnical consultant shall select the type of testing that best resembles the way the proposed LID feature will function once constructed. For example, if deep drywells are proposed, then performing a double-ring infiltrometer or shallow pit test at the surface will not be representative of the drywell performance. The following table provides examples of the appropriate type of testing for various types of LID features.

Infiltration Test Methods by LID Features		
Type of LID Feature	**LID Feature Depth**	**Type of Infiltration Testing**
Retention Basin Bioswale	Shallow	Double-Ring Shallow Test Pit Small Diameter Boring
Underground Gallery	Shallow and Deep	Shallow Test Pit Small Diameter Boring Large Diameter Boring
Drywell	Deep	Large Diameter Boring

Double-Ring Infiltrometer Test (ASTM D3385)

A double-ring infiltrometer consists of two concentric metal rings. The rings are driven into the ground to preclude leakage and then filled with water. Water in the outer ring keeps the flow in the inner ring vertical, and the drop in water level in the inner ring is used to establish the vertical infiltration rate. This test is useful for evaluating LID features that are proposed close to the ground surface or can be performed at depth in a trench excavation. This test is generally only appropriate for small scale projects with low design volumes. Procedures and sample data forms for double-ring infiltrometer testing are provided in ASTM D3385. The field log template with an example are attached on Plates 1-A, 1-B, and 1-C.

Shallow Pit Test

A shallow pit test consists of an infiltration test performed in a rectangular- or square-shaped excavation that is dug with hand tools or heavy equipment. It is generally appropriate to perform this test for LID features such as gravel pits, bioswales, retention basins, and underground galleries. The engineer shall size the infiltration test pit and duration of testing to simulate the performance of the proposed LID features. See Plate 2-A for examples of test pit setups. See Plate 3-A for the Test Pit Infiltration Field Log.

1. Excavate the test pit to the proposed invert depth with equal widths and lengths. The excavated test pit must also have a flush bottom.

2. Presoak the hole by filling it with water prior to infiltration testing. If the water seeps completely away within 30 minutes after filling the excavation, two consecutive times, and the subsurface exploration has yielded permeable soils beneath the proposed invert of infiltration, presoaking can be considered complete and the testing can proceed. If the water does not completely drain within 30 minutes, presoak the excavation maintaining 12 inches of water for at least 4 hours before conducting the infiltration testing. Record all water levels to the nearest ⅛-inch increment.

3. Determine whether a constant head or falling head test is more appropriate; if a falling head test is more appropriate, determine the time interval for recording the water drop between readings. Fill the excavation at least 12 inches above the bottom. The height of the water may be higher than 12 inches and may be determined by the engineer to simulate the expected performance of the LID feature. Observe the drop in the water during the next 30 minutes and compare with the condition that applies below. This will determine the type of test and time interval for this test location.

   a. If water drains very quickly (less than 10 minutes), a constant head test may be more appropriate. See Step 8.

   b. If water remains in the hole after 30 minutes, a falling head test may be more appropriate and the time interval between readings shall be 30 minutes.

   c. If water remains in the hole after 30 minutes but takes more than 10 minutes to drain, the engineer shall determine whether a constant head or falling head test should be performed. For a falling head test, the time interval shall be the time it takes for the water to completely drain from the test pit. For a constant head test, see Step 8.

4. Once the time interval for the test has been determined, add water to the height determined from the previous steps. For each successive test reading, the starting water level must be at this initial water height.

5. Take readings of the water drop from the initial water height. Record the time and the drop in water level during the time interval determined in Step 3. Fill the excavation back to the initial water depth and record the filling time.

6. Perform the infiltration test for at least 3 hours. The test can be concluded when a stabilized rate of drop is obtained, which is when the highest and lowest readings are within 10 percent of each other for three consecutive readings. If insufficient data is collected to demonstrate that the test was performed for at least 3 hours and that a stabilized rate of drop was achieved, the test will not be considered acceptable for design.

7. Calculate the average of the last three consecutive readings to determine the field infiltration rate, expressed in inches per hour. The field infiltration rate must account for non-vertical flow through the sides of the excavation in addition to the bottom of the excavation.

8. Performing a constant head test requires an adequate water supply to maintain a constant water level throughout the entire duration of the test (3 hours). A flow meter is required to record the volumetric flow rate of water entering the test pit. The flow rate and cumulative volume shall be recorded at sufficient time intervals and shall not be less than four reads per hour. The infiltration rate can be determined by dividing the average stabilized volumetric rate by the total surface area of infiltration within the test pit.

<u>Small Diameter Boring Infiltration Test</u>

This procedure allows an infiltration test to be performed within a small-diameter boring that can be excavated using conventional drilling methods. The depth of testing can be isolated with slotted sections of polyvinyl chloride (PVC) pipe, surrounded by a bentonite cap, and placed at any depth in the borehole. Its primary advantage is the ability to test soil layers at greater depths; however, the surface area of soil tested is smaller in comparison to other types of tests that are performed in larger diameter borings. A sufficient and reliable source of water (e.g. fire hydrant or water truck) is required to perform this test properly. A schematic showing various test setups is attached on Plates 2-B and 2-C. The field log template is attached on Plate 3-B.

1. Drill a boring to at least 12 inches below the elevation of proposed invert of infiltration. Rotate the auger until all cuttings are removed. Care shall be taken to ensure smearing of clayey soils does not occur along the sidewalls of the borehole

as this will dramatically reduce the infiltration potential. Record the boring diameter and depth to be tested. Subsurface conditions should be logged and documented by a licensed professional engineer or geologist to the same standard as an exploratory boring.

2. Install through the auger, a 2- to 4-inch-diameter perforated PVC casing with a solid end cap. Perforations shall be 0.02-inch slot or larger. Pour filter pack down inside of auger while withdrawing the auger such that the PVC casing is surrounded by the filter pack. The filter pack and perforated casing must have a larger hydraulic conductivity than the soil or rock that is to be tested.

3. For borings drilled below the proposed invert of infiltration that are being converted to perform infiltration tests, careful attention must be paid to isolate the depth of the test section with an impermeable cap above and below it. The annulus between the slotted PVC and native materials in the test section must be backfilled with well-draining sand. The boring below the desired test section and the annulus between the solid PVC and native materials above the desired test section must be backfilled with bentonite or similar low-permeability material. The boring itself shall not create a path of less resistance for the water than the in-situ materials being tested. Ideally, the zone of infiltration should be predetermined such that the final depth of the boring corresponds with the invert depth to be tested.

4. Presoak the boring immediately prior to testing for at least 1 hour to ensure the sand around the annulus of the perforated pipe is fully saturated.

5. Determine whether a constant head or falling head test is more appropriate; if a falling head test is more appropriate, determine the time interval for recording the water drop between readings. Fill the excavation at least 12 inches above the bottom. The height of the water may be higher than 12 inches and may be determined by the engineer to simulate the expected performance of the LID feature. Observe the drop in the water during the next 30 minutes and compare with the condition that applies below. This will determine the type of test and time interval for this test location.

   a. If water drains very quickly (less than 10 minutes), a constant head test may be more appropriate. See Step 11.

   b. If water remains in the hole after 30 minutes, a falling head test may be more appropriate and the time interval between readings shall be 30 minutes.

c. If water remains in the hole after 30 minutes but takes more than 10 minutes to drain, the engineer shall determine whether a constant head or falling head test should be performed. For a falling head test, the time interval shall be the time it takes for the water to completely drain from the test pit. For a constant head test, see Step 11.

6. Once the time interval for the test has been determined, add water to the casing for the depth of soil to be tested. The water depth must be less than or equal to the water level used to presoak the hole and a minimum depth of 12 inches above the bentonite plug. For a falling head test, the starting water level must be refilled to this initial water depth after each successive test reading.

7. Take readings of the volume and water drop from the initial water depth. Record the time, volume, and drop in water level during the time interval determined in Step 5. Fill the boring back to the initial water depth and record the time of filling for each successive infiltration test reading. A sounder or piezometer may be used to determine the water level for test sections at depth. Measurements of all water levels must be taken to the nearest ⅛-inch increment.

8. Perform the infiltration test for at least 3 hours. The test can be concluded when a stabilized rate of drop is obtained, which is when the highest and lowest readings are within ten percent of each other for three consecutive readings. If insufficient data is collected to demonstrate that the test was performed for at least 3 hours and that a stabilized rate of drop was achieved, the test will not be considered acceptable for design

9. Calculate the average of the last three consecutive readings to determine the field infiltration rate, expressed in inches per hour. The field infiltration rate must account for non-vertical flow through the sides of the boring in addition to the bottom of the boring.

