CHAPTER 4 – GEOTECHNICAL SITE CHARACTERIZATION

Chapter Organization

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4.1 INTRODUCTION

This chapter outlines the minimum requirements for a geotechnical site characterization (GSC), which is used in developing recommendations for stormwater disposal and determining the feasibility of constructing sub-level structures. A qualified geotechnical engineer (a professional engineer currently licensed in the State of Washington with geotechnical engineering as a specialty) is required to perform the GSC. Hydrogeologists and engineering geologists may prepare geotechnical site characterization studies, excluding structural, foundation and pavement design. The following geotechnical studies, if required, can be performed at the same time as the GSC:

- Geohazard analysis;
- Pavement subgrade evaluation;
- Down-gradient analysis (refer to Section 3.4.5);
- Evaporative or detention pond liner recommendations, including potential groundwater effects on impervious pond liners (mounding, uplift, etc.);
- Embankment recommendations for proposed disposal facilities that would impound stormwater (refer to Section 7.8.6 for embankment criteria).
- Recommendations for all cut and fill slopes.

Contact the local jurisdiction for specific requirements with regard to geohazardous areas and road surfacing. The requirements of this chapter are in addition to any field or laboratory testing that may be required, or recommended by the project engineer, with regard to footings, foundations, utility work, etc.

In areas other than Special Drainage Areas (SDAs) and known drainage problem areas, the geotechnical engineer may make recommendations on the feasibility of sub-level structures based on the information available from the initial site investigation.

4.2 APPLICABILITY

A GSC will be required for most projects. The scope and geographic extent of the investigation may vary depending on the general location and setting of the site, the characteristics of the target soil layer, and whether there are known or anticipated drainage problems in the vicinity of the site.

A GSC is required for:

- Projects proposing infiltration (drywells, detention facilities receiving credit for pond bottom infiltration, etc.) or non-standard drainage systems;

- Projects located in a Special Drainage Area (SDA) or a Special Drainage District (SDD);
- Projects located within or draining to a drainage problem or study area as recognized by the local jurisdiction;
- Projects with administrative conditions requiring a GSC; or,
- Projects with proposed sub-level structures, as required by the local jurisdiction.

In areas where there has been a long-standing record of satisfactory performance of standard subsurface disposal facilities and no drainage problems are known to exist, the minimum requirements found in Section 4.3 may be reduced or waived after a formal written request from the project proponent's engineer has been reviewed and accepted by the local jurisdiction.

4.3 GEOTECHNICAL SITE CHARACTERIZATION REPORT

The following are minimum requirements for the GSC:

- The Study shall include:
    - A surface reconnaissance of the site and adjacent properties to assess potential impacts from the proposed stormwater system and to verify that the conditions are consistent with the mapped information. Typically, the evaluation should extend a quarter of a mile down gradient. Where access to adjacent properties is unavailable, the project proponent shall rely upon the best known information for the area, supplemented with information available from the local jurisdiction, including any existing geotechnical engineering reports or studies for sites in the vicinity;
    - A review of available geologic, topographic, soils, and Critical Areas maps to identify any site conditions that could impact the use of storm drainage systems or the construction of sub-level structures. This review shall include all available previous geotechnical engineering reports or studies for sites in the vicinity; and,
    - An evaluation of the potential impacts of groundwater on the proposed storm drainage facilities and roadways, when a seasonally high groundwater table is suspected.
- The Report Narrative shall include:
    - A brief project description including size, number of lots proposed, project location (section, township and range), and background information relevant for drainage design;
    - A discussion of the study investigations;
    - A description of the soil units on the site and in the vicinity of the site;

  - A description of the site including surface, soil, and groundwater conditions, etc; and,
  - Conclusions and recommendations

- The Site Plan shall include:
  - Project boundaries (including all existing and proposed property lines);
  - Labeled topographic contours, extending beyond the project and drainage basin. Projects in an urban area shall use a maximum contour spacing of 2 feet. At the discretion of the local jurisdiction, projects outside an urban area, such as a large lot subdivision, may use the best available topographic information, which may involve contours with spacing of more than 2 feet. In either case, the engineer shall field verify the basin limits;
  - Location of the soil units identified;
  - Location of significant structures, properties or geologic features (such as basalt outcroppings, etc.) on site and in the project vicinity;
  - Location of existing natural or constructed drainage features on site and in the project vicinity; and,
  - Location of proposed site infrastructure including roadways and drainage features such as ponds, drywells, etc.