10. After the test is complete, turn the water off and record the drop on the measuring rod in inches per minute until the pit is empty. Consider running this falling head phase of the test several times to estimate the dependency of infiltration rate with water head and whether different soil strata at depth may have different infiltration characteristics

11. Performing a constant head test requires an adequate water supply to maintain a constant water level throughout the entire duration of the test (3 hours minimum). A flow meter is required to record the volumetric flow rate of water entering the test boring. The flow rate and cumulative volume shall be recorded at sufficient time intervals and shall not be less than four reads per hour. A water sounder is required to ensure a constant head is achieved throughout the test duration.

The infiltration rate can be determined by dividing the average stabilized volumetric rate by the total surface area of infiltration within the boring.

<u>Large Diameter Boring Infiltration Test</u>

This procedure allows an infiltration test to be performed within a large-diameter boring that will require augers with diameters ranging from 18 to 36 inches. The test can be modified to simulate the performance of an underground gallery (Plate 2-D) or a drywell (Plate 2-E). Its primary advantage is the ability to test a much larger surface area than any of the aforementioned tests. This reduces the scaling errors associated with extrapolating infiltration rates taken from smaller scale tests and applying it to larger LID features. In general, infiltration rates obtained from large diameter borings tend to be higher than infiltration rates obtained from smaller scale versions of the same test; this can potentially translate to a more optimized design and reduced construction costs depending on the size of the project and volume of water to be captured. A sufficient and reliable source of water (e.g., fire hydrant or water truck) is required to perform this test properly.

1. Drill a boring to the proposed invert of infiltration. Care shall be taken during auger retrieval to ensure smearing of clayey soils does not occur along the sidewalls of the boring as this will dramatically reduce the infiltration potential. Record the boring diameter and depth to be tested. Subsurface conditions should be logged and documented by a licensed professional engineer or geologist to the same standard as an exploratory boring.

2. Install two 2- to 4-inch-diameter perforated PVC casing with a solid end cap. Perforations shall be 0.02-inch slot or larger. One PVC should be completely perforated and used for measuring water levels. The second PVC should be slotted along the lengths corresponding to the zone of infiltration to be tested; the remaining sections should be solid; water should be introduced through the second PVC during testing. Pour filter pack until the PVC casings is surrounded by the filter pack. The filter pack and perforated casing must have a larger hydraulic conductivity than the soil or rock that is to be tested.

3. Presoak the boring immediately prior to testing for at least 1 hour to ensure the zone of infiltration is fully saturated. The height of water should be held constant during the presoak and should correspond to the anticipated performance of the proposed LID feature. For underground galleries that rely primarily on vertical infiltration, the water height should be at least 12 inches from the bottom. For drywells and other features that rely on infiltration along the sides, the water height should be increased accordingly.

4. Determine whether a constant head or falling head test is more appropriate; if a falling head test is more appropriate, determine the time interval for recording the water drop between readings. Introduce water into the boring to a height determined by the engineer to simulate the expected performance of the LID feature. Observe the drop in the water during the next 30 minutes and compare with the condition that applies below. This will determine the type of test and time interval for this test location.

    a. If water drains very quickly (less than 10 minutes), a constant head test may be more appropriate. See Step 10.

    b. If water remains in the hole after 30 minutes, a falling head test may be more appropriate and the time interval between readings shall be 30 minutes.

    c. If water remains in the hole after 30 minutes, but takes more than 10 minutes to drain, the engineer shall determine whether a constant head or falling head test should be performed. For a falling head test, the time interval shall be the time it takes for the water to completely drain from the test pit. For a constant head test, see Step 10.

5. Once the time interval for the test has been determined, introduce water through the PVC casing until the predetermined height is reached. This height should correspond approximately to the height of water maintained during the presoak period. For a falling head test, the starting water level must be refilled to this initial water depth after each successive test reading.

6. Take readings of the volume and water drop from the initial water height. Record the time, volume, and drop in water level during the time interval determined in Step 4. Fill the boring back to the initial water height and record the filling time for each successive reading. A sounder or piezometer may be used to determine the water level for test sections at depth. Measurements of all water levels must be taken to the nearest ⅛-inch increment.

7. Perform the infiltration test for at least 3 hours. The test can be concluded when a stabilized rate of drop is obtained, which is when the highest and lowest readings are within 10 percent of each other for three consecutive readings. If insufficient data is collected to demonstrate that the test was performed for at least 3 hours and that a stabilized rate of drop was achieved, the test will not be considered acceptable for design.

8. Calculate the average of the last three consecutive readings to determine the field infiltration rate, expressed in inches per hour. The field infiltration rate must account for non-vertical flow through the sides of the boring in addition to the bottom of the boring.

9. After the test is complete turn the water off and record the drop on the measuring rod in inches per minute until the pit is empty. Consider running this falling head phase of the test several times to estimate the dependency of infiltration rate with water head and whether different soil strata at depth may have different infiltration characteristics.

10. Performing a constant head test requires an adequate water supply to maintain a constant water level throughout the entire duration of the test (3 hours minimum). A flow meter is required to record the volumetric flow rate of water entering the test boring. The flow rate and cumulative volume shall be recorded at sufficient time intervals and shall not be less than four reads per hour. A water sounder is required to ensure a constant head is achieved throughout the test duration. The infiltration rate can be determined by dividing the average stabilized volumetric rate by the total surface area of infiltration within the boring.

Infiltration Rate Based on Grain-size Analysis

The engineer may choose to use the grain-size distribution of soils to determine the design infiltration rate. The method may only be used for sand mixtures where the grain diameter corresponding to ten percent passing by weight, D_{10}, is between 0.1 and 1.0 millimeter. This method should not be applied to areas containing fill or be used in areas where bedrock is present within 10 feet of the invert of the proposed LID system. Additionally, this method of determining the design infiltration rate shall only be used for a development on a single lot that is not larger than 50,000 square feet. In-situ infiltration testing will be required for all other types of development, including subdivisions. When using this method, the maximum design infiltration rate shall not exceed 10 inches per hour.

Engineers may use the Hazen equation to determine the hydraulic conductivity of soils.

$$K = C \times (D_{10})^2$$
$$where\ K = hydraulic\ conductivity\ (in\ cm/s);$$
$$C = 1, Hazen's\ empirical\ coeffecient.$$
$$D_{10} = grain\ diameter\ (in\ mm) corresponding\ to\ 10\%\ passing\ by\ weight.$$

The computed hydraulic conductivity may then be assumed to be the infiltration rate of the soils. This assumption may be overly conservative for drywells; in-situ testing may be more appropriate for determining an infiltration rate. A reduction factor of 2 to 3 should be applied to RF_t for this method to determine the design infiltration rate. Layers at greater depth than the proposed LID invert depth should be assessed by the engineer to determine whether those will influence the infiltration rate. This may require additional grain-size distribution analysis.

REDUCTION FACTORS

Reduction factors should be applied to measured infiltration rates to provide guidance on design values that will represent long-term performance of the proposed infiltration BMPs. It is the responsibility of the geotechnical engineer to recommend appropriate site-specific reduction factors that account for the test methods, site variability, and long-term siltation.

- Test-specific reduction factors must be applied to account for the direction of flow during the test and reliability of different test methods.

- Reduction factors for site variability, number of tests performed, and thoroughness of the subsurface investigation shall be selected by comparing the size and scope of subsurface exploration to similar projects.
- The reduction factor for siltation, plugging, and maintenance shall be selected based on the specified levels of pre-treatment and maintenance requirements.

The following table provides guidance for the range of values that may be used for each factor. All reduction factors will be subject to review and approval by the County.

Reduction Factors	
Double-ring Infiltrometer	RF_t = 1 to 3
Shallow Test Pit	RF_t = 1 to 3
Small Diameter Boring	RF_t = 1 to 3
Large Diameter Boring	RF_t = 1 to 3
High Flow-rate	RF_t = 3
Grain Size Analysis Method	RF_t = 2 to 3
Site variability, number of tests, and thoroughness of subsurface investigation	RF_v = 1 to 3
Long-term siltation, plugging, and maintenance	RF_s = 1 to 3

Total Reduction Factor, $RF = RF_t + RF_v + RF_s$
Design Infiltration Rate = Measured Infiltration Rate/RF

REPORTING

The engineer shall compile and analyze the field infiltration rates and total water volume used during testing. A table shall be provided with all field test results and two graphs representing the time-discharge curve and field infiltration rate. The time-discharge curve should the "total accumulated volume" versus "time." The field infiltration rate should be graphed separately as "infiltration rate" versus "time." See Plates 4-A, 4-B, and 4-C for an example of the tabulated and graphed field infiltration test results.

The geotechnical report shall address any potential geotechnical hazards regarding stormwater infiltration and possible mitigation measures; these should be implemented into the design plans. There shall be a discussion on the infiltration test procedure including field data sheets, test results, reduction factors, and final design infiltration rates. The report must provide both the field and design infiltration rates, applicable locations, and depths where the proposed LID features will be constructed.

Finite element analysis and computer modeling may be used as supplementary analysis to understanding the flow of water through the subsurface and any potential impacts on the groundwater table. However, it may not be used to determine infiltration rates in lieu of field testing and other methods described in these guidelines.

Guidance shall be provided to the developer that no grading or construction can disturb soils at or below the proposed invert depth of infiltration. The geotechnical consultant shall provide recommendations for underdrains and overflows, as necessary, and discuss best practices for operation and maintenance to maintain the effectiveness of the proposed facility for its design life. All recommendations from the geotechnical consultant must be incorporated in the design or shown as notes on the plans.

The report must be signed and stamped by a State of California licensed engineering geologist, geotechnical engineer, or civil engineer experienced in geotechnical engineering.

DISCUSSION

Infiltration rates are understood to have a very large range by orders of magnitude for different soil types. There is also substantial uncertainty associated with even the most rigorous testing procedures. For these reasons, it is important that the recommended design infiltration rate fall in the general order of magnitude for the soil type classifications at the site. If there is discrepancy between the presented data and the recommended infiltration rates, the consultant shall revisit soil descriptions, soil data, infiltration testing procedures, and analyses to provide a substantiated explanation for any variance. Additional testing and discussion may be necessary to verify any recommendations and infiltration rates prior to acceptance by the County.

Approved by:

Mitch Miller
Principal Engineer

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RESOURCES

American Society for Testing and Materials (ASTM) Method, Designation D 3385, *Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer* (latest edition). http://www.astm.org/Standards/D3385.htm

California Department of Conservation, *Seismic Hazard Zone Reports*, Division of Mines and Geology, Los Angeles County, 1998. http://www.consrv.ca.gov/cgs/shzp/pages/index.aspx

California Regional Water Quality Control Board Los Angeles Region, *Waste Discharge Requirements for Municipal Separate Storm Sewer System (MS4),* NPDES Permit No. CAS004001, Order No. R4-2012-0175, November 8, 2012. http://www.waterboards.ca.gov/rwqcb4/water_issues/programs/stormwater/municipal/

County of Los Angeles, Code of Ordinances, Title 12, Chapter 12.84, *Low Impact Development Standards*. https://library.municode.com/html/16274/level2/Tit12EnPr_Ch12.84loimdest.html

County of Los Angeles, Department of Public Health, Conventional and Non-Conventional *Onsite Wastewater Treatment Systems – Requirements and Procedures,* July, 2016. http://www.publichealth.lacounty.gov/eh/EP/lu/lu_owts.htm

County of Los Angeles, Department of Public Works, Low Impact Development Standards Manual, February 2014. http://dpw.lacounty.gov/ldd/lib/fp/Hydrology/Low Impact Development Standards Manual.pdf

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DOUBLE-RING INFILTROMETER TEST
(use ASTM D 3385)

Project: ______________________________

Test Location: ______________________________

____

Water Source: ____________________ pH: ________

Tested By: __________________ Water level maintained using: ☐ Flow valve ☐ Float valve ☐ Mariotte tube

Depth to water table: ________ Penetration of rings: Inner: ________ Outer: ________

Constants	Area (in^2)	Depth of water (in)	Water Containers No.	Water Containers Volume/ΔH (in^2/in)
Inner Ring				
Annular Space				

Trial No.		Date	Time (24hr format)	Elapsed Time Δ/(total),	Flow Readings				Water Temp.	Incremental Infiltration		Remarks: weather conditions, etc.
					Inner Ring		Annular Space			Inner	Annular	
					Reading	Flow	Reading	Flow				
		____	hh:mm	min	in	in^3	in	in^3	°F	in/hr	in/hr	
1												

DOUBLE-RING INFILTROMETER TEST
(use ASTM D 3385)

Project: Practice Infiltration Testing

Test Location: 123 Drive Road, Alhambra, CA

Constants	Area (in^2)	Depth of water (in)	No.	Water Containers Volume/ΔH (in^3/in)
Inner Ring	109.59	1.57	1	12.17
Annular Space	326.43	1.61	2	27.39

Water Source: Potable Water pH: 7.5

Tested By: BDS, YH, & WM Water level maintained using: ☐ Flow valve ☐ Float valve ☒ Mariotte tube

Depth to water table: 17 ft Penetration of rings: Inner: 3.0 in Outer: 6.9 in

Trial No.		Date 1982	Time (24hr format) hh:mm	Elapsed Time Δ/(total), min	Flow Readings Inner Ring Reading in	Inner Ring Flow in^3	Annular Space Reading in	Annular Space Flow in^3	Water Temp. °F	Incremental Infiltration Inner in/hr	Incremental Infiltration Annular in/hr	Remarks: weather conditions, etc.
1	S	10/14	10:00	15	1.18	6.96	0.87	23.74	59	0.25	0.29	Cloudy, slight wind
	E	" "	10:15	(15)	1.75		1.73		59			
2	S	" "	10:15	15	1.75	12.94	1.73	48.51	59	0.47	0.59	
	E	" "	10:30	(30)	2.81		3.5		59			
3	S	" "	10:30	15	2.81	16.05	3.5	51.75	59	0.59	0.63	
	E	" "	10:45	(45)	4.13		5.39		59			
4	S	" "	10:45	15	4.13	18.67	5.39	57.67	59	0.68	0.71	
	E	" "	11:00	(60)	5.67		7.5		60			
5	S	" "	11:00	30	5.67	46.26	7.5	141.82	60	0.84	0.87	
	E	" "	11:30	(90)	9.47		12.68		61			
6	S	" "	11:30	30	9.47	51.75	12.68	157.44	61	0.95	0.96	Refilled tubes
	E	" "	12:00	(120)	13.72		18.43		62			
7	S	" "	12:10	60	1.38	118.63	0.87	360.16	62	1.08	1.1	" "
	E	" "	13:10	(180)	11.12		14.02		63			
8	S	" "	13:20	60	0.94	114.54	1.26	347.22	64	1.04	1.06	" "
	E	" "	14:20	(240)	10.35		13.94		64			
9	S	" "	14:30	60	1.69	103.5	1.85	308.41	64	0.95	0.94	" "
	E	" "	15:30	(300)	10.2		13.11		64			
10	S	" "	15:40	60	0.87	96.78	1.77	295.48	64	0.88	0.9	" "
	E	" "	16:40	(360)	8.82		12.56		64			Cloudy, slight wind