- Test Method Documentation shall include:
  - A map with the location of all subsurface field explorations and any in-place field tests;
  - A description of any difficulties encountered during excavation and testing;
  - A description of the equipment used to perform the field explorations or tests. When applicable, describe the type of fabric lining and gravel backfill used;
  - Logs of subsurface explorations which shall identify the depth to groundwater, the presence of any limiting layers and the target soil layer; include test pit or excavation dimensions, with photographs, where applicable;
  - Report test data in a format that includes time of day, flow meter readings, incremental flow rates, observed head levels, water depths and total flow volumes in the drywell, test pit or infiltrometer;
  - A description of the condition of any existing facilities being tested, noting any silt build-up, water level, connections to other structures (including distance to inverts of any interconnecting pipes), measured depths and dimensions, etc.;

- Results of field and laboratory testing conducted, including the grain size analysis represented both graphically and in tabular format (refer to Section 4.3.1). For the Spokane 200 method, results shall also be summarized using the formatting shown in Table 4-1.;
- A report on the normalized outflow rates for drywells, and the actual and proposed design outflow rates for test pits;
- Results of the sub-level structure feasibility study (refer to Section 4.3.2) and a summary of the down-gradient analysis (refer to Section 3.4.5), as applicable;
- A geologic cross-section of the stormwater disposal area drawn to scale, with the proposed stormwater disposal facilities superimposed on the cross-section. All relevant geologic units shall be clearly identified including the target disposal layer and limiting layers; and,
- For the Spokane 200 Method, results summarized using the formatting shown in Table 4-1, as well as the sieve analysis data, presented both graphically and in tabular format.

TABLE 4-1
SPOKANE 200 METHOD RESULTS SUMMARY

Exploration ID	Sample Depth	USCS Classification	Percent Fines	Hydraulic Conductivity	Normalized Drywell Outflow Rate	Factor of Safety
TP #2	4.0’	SP-SM	6.3%	0.011 cm/sec	0.032 cf/ft	2.0
TP #2	10.5’	GP	4.5%	0.035 cm/sec	0.090 cf/ft	1.3

4.3.1 FIELD AND LABORATORY TESTING

The subsurface exploration, testing, and associated engineering evaluations are necessary to identify permeable soils and to determine the thickness, extent, and variability of the soils. This information is necessary to properly design stormwater disposal facilities.

Field explorations and laboratory testing shall be conducted under the direct supervision of a geotechnical engineer.

Test Methods

Soil infiltration and drywell outflow rates shall be determined using one or more of the following methods:

- The Spokane 200 Method (refer to Appendix 4A) uses "percent fines" (i.e. soil gradation data) to estimate drywell outflow rates for design purposes. This test method is an option provided to the geotechnical engineer to initially assess the suitability of the on-site soils for subsurface stormwater disposal in drywells;
- The full-scale drywell test (refer to Appendix 4B) uses field data to determine the actual outflow rates of a drywell. This test method is required for all existing drywells to verify the condition and capacity of the structure;
- The test pit method (refer to Appendix 4C) uses field data to estimate the outflow rates of drywells and other subsurface disposal facilities. A geotechnical engineer may elect to use this test method to further verify the design outflow rates used in the drainage design when soil gradations indicate marginal outflow rates, as determined by the Spokane County 200 Method. Also, this test method may be used for estimating outflow rates for non-standard subsurface disposal systems (infiltration galleries, under-drain systems, etc);
- The single-ring infiltrometer test (refer to Appendix 4D) or pond flood test (refer to Appendix 4F) can be used to verify pond drawdown times as required in Section 7.8.3, as well as the infiltration rates of the subgrade and treatment zone of a water quality facility as discussed in Section 6.7.1. The single-ring infiltrometer test uses field data to determine the hydraulic conductivity of surficial soils;
- The swale flood test (refer to Appendix 4E) uses field data to verify swale drawdown times and functionality; and,
- Additional or alternate test methods, upon approval from the local jurisdiction.

Minimum Requirements

The following minimum requirements, when applicable, shall be met for field explorations and laboratory testing when subsurface disposal is proposed:

- Test borings and/or test pits shall be located within the footprint of proposed stormwater disposal facilities;
- For each facility, a minimum of one subsurface exploration shall be performed for up to 1200 square feet of disposal area. Another subsurface exploration shall be performed for each additional 15,000 square feet, or fraction thereof, of disposal area. For a linear roadside swale, a minimum of one subsurface exploration shall be performed every 500 feet, staggered on both sides of the road, unless site conditions or test results indicate that additional explorations are necessary. Subsurface explorations and sampling shall be conducted

according to applicable standards of the American Society for Testing and Materials (ASTM);

- Unless otherwise recommended by the geotechnical engineer, subsurface explorations shall extend to a depth of H plus 5 feet below the stormwater facility, where H is equivalent to the maximum head of water within the facility. For example, for a double depth drywell with a maximum head of 10 feet, the minimum required depth of exploration below the drywell is 15 feet, or 25 feet below the proposed rim of drywell; and,
- When the Spokane 200 Method is used, a minimum of two "percent fines" tests shall be performed per subsurface exploration. Tests should be performed on samples taken at varying depths below the ground surface, within the target soil layer, in order to adequately characterize the proposed disposal site soils. Laboratory testing shall be conducted according to applicable ASTM standards.

Post-Construction Testing

Newly constructed drywells may require a full-scale drywell test prior to project certification. Swales may also require a flood test or infiltrometer test prior to project certification, bond release or issuing a Certificate of Occupancy. Contact the local jurisdiction for additional information.

4.3.2 SUB-LEVEL STRUCTURE FEASIBILITY

If sub-level structure construction is being considered, a sub-level structure feasibility study is required. In the City of Spokane Valley, contact the Building Department for basement restriction information. The sub-level structure feasibility study shall include the following, at a minimum:

- A layout of the site showing lot lines and lot and block numbers;
- Identification by lot and block number of sites where sub-level structure construction is feasible. Provide recommendations with details of construction (i.e. maximum below grade floor elevations, minimum drainage system requirements, and any site specific recommendations). Recommendations shall be coordinated with the International Building Code (IBC) and International Residential Code (IRC);
- Discussion of the effects of hydrostatic pressure that may lead to basement flooding and recommendations as to the effectiveness of waterproofing;
- If infiltration is proposed as a method for stormwater disposal, discussion of any potential adverse impacts on proposed sub-level

structures, taking into consideration the contribution of imported water (due to lawn watering, etc.); and,

- Identification of locations where sub-level structure construction is not feasible.

In-lieu of conducting a sub-level structure feasibility study, the owner may elect to prohibit sub-level structure construction throughout the entire plat. If a potential buyer would like to construct a sub-level structure, then a site specific geotechnical evaluation shall be performed by a geotechnical engineer for the individual lot prior to a building permit being issued. Language regarding sub-level structure restrictions, as provided by the local jurisdiction, shall be placed or referenced on the face of the plat.

Recommendations shall be summarized and provided electronically in Microsoft Excel, per the format found in Table 4-2.

TABLE 4-2
EXAMPLE SUB-LEVEL STRUCTURE FEASIBILITY SUMMARY

Block No.	Lot No.	Sub-Level Construction Feasible?	Maximum Depth Below Finish Grade[1]	Depth to Limiting Layer[2]	Summary of Geotechnical Recommendations[3]
Block 1	Lots 1-8	yes	Maximum allowable	C=15 feet GrW=25 feet B=30 feet	Based upon the clean nature of the soils at the sub-level elevations and the depth to groundwater, footing drains are not required. However, below-grade walls shall be well reinforced to reducing cracking and thoroughly damp-proofed with a water-resistant bituminous emulsion or modified cement base coating. Backfill material shall consist of only clean granular material which is free of fine-grained soils, organic material, debris and large rocks.
Block 2	Lots 1-3	yes	4 feet	GrW=13 feet	Below-grade walls shall be well reinforced to reduce cracking and waterproofed with a membrane (per IRC) which is lapped and sealed from the top of the footing to the finished grade. An under slab waterproof membrane (per IBC) which is lapped and sealed shall be integrated with the wall membrane. Backfill material shall consist of only clean granular material which is free of fine-grained soils, organic material, debris and large rocks. Walls and footings shall have a drain system with cleanouts, emptying a minimum of 15 feet in a down-slope direction away from structures. Precautions shall be taken not to excavate a closed depression over rock or clay that is intended to dispose of sump water from a foundation drain system.
Block 2	Lots 4-8	no	n/a	GrW=3 feet B=7 feet	Due to the very shallow presence of groundwater, sub-level structures are not recommended on these lots. If a crawl space is proposed, a drain system with cleanouts shall be provided that empties a minimum of 15 feet in a down-slope direction away from structures. Precautions shall be taken not to excavate a closed depression over rock or clay that is intended to dispose of sump water from foundation drain system.

1 Maximum depth measured from original pre-construction/pre-grading ground surface elevation or existing ground surface, whichever provides a greater distance between the lowest floor elevation and the limiting layer.

2 GrW=groundwater, B=bedrock or basalt, C=clayey-silty soils

3 Refer to the Geotechnical Report for this project for further information, which may include construction details that support these recommendations.

APPENDIX 4A – SPOKANE 200 METHOD

PURPOSE AND APPLICABILITY

The Spokane 200 Method estimates the normalized outflow rates for drywells and the hydraulic conductivity of a soil using the results of laboratory soil gradation tests.

The geotechnical engineer may use this method to initially assess the suitability of site soils for stormwater disposal. A full-scale drywell test, as deemed necessary by the local jurisdiction, may be required prior to final project certification in order to verify design outflow rates determined by this method.

PROCEDURE

The following procedure for the Spokane 200 Method is taken from *Infiltration Rate and Soil Classification Correlation* (File No. 0188-082-00, May 28, 2004; prepared by GeoEngineers, Budinger & Associates, Inc., and Cummings Geotechnology, Inc.)