Graphical Representation of Data from Example

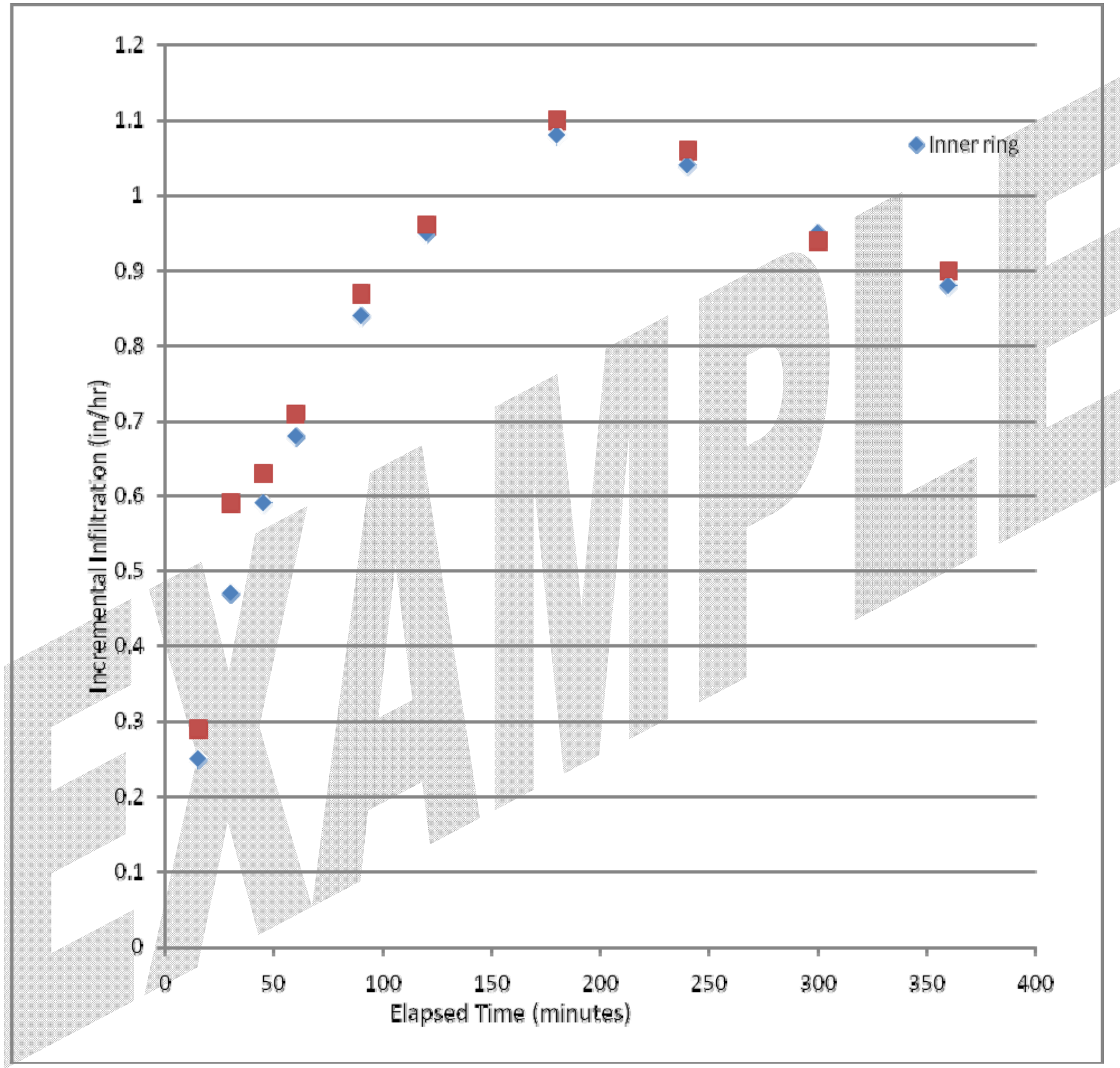

Plate 1-C

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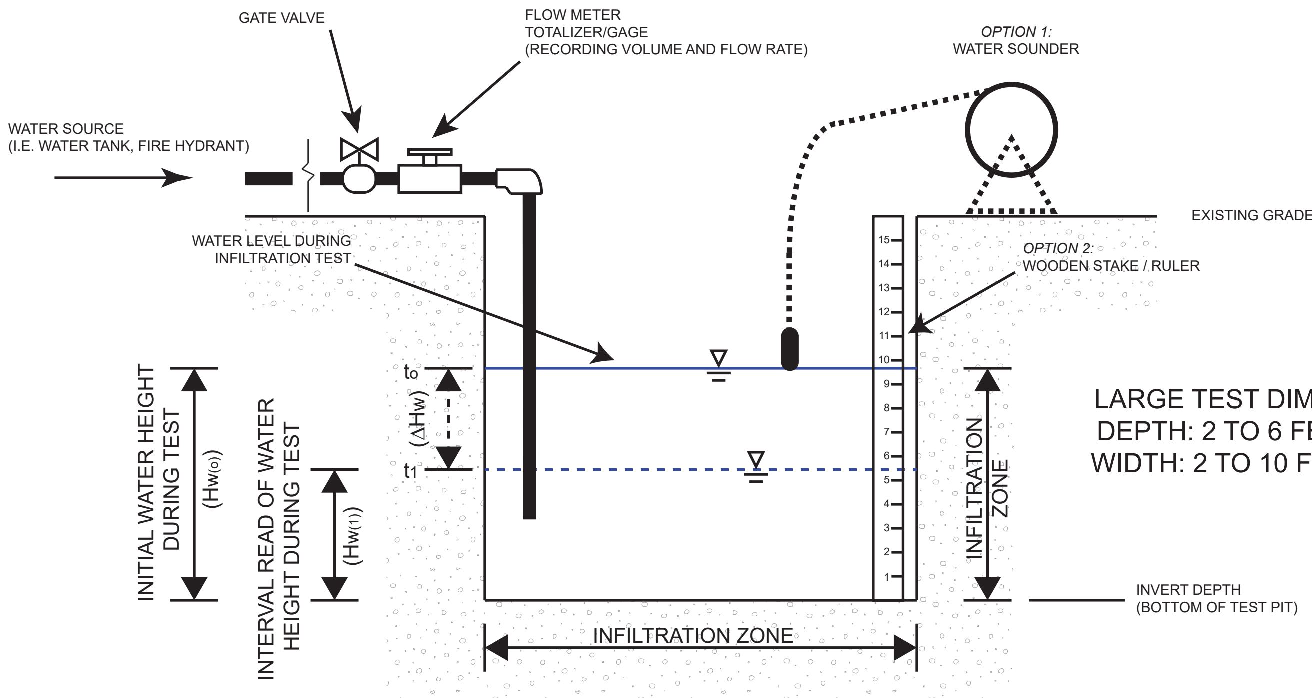
LARGE RECTANGULAR/SQUARE TEST PIT

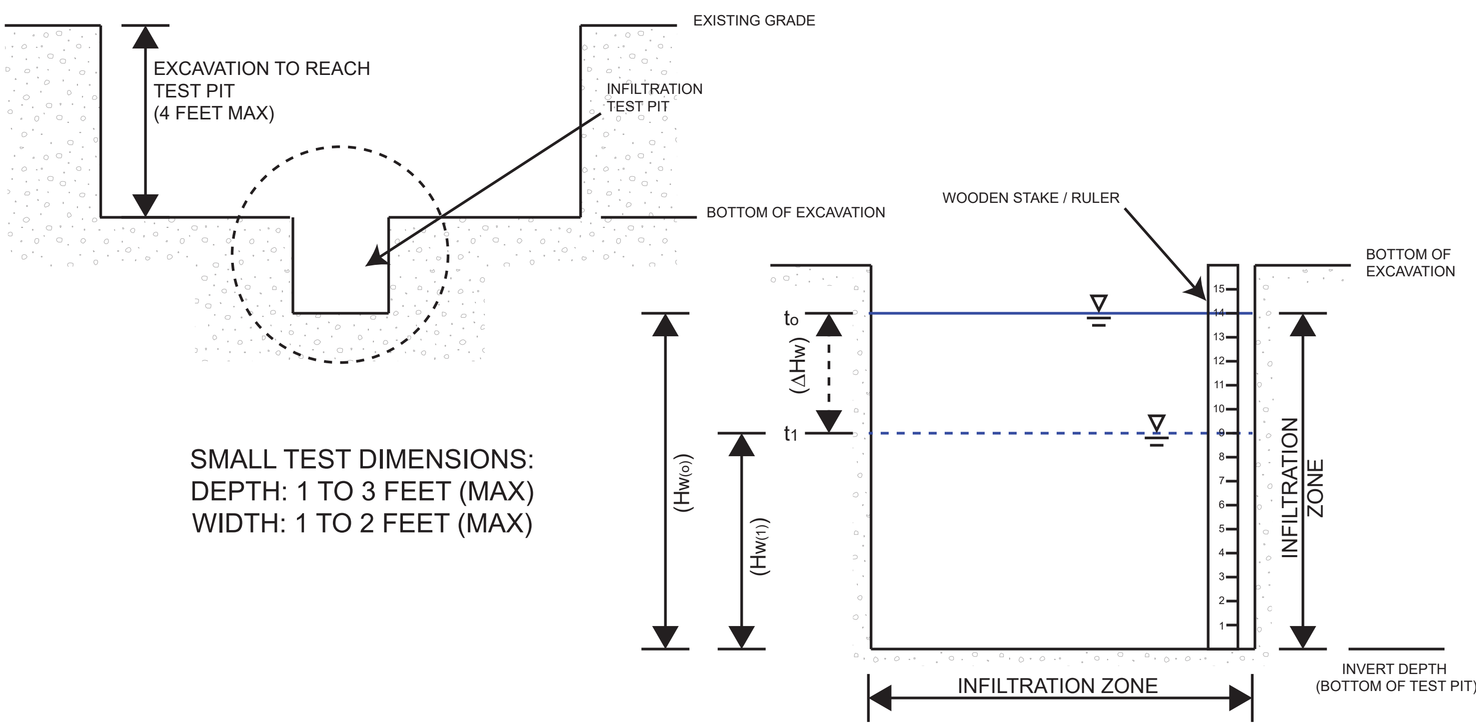


LARGE TEST DIMENSIONS:
DEPTH: 2 TO 6 FEET (MAX)
WIDTH: 2 TO 10 FEET (MAX)

FALLING HEAD
CALCULATED FLOW RATE:
(WIDTH*LENGTH*ΔHw) / (Δt)

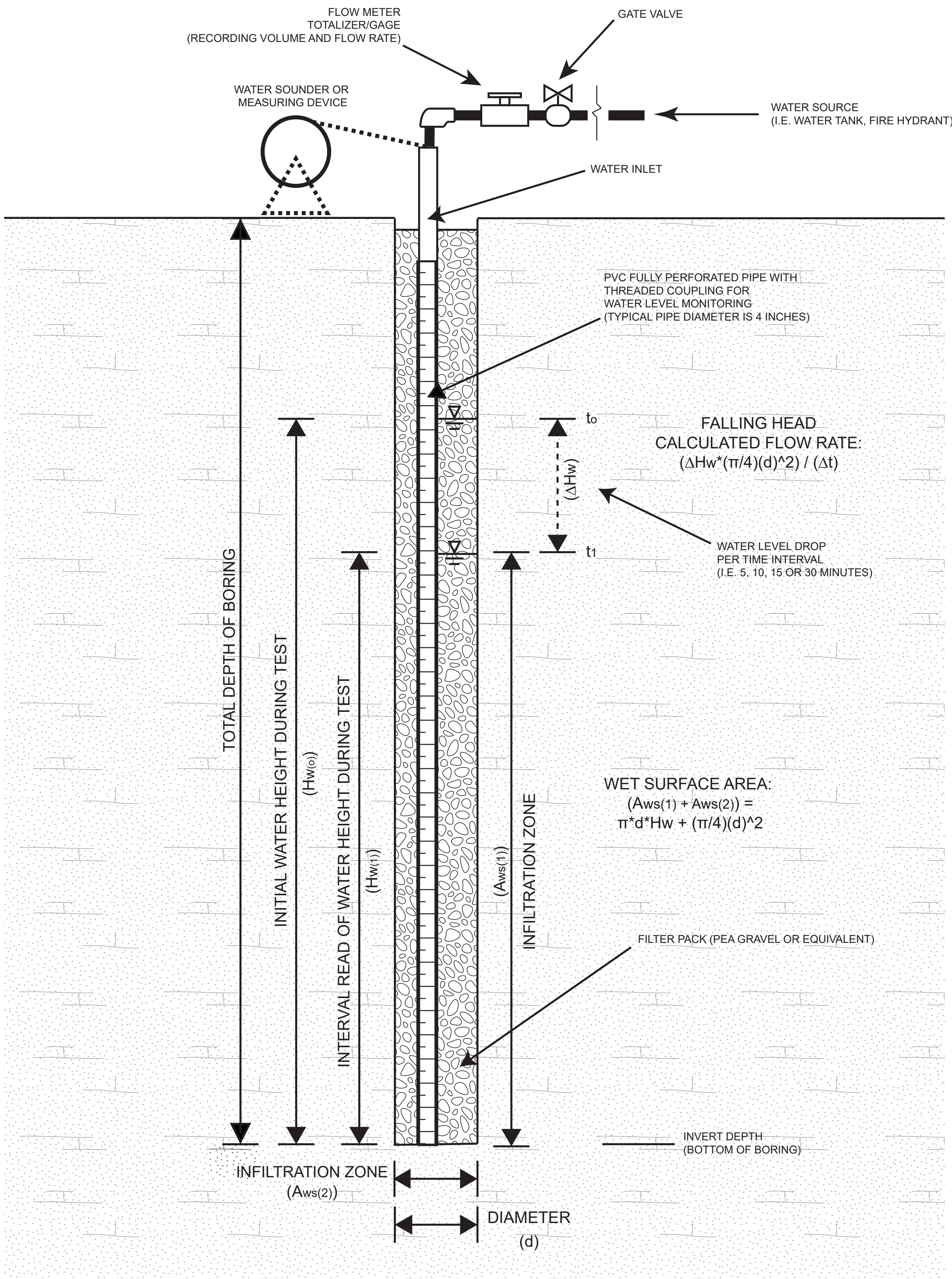
WET SURFACE AREA:
2*(WIDTH*Hw) + 2*(LENGTH*Hw) + WIDTH*LENGTH

SMALL RECTANGULAR/SQUARE TEST PIT



SMALL TEST DIMENSIONS:
DEPTH: 1 TO 3 FEET (MAX)
WIDTH: 1 TO 2 FEET (MAX)

SHALLOW TEST PIT SETUP SCHEMATIC	LOS ANGELES COUNTY PUBLIC WORKS GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION Plate 2-A