1. Determine the percent of fines (percent passing the #200 sieve) for the target soil layer, based on a minimum of 2 gradation tests.

2. Estimate the hydraulic conductivity (k) using the percent fines value and the best-fit line on Figure 4A-1. Enter the figure on the x-axis with the percent fines value from Step 1. Extend a vertical line from that value until the Best Fit Line is intersected. Drawing a horizontal line from that point to the y-axis will yield the hydraulic conductivity. Alternatively the equation $K = 0.6392\,F^{-1.8796}$ may be used, where K is the hydraulic conductivity and F is the percent fines.

3. Determine the normalized outflow rate for a drywell using the estimated hydraulic conductivity from Step 2, and the best-fit line-drywell data on Figure 4A-2. Enter the figure on the x-axis with the estimated hydraulic conductivity (k) from Step 2. Extend a vertical line from that value until the Best-Fit Line-Drywell Data is intersected. Drawing a horizontal line from that point to the y-axis will yield the normalized outflow rate. Alternatively the drywell equation $q_a = 1.5582\,K^{0.8601}$ may be used, where K is the hydraulic conductivity and q_A is the normalized outflow rate.

4. Determine the actual outflow rate for a drywell (q_A) by multiplying the normalized outflow rate by the maximum design drywell head (6 feet for a single-depth drywell and 10 feet for a double-depth drywell).

5. Determine the design outflow rates for a drywell (q_D) by applying the appropriate factor of safety (FS) from Table 4A-1. $q_D = \frac{q_A}{FS}$

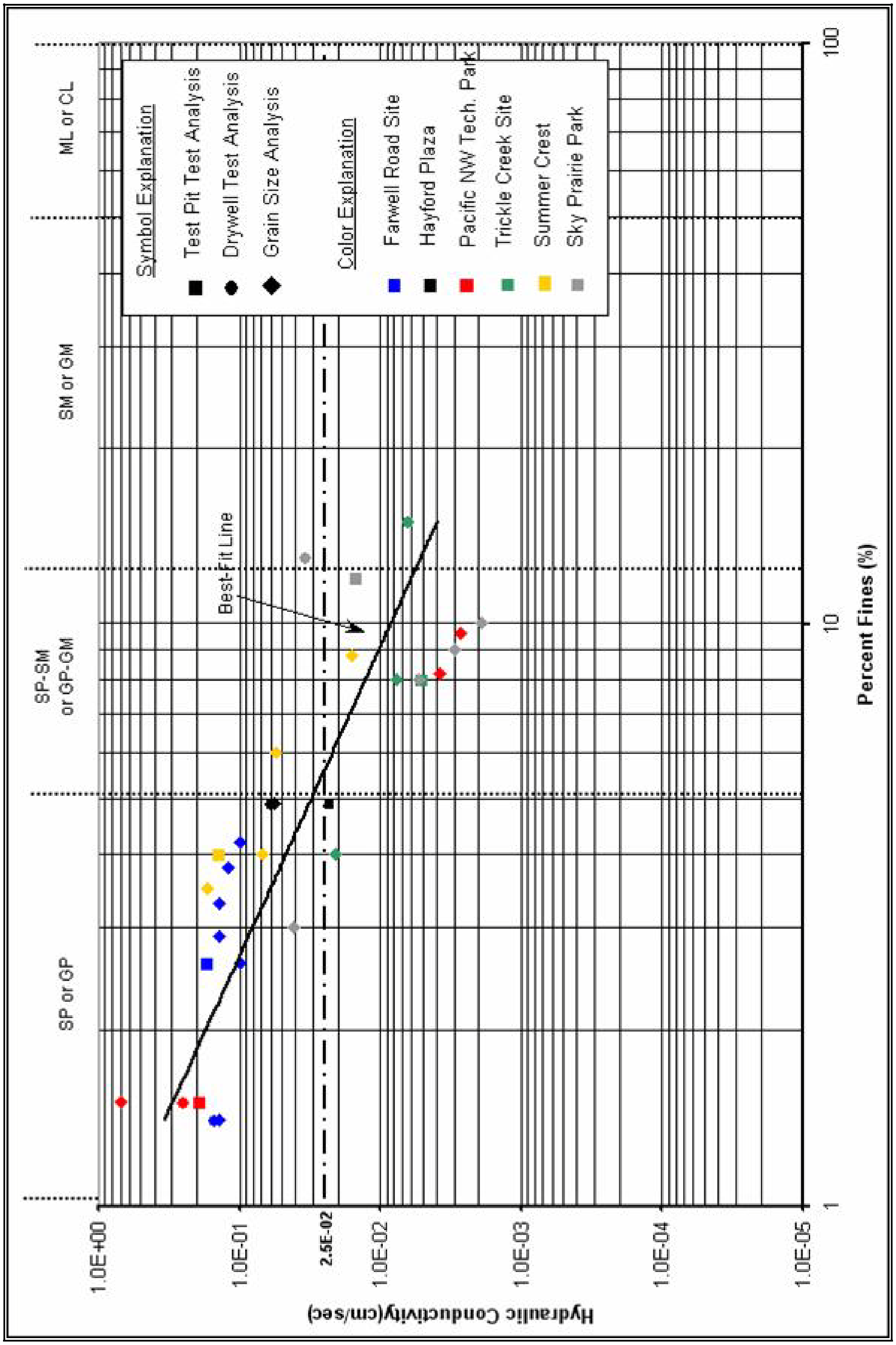

Figure 4A-1 – Percentage of Fines (% passing the No. 200 Sieve) vs. Hydraulic Conductivity (k)

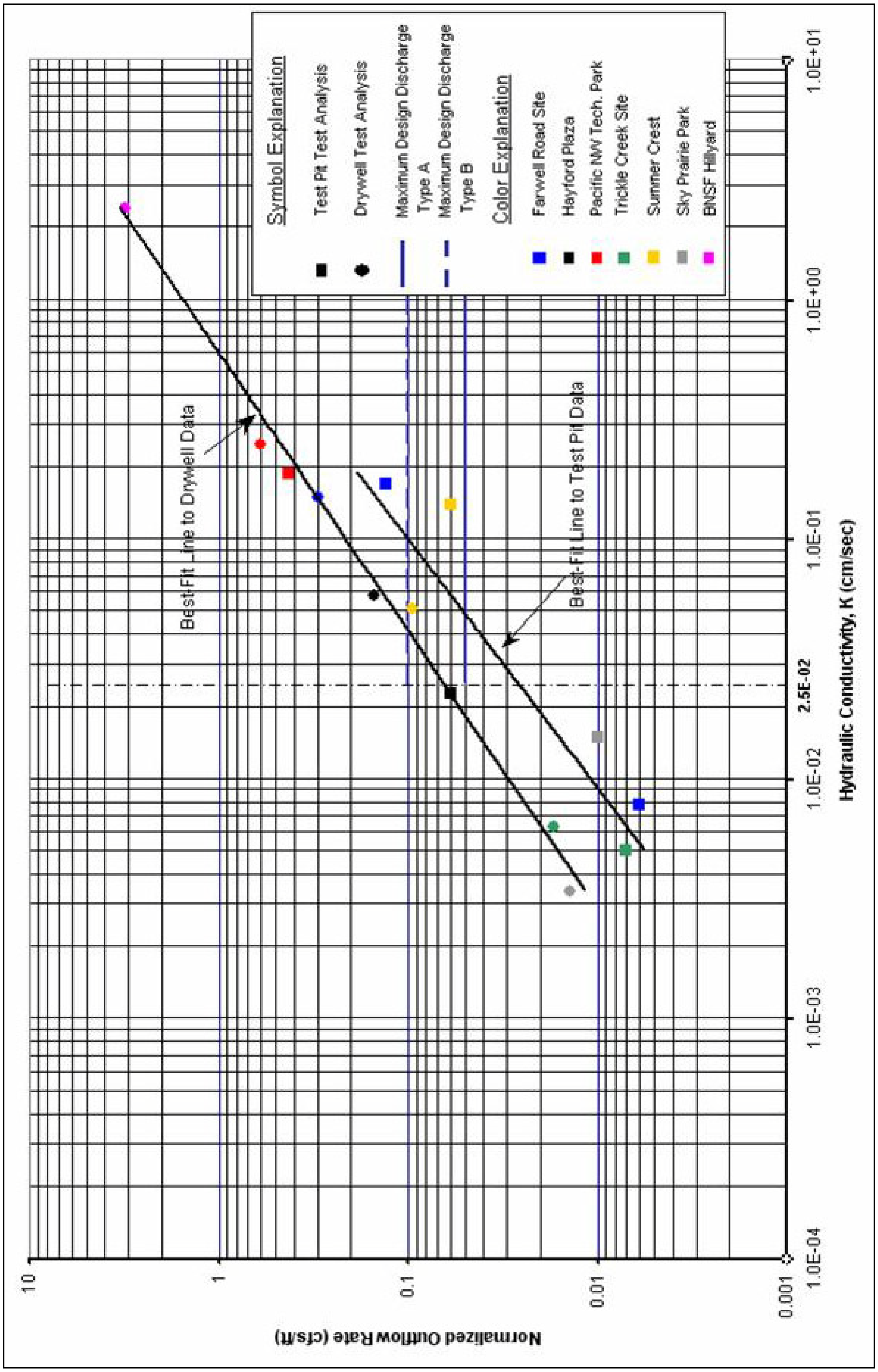

Figure 4A-2 – Hydraulic Conductivity (k) vs. Normalized Outflow Rate

TABLE 4A-1
OUTFLOW RATE FACTORS OF SAFETY
FOR SPOKANE 200 METHOD

Percent Finer than U.S. No. 200 Sieve	Minimum Factor of Safety
0 to 5%	1.3
>5 to 6%	1.5
>6 to 8%	2.0
>8 to 10%	2.3
>10 to 12%	2.7
>12%	not suitable for drywell disposal