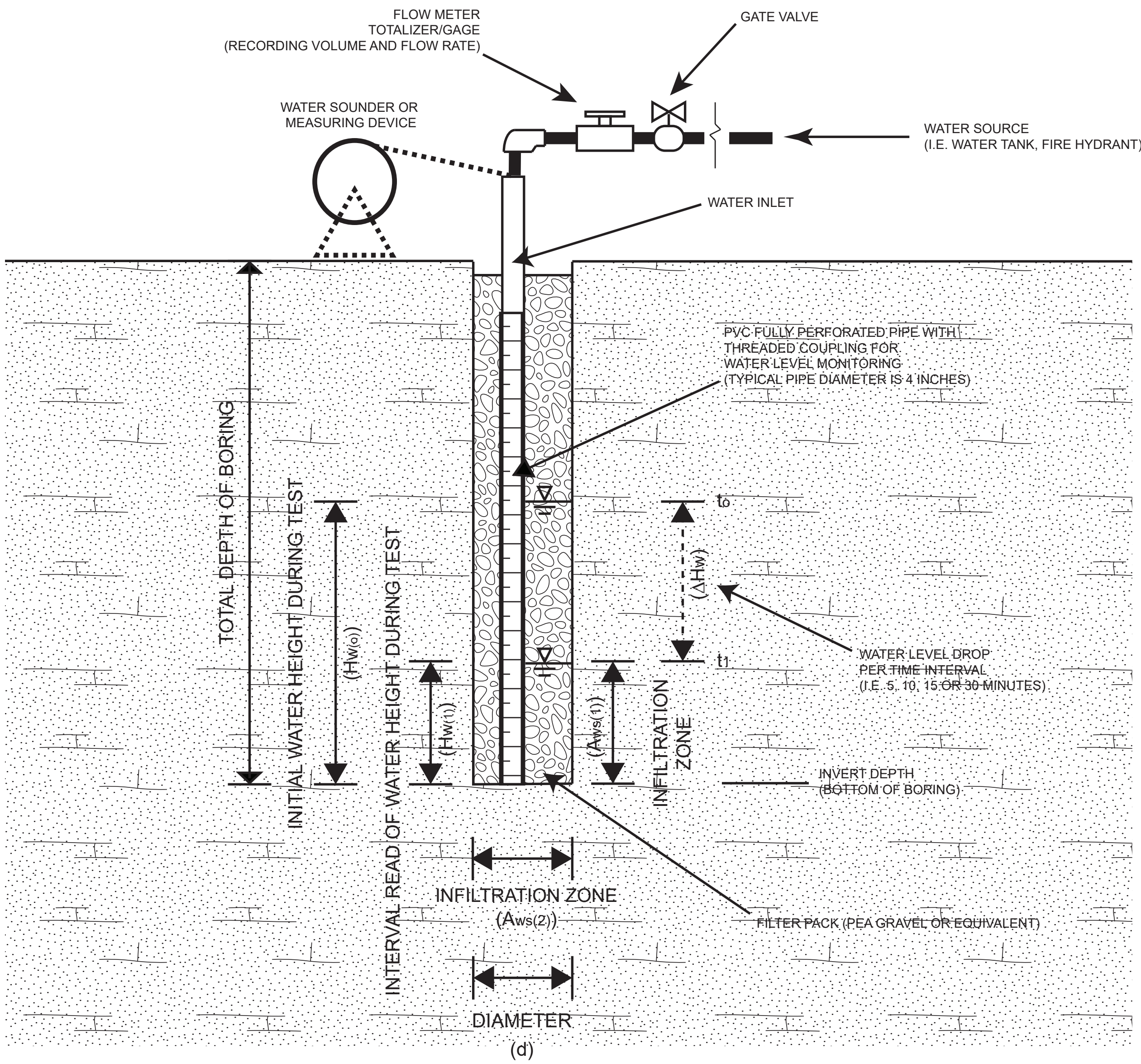
SMALL DIAMETER BORING
DEEP INFILTRATION TEST SETUP
SCHEMATIC

IDEAL FOR DEPTHS BETWEEN 5 TO 60 FEET
TYPICAL DIAMETER: 8 TO 12 INCH

LOS ANGELES COUNTY PUBLIC WORKS

GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION

Plate 2-B



FALLING HEAD
CALCULATED FLOW RATE:
$(\Delta Hw*(\pi/4)(d)^2) / (\Delta t)$

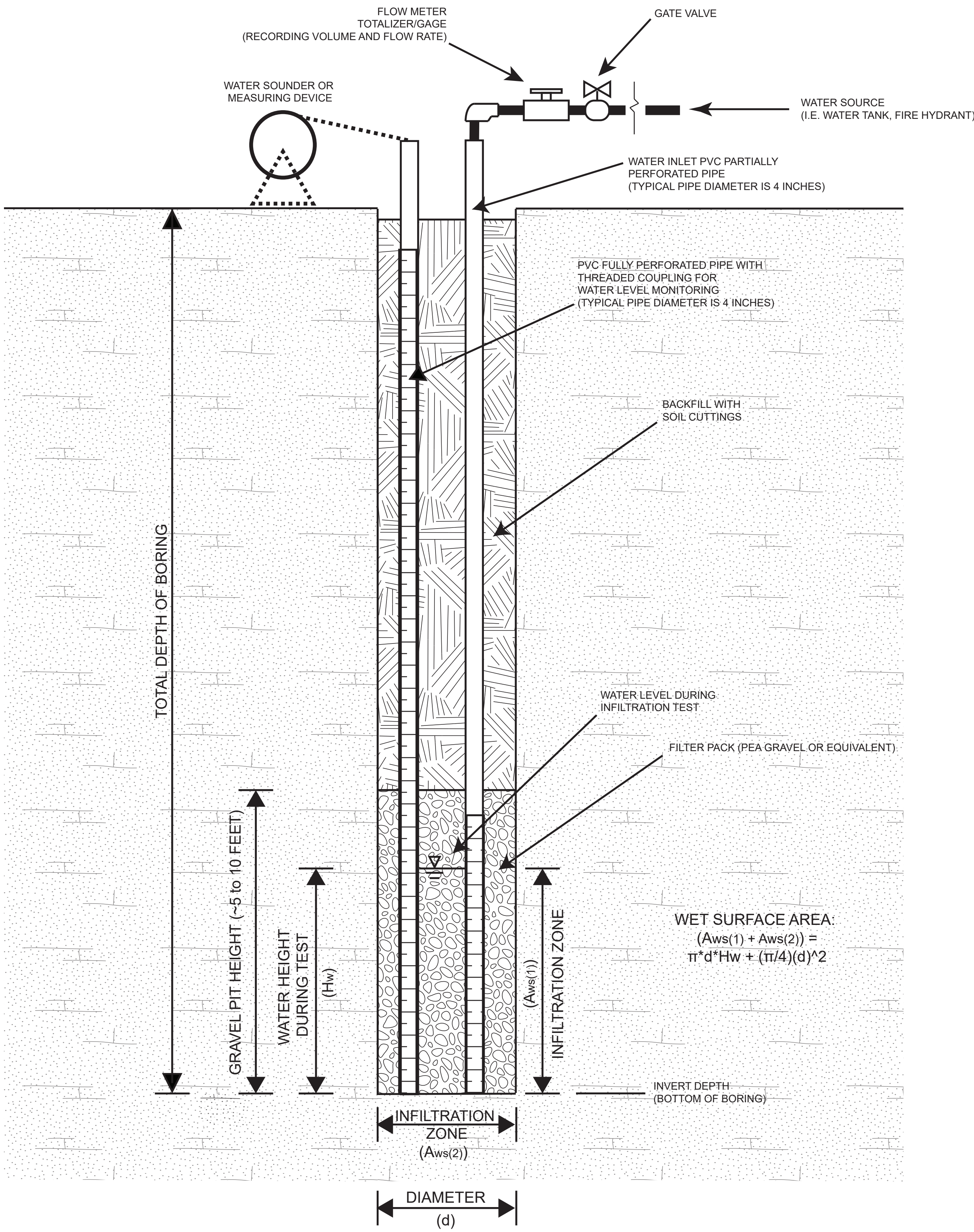
WET SURFACE AREA:
$(Aws_{(1)} + Aws_{(2)}) =$
$\pi*d*Hw + (\pi/4)(d)^2$

SMALL DIAMETER BORING
SHALLOW INFILTRATION TEST SETUP
SCHEMATIC

IDEAL FOR DEPTHS BETWEEN 5 TO 10 FEET
TYPICAL DIAMETER: 8 TO 16 INCH

LOS ANGELES COUNTY PUBLIC WORKS
GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION

Plate 2-C



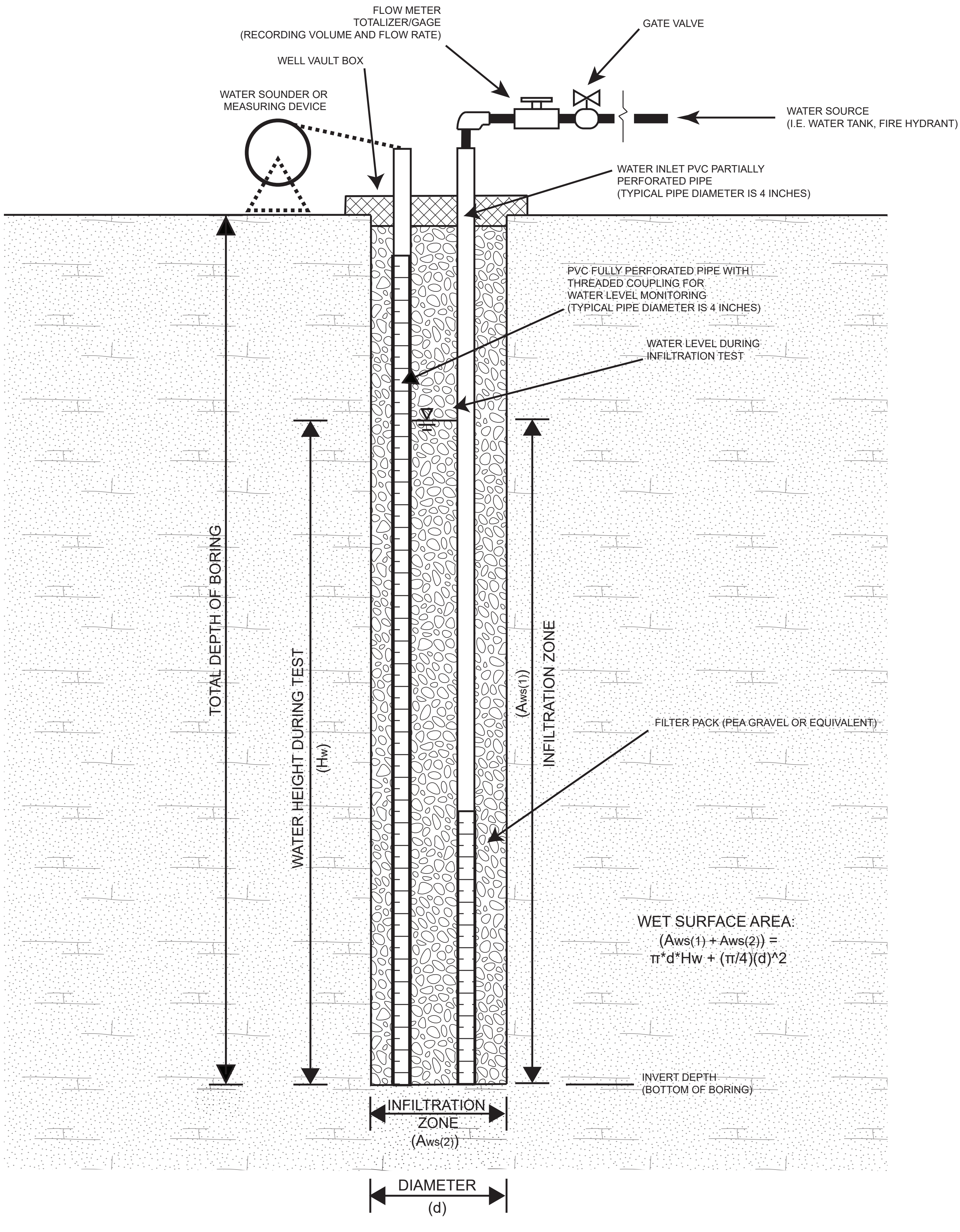
LARGE DIAMETER BORING
INFILTRATION TEST SETUP FOR
UNDERGROUND GALLERIES SCHEMATIC

IDEAL FOR DEPTHS BETWEEN 5 TO 25 FEET
TYPICAL DIAMETER: 18 TO 36 INCH

LOS ANGELES COUNTY PUBLIC WORKS

GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION

Plate 2-D



DRYWELL INFILTRATION TEST SETUP
SCHEMATIC

IDEAL FOR DEPTHS BETWEEN 20 TO 60 FEET
TYPICAL DIAMETER: 18 TO 36 INCH

LOS ANGELES COUNTY PUBLIC WORKS

GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION

Plate 2-E

Test Pit Infiltration Field Log

Test Date: ____________________

Project Name: ____________________ **PCA:** ____________________ **Test Number:** ____________________

Test Location: ____________________

Soil Description: ____________________ **Test Pit Width:** __________ In/Ft. **Required Pavement Cutting:** Yes / No

Test Conducted by: ____________________ **Test Pit Length:** __________ In/Ft. **Constant Head Test:** Yes / No

Liquid Description: ____________________ **Test Pit Height:** __________ In/Ft. **Target Depth for Constant Head:** __________ In/Ft.