The factors of safety listed in Table 4A-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single depth drywells and 10 feet for double depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety from Table 4A-1 shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for a 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4A-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

For infiltration facilities other than drywells, a geotechnical engineer shall make a conservative recommendation for design outflow rates.

6. Hydraulic conductivities estimated using Figure 4A-1 may be used to estimate design outflow rates for infiltration facilities other than drywells.

APPENDIX 4B – FULL-SCALE DRYWELL TEST METHOD

PURPOSE AND APPLICABILITY

The full-scale drywell test method determines the normalized outflow rates for drywells. This testing is required for drywells if requested by the local jurisdiction.

PROCEDURE

1. Install the drywell per the local jurisdiction’s standard plans, specifications and applicable construction guidelines.

2. Inspect the drywell and take photographs, if necessary.

3. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a calibrated 55-gallon barrel.

4. Introduce clean water into the drywell. Monitor flow using an in-line flow meter.

5. Raise the water level in the drywell until it reaches the top of the active barrel section. In the case of drywells interconnected by pipes, raise the water level to the invert elevation of the connecting pipe, or use an expandable pipe plug to seal the connecting pipe.

6. Monitor and record the flow rate required to maintain the constant head level in the drywell at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

7. Maintain the water level in the drywell, by adjusting the flow rate, for a minimum of 2 hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the drywell has reached the top of the active barrel section, or the invert elevation of any interconnecting pipes. The flow rate is considered stable when the water level in the drywell is maintained and the incremental flow rate does not vary by more than 10%.

8. Upon completion of the constant head period, discontinue flow and monitor and record the water level in the drywell at intervals of no longer than 5 minutes, for a 30-minute time period. This time may need to be extended depending upon the soil performance.

CALCULATIONS

1. Calculate the normalized outflow rate (q_A)

$$q_A = \left(\frac{Q}{H}\right) * H_D$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test, in cubic feet per second (cfs);

H = level of water within the drywell (feet); and,

H_D = maximum design drywell head (6 feet for single-depth, 10 feet for double-depth).

2. Determine the design outflow rates for a drywell (q_D). Apply the appropriate factor of safety (FS) from Table 4B-1. When sieve analysis data is unavailable a FS of 2.5 shall be used.

$$q_D = \frac{q_A}{FS}$$

TABLE 4B-1
OUTFLOW RATE FACTORS OF SAFETY
FOR FULL-SCALE DRYWELL TEST METHOD

Percent Finer than U.S. No. 200 Sieve[1]	Minimum Factor of Safety
0 to 5%	1.1
>5 to 6%	1.3
>6 to 8%	1.8
>8 to 10%	2.1
>10 to 12%	2.5
>12%	not suitable for drywell disposal

[1] When no sieve analysis data are available, a factor of safety of 2.5 shall be applied to field-determined outflow rate.

The factors of safety listed in Table 4B-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for a 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4B-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

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APPENDIX 4C – TEST PIT METHOD

PURPOSE AND APPLICABILITY

This test method is used to estimate drywell outflow rates using test pits. This test method may also be used for analyzing non-standard subsurface disposal systems (infiltration galleries, under-drain systems, etc). However, more complex calculations that are not presented in this Manual may be required to correlate the results and substantiate the recommended infiltration rates.

PROCEDURE

1. Excavate a test pit to an elevation such that the walls and the bottom of the test pit expose the target soil layer being tested. As much as practical, excavate the pit to neat-line dimensions, and keep it free of surface slough, organics, and other deleterious material.

2. Measure and record the dimensions (length, width, depth) of the test pit. Include photographs of the test pit.

3. Line the walls and bottom of the pit with a highly porous, non woven, geotextile fabric. Install a vertical, PVC observation pipe in the pit. Then backfill the pit with clean, uniform, pervious, fine gravel; or clean, uniform, pervious, open graded coarse gravel. The omission of the PVC observation pipe and pervious gravel backfill is an allowable practice if the test pit walls will not slough when water is introduced.

4. Introduce clean water into the test pit. Monitor flow using an in-line flow meter. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a calibrated 55-gallon barrel.

5. Raise the water level in the pit until a level consistent with the operating head anticipated in the proposed drainage structure is achieved.