Measurement Method: ____________________ **Invert Depth:** __________ In/Ft. **Target Depth for Falling Head:** __________ In/Ft.

Measurement from Ground Surface to Test Pit Bottom: __________ In/Ft.

Test Parameters

Date of Test Pit Constructed: ____________________

Presoak Start Time & Date: ____________________

Presoak Volume Poured into Well: ____________________

Duration Time for Presoak: ____________________

Construction Meter Start Read: ____________________

Construction Meter End Read: ____________________

Test Flow Meter Start Read: ____________________

Test Flow Meter End Read: ____________________

1 GPM = 13858.65 IN^3/HR = 8.021 FT^3/HR

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Revised (10/22/2019)

Well Infiltration Test Field Log

Test Date:___________________

Project Name: ____________________ **PCA:** _______________ **Test Number:** __________

Test Location: ____

Soil Description: ________ **Auger Bit/Bucket Diameter:** _____ In/Ft. **Required Pavement Cutting:** Yes / No

Test Conducted by: ________ **Boring Cut Diameter:** _____ In/Ft. **Constant Head Test:** Yes / No

Liquid Description: ________ **Well Total Depth:** _____ In/Ft. **Target Depth for Constant Head:** _____ In/Ft.

Measurement Method: ________ **PVC Pipe Diameter:** _____ In/Ft. **Target Depth for Falling Head:** _____ In/Ft.

Well Measurement Datum, (+/-) from Ground Surface: _____ In/Ft.

Test Parameters

Date of Test Pit Constructed: ____________ **Construction Meter Start Read:** ____________

Presoak Start Time & Date: ____________ **Construction Meter End Read:** ____________

Presoak Volume Poured into Well: ____________ **Test Flow Meter Start Read:** ____________

Duration Time for Presoak: ____________ **Test Flow Meter End Read:** ____________

1 GPM = 13858.65 IN^3/HR = 8.021 FT^3/HR

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Revised (10/22/2019)

Drywell No.4 Field Test Data

Project: Norwalk Blvd Et Al
Location: 7203 Cedarcliff Ave
Unincorporated West Whittier
PCA: F21816i04
Tester: AA / JJU

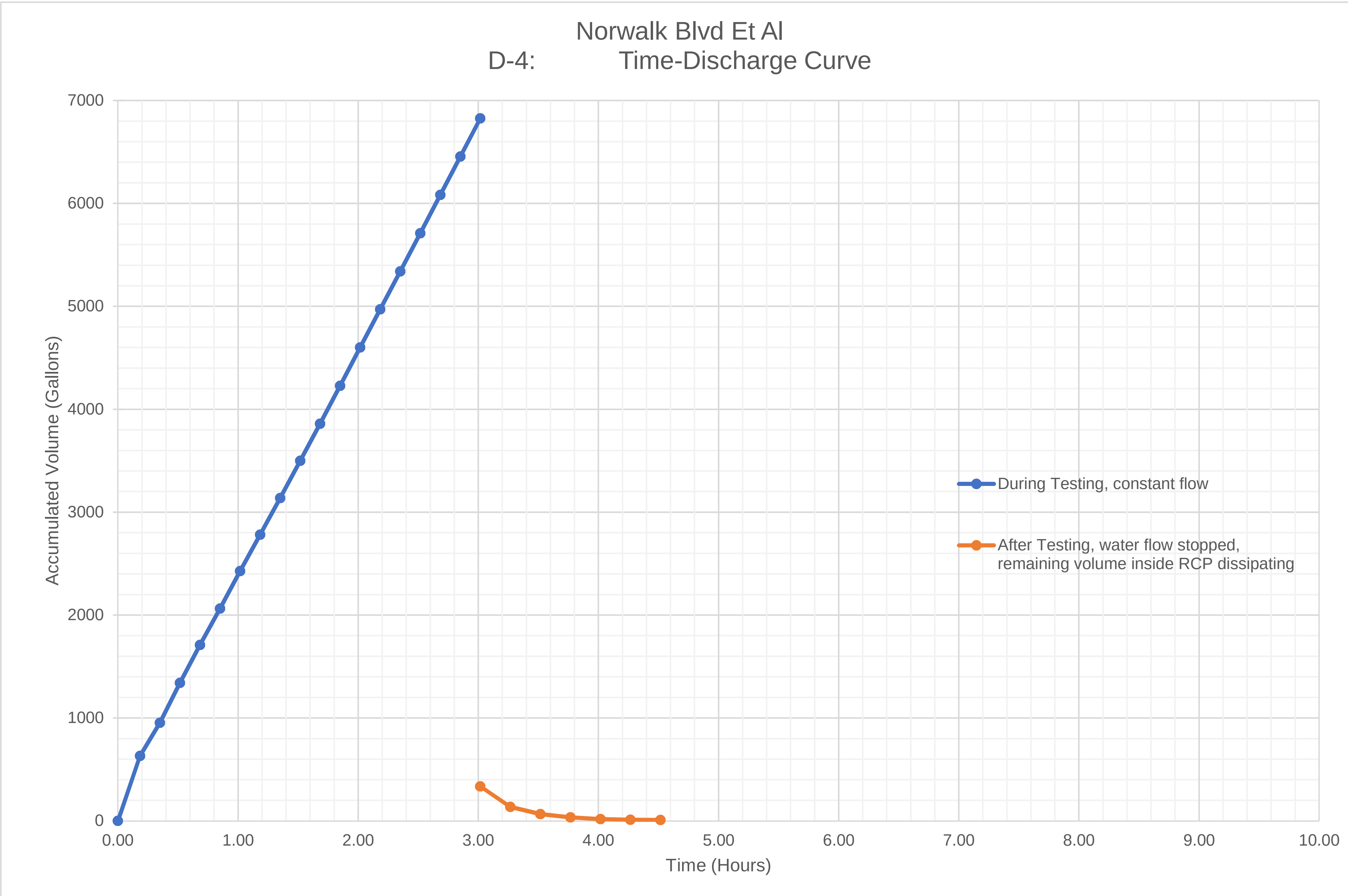
Measurement depth from well datum (ft):	41
Well height above ground (ft):	0
Drywell total depth below grade (ft):	41
Drywell perforated section height (ft):	41
Total Water Input into Well (gal):	6884.72
Construction Meter Total Usage (hcf):	12
Construction Meter Total Usage (gal):	8976.62