6. Adjust the flow rate as needed to maintain a constant head level in the pit. Monitor and record the flow rate required to maintain the constant head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

7. Maintain the water level in the pit, by adjusting the flow rate, for a minimum of two hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the pit has reached the operating level of the proposed structure. The flow rate is considered stable when the water level in the pit is maintained and the incremental flow rate does not vary by more than 10%.

8. Upon completion of the constant head period, discontinue flow, then monitor and record the water level in the test pit at intervals of no longer than five minutes, for a

30-minute falling head time period. This time may need to be extended depending upon the soil performance.

CALCULATIONS

1. Calculate the normalized outflow rate of the test pit (q_N):

$$q_N = \left(\frac{Q}{H}\right) \qquad \text{(cfs/foot)}$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test (cfs); and,

H = level of water in the test pit (feet).

2. Estimate the hydraulic conductivity of the soil using Figure 4C-1, from Step 1, and the Best Fit Line to Test Pit data. Determine the normalized outflow rate of the drywell (q_{ND}). Enter into Figure 4C-1 on the y-axis with the normalized outflow rate (q_N) calculated in Step 1. Extend a horizontal line from that value until the Best-Fit Line to Test-Pit Data is intersected. From that point, draw a vertical line to the Best-Fit Line to Drywell Data. The normalized outflow rate of the drywell may then be obtained by drawing a horizontal line from that point on the Best-Fit Line to Drywell Data back to the y-axis. Alternatively the test pit equation $q_{ND} = 0.9242\,K^{0.9646}$ may be used, where K is the hydraulic conductivity and q_{ND} is the normalized outflow rate of the test pit. Then the K can be inserted into drywell equation $q_{ND} = 1.5582\,K^{0.8601}$, where K is the hydraulic conductivity and q_{ND} is now the normalized outflow xof the drywell.

3. Calculate the actual outflow rate (q_A):

$$q_A = q_{ND} * H_D \qquad \text{(cfs)}$$

Where: H_D = maximum design drywell head (6 feet for single-depth, 10 feet for double-depth).

4. Determine the design outflow rates for a drywell (q_D). Apply the appropriate factor of safety (FS) from Table 4C-1. When sieve analysis data is unavailable, a FS of 2.5 shall be used.

$$q_D = \frac{q_A}{FS} \qquad \text{(cfs)}$$

For infiltration facilities other than drywells, a geotechnical engineer shall make a conservative recommendation for design outflow rates. The above calculations shall be considered when determining the design outflow rates.