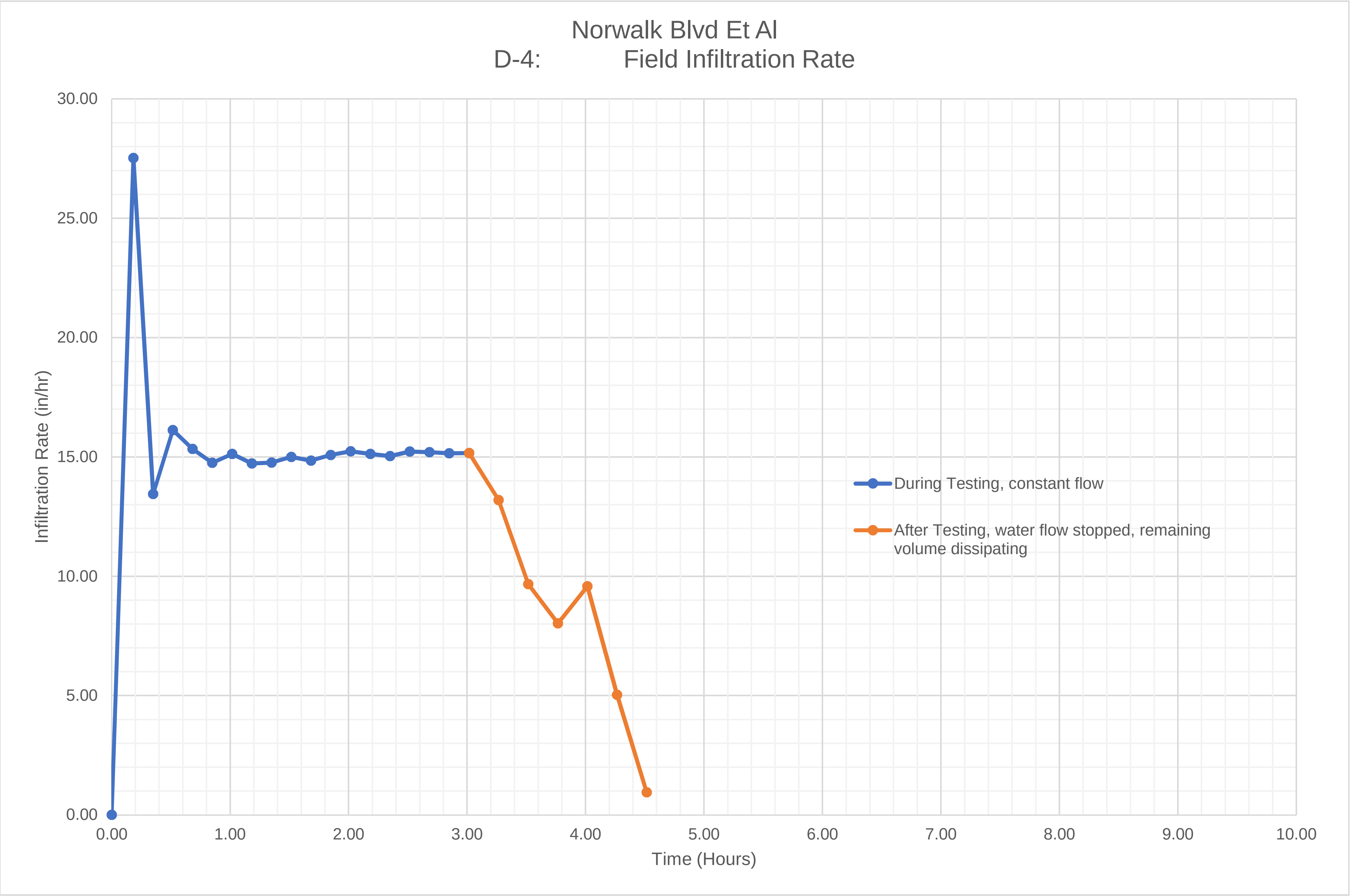
	During Testing:	**After Testing, drainage:**
Average Infiltration Rate (in/hr):	15.02	8.80
Median Infiltration Rate (in/hr):	15.12	9.58
Lowest Infiltration Rate (in/hr):	13.45	0.95
Average Water Depth (ft):	15.71	---
Median Water Depth (ft):	15.56	---
Total Time of Testing Conducted (hr):	3.02	4.52

Test Read No.	Test Date	Boring	Boring Diameter D_o (in)	Boring X-section Area A_b (ft^2)	Time Interval Read	Water Depth Reading (ft)	Total Volume Reading (gal)	Flow Rate Reading (gpm)	Δ Time From Reads (mins)	Δ Time Converted (hr)	Δ Volume from Reads (gal)	Calculated Flow Rate (gpm)	Boring Wet Surface Area A_s (ft^2)	Calculated Flow Rate (ft^3/hr)	**Infiltration Rate (in/hr)**	**Accumulated Volume (gal)**	**Accumulated Time (hr)**	Comments
0	4/15/2019	D-4	35.00	6.68	0926	---	0.00	---	0	0.00	---	---	---	---	0.00	0.00	0.00	
1	4/15/2019	D-4	35.00	6.68	0935	19.10	631.10	17.03	11	0.18	631.10	57.37	200.67	460.19	27.52	631.10	0.18	
2	4/15/2019	D-4	35.00	6.68	0945	15.85	953.10	9.88	10	0.17	322.00	32.20	230.45	258.28	13.45	953.10	0.35	
3	4/15/2019	D-4	35.00	6.68	0955	15.70	1341.41	9.22	10	0.17	388.31	38.83	231.82	311.46	16.12	1341.41	0.52	
4	4/15/2019	D-4	35.00	6.68	1005	15.75	1709.98	9.82	10	0.17	368.57	36.86	231.37	295.63	15.33	1709.98	0.68	
5	4/15/2019	D-4	35.00	6.68	1015	15.90	2062.45	10.64	10	0.17	352.47	35.25	229.99	282.72	14.75	2062.45	0.85	
6	4/15/2019	D-4	35.00	6.68	1025	15.66	2427.27	11.74	10	0.17	364.82	36.48	232.19	292.62	15.12	2427.27	1.02	
7	4/15/2019	D-4	35.00	6.68	1035	15.70	2781.84	9.54	10	0.17	354.57	35.46	231.82	284.40	14.72	2781.84	1.18	
8	4/15/2019	D-4	35.00	6.68	1045	15.70	3137.32	9.66	10	0.17	355.48	35.55	231.82	285.13	14.76	3137.32	1.35	
9	4/15/2019	D-4	35.00	6.68	1055	15.71	3498.38	9.60	10	0.17	361.06	36.11	231.73	289.61	15.00	3498.38	1.52	
10	4/15/2019	D-4	35.00	6.68	1105	15.46	3859.22	9.49	10	0.17	360.84	36.08	234.02	289.43	14.84	3859.22	1.68	
11	4/15/2019	D-4	35.00	6.68	1115	15.34	4227.52	9.71	10	0.17	368.30	36.83	235.12	295.41	15.08	4227.52	1.85	
12	4/15/2019	D-4	35.00	6.68	1125	15.25	4601.02	9.93	10	0.17	373.50	37.35	235.95	299.58	15.24	4601.02	2.02	
13	4/15/2019	D-4	35.00	6.68	1135	15.23	4972.06	8.22	10	0.17	371.04	37.10	236.13	297.61	15.12	4972.06	2.18	
14	4/15/2019	D-4	35.00	6.68	1145	15.33	5339.52	10.26	10	0.17	367.46	36.75	235.21	294.74	15.04	5339.52	2.35	
15	4/15/2019	D-4	35.00	6.68	1155	15.35	5711.34	6.69	10	0.17	371.82	37.18	235.03	298.24	15.23	5711.34	2.52	
16	4/15/2019	D-4	35.00	6.68	1205	15.23	6084.10	10.84	10	0.17	372.76	37.28	236.13	298.99	15.19	6084.10	2.68	
17	4/15/2019	D-4	35.00	6.68	1215	15.28	6455.12	8.44	10	0.17	371.02	37.10	235.67	297.60	15.15	6455.12	2.85	
18	4/15/2019	D-4	35.00	6.68	1225	15.23	6827.07	8.50	10	0.17	371.95	37.20	236.13	298.34	15.16	6827.07	3.02	end of test

Drainage After Testing

Test Read No.	Test Date	Boring	Boring Diameter D_o (in)	Boring X-section Area A_b (ft^2)	Time Interval Read	Water Depth Reading (ft)	Total Volume Left in Drywell (gal)		Δ Time From Reads (mins)	Δ Time Converted (hr)	Δ Volume (gal)	Calculated Flow Rate (gpm)	Boring Wet Surface Area A_s (ft^2)	Calculated Flow Rate (ft^3/hr)	**Infiltration Rate (in/hr)**		**Accumulated Time (hr)**	Comments
0	3/21/2019	D-4	35.00	6.68	1225	15.23	334.85		---	0.00	---	---	---	---	15.16		3.02	
1	3/21/2019	D-4	35.00	6.68	1240	30.48	136.70		15	0.25	198.16	13.21	96.39	105.96	13.19		3.27	
2	3/21/2019	D-4	35.00	6.68	1255	35.90	66.27		15	0.25	70.43	4.70	46.73	37.66	9.67		3.52	drainage rate consistent throughout strata
3	3/21/2019	D-4	35.00	6.68	1310	38.29	35.21		15	0.25	31.06	2.07	24.83	16.61	8.03		3.77	
4	3/21/2019	D-4	35.00	6.68	1325	39.68	17.15		15	0.25	18.06	1.20	12.10	9.66	9.58		4.02	
5	3/21/2019	D-4	35.00	6.68	1340	40.15	11.04		15	0.25	6.11	0.41	7.79	3.27	5.03		4.27	
6	3/21/2019	D-4	35.00	6.68	1355	40.23	10.01		15	0.25	1.04	0.07	7.06	0.56	0.95		4.52	end of test, completely drained


Norwalk Blvd Et Al
D-4: Time-Discharge Curve
Accumulated Volume (Gallons)
7000
6000
5000
4000
3000
2000
1000
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time (Hours)
During Testing, constant flow
After Testing, water flow stopped, remaining volume inside RCP dissipating



Norwalk Blvd Et Al
D-4: Field Infiltration Rate
Infiltration Rate (in/hr)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time (Hours)
During Testing, constant flow
After Testing, water flow stopped, remaining volume dissipating