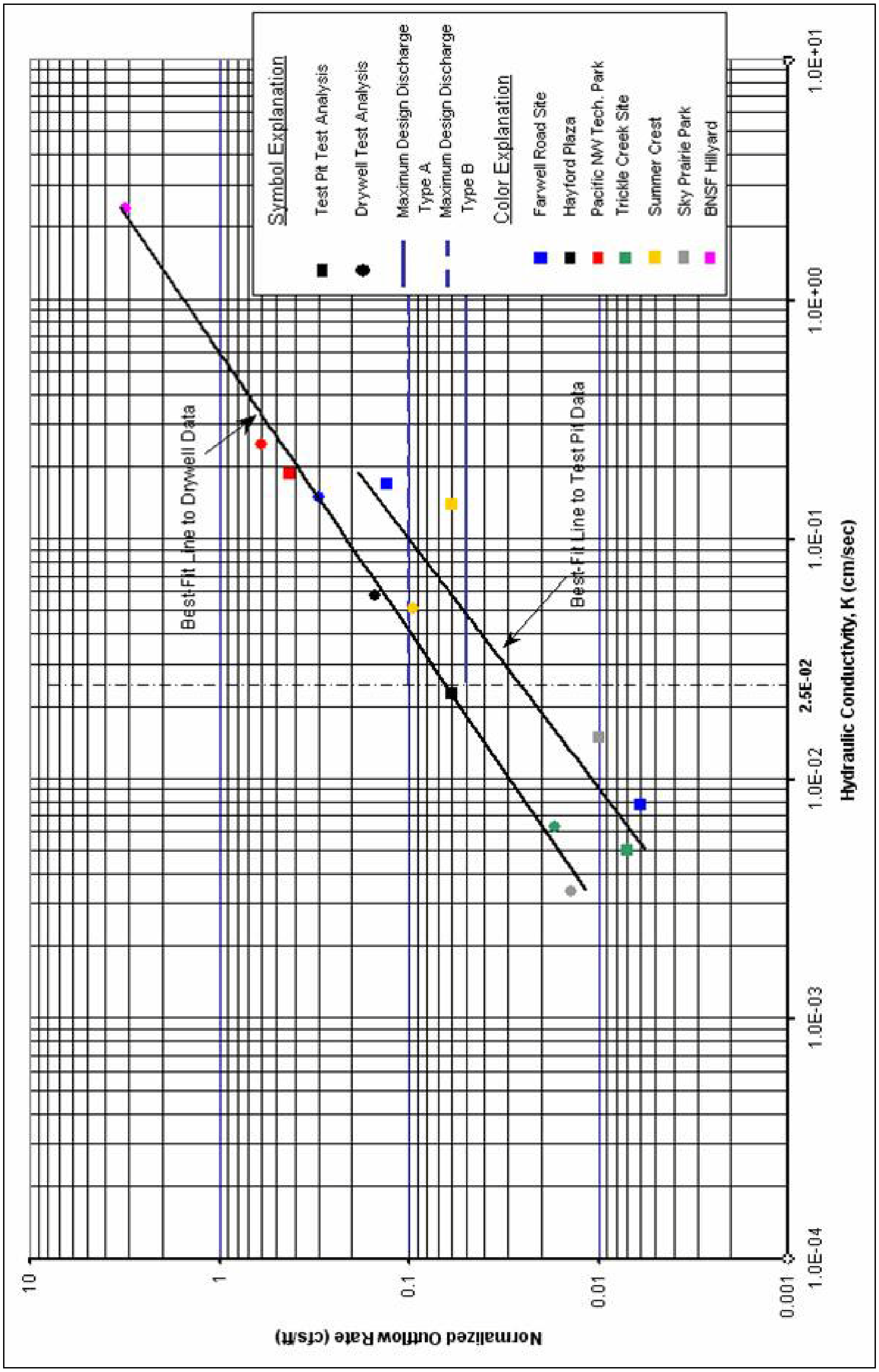

Figure 4C-1 – Hydraulic Conductivity (k) vs. Normalized Outflow Rate

TABLE 4C-1
OUTFLOW RATE FACTORS OF SAFETY
FOR TEST PIT METHOD

Percent Finer than U.S. No. 200 Sieve[1]	Minimum Factor of Safety
0 to 5%	1.1
>5 to 6%	1.3
>6 to 8%	1.8
>8 to 10%	2.1
>10 to 12%	2.5
>12%	not suitable for drywell disposal

[1] When no sieve analysis data are available, a factor of safety of 2.5 shall be applied to field-determined outflow rate.

The factors of safety listed in Table 4C-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety from Table 4C-1 shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for the 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4C-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

APPENDIX 4D – SINGLE-RING INFILTROMETER TEST METHOD

PURPOSE

The single-ring infiltrometer test method is applicable for estimating infiltration and permeability rates of surficial soils to verify drawdown times in bio-infiltration swales and detention ponds.

PROCEDURE

1. Drive, jack, or hand advance a short section of steel or PVC pipe, at least 20 inches long and with a minimum inside diameter of 12 inches and a beveled leading edge, (referred to as a "ring" in this test method) into the soil surface to a depth of about 8 inches, leaving approximately 12 inches of pipe exposed above the ground surface. If after installation the surface of the soil surrounding the wall of the ring shows signs of excessive disturbance such as extensive cracking or heaving, reset the ring at another location using methods that will minimize the disturbance. If the surface of the soil is only slightly disturbed, tamp the soil surrounding the inside and outside wall of the ring until it is as firm as it was prior to disturbance.

2. Introduce clean water into the ring. Use some form of splash guard such as a sheet of thin aluminum or a diffuser apparatus such as a highly porous, non woven, geotextile fabric to prevent erosion at the surface of the soil during filling and testing. Monitor flow using an in-line flow meter. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a 5-gallon bucket or a 55-gallon barrel.

3. Raise the water level in the ring until a head level of at least 6 inches above the soil surface is achieved.

4. Monitor and record the flow rate required to maintain the constant head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

5. Maintain the water level in the ring, by adjusting the flow rate, for a minimum of 2 hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the ring has reached 6 inches above the soil surface. The flow rate is considered stable when the water level in the ring is maintained and the incremental flow rate does not vary by more than 10%.

6. Upon completion of the constant-head period, discontinue flow, and monitor and record the water level in the ring at intervals of no longer than 5 minutes, for a 30-minute period.

7. One single-ring infiltrometer test shall be performed for every 2,500 square feet of bio-infiltration swale/pond bottom area or detention pond bottom area, with a minimum of one per swale or pond or as required by the local jurisdiction.

CALCULATIONS

1. Calculate the surface infiltration rate (I)

$$I = \frac{Q}{A} \qquad \text{(feet/second)}$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test (cfs); and,

A = area of soil inside the ring (square feet).

2. Compute the permeability rate (K)

$$K = \frac{(Q * L)}{(A * H)} \qquad \text{(feet/second)}$$

Where: L = depth of soil contained within the ring (inches);

A = area of soil inside the ring (square feet); and,

H = constant level of water within the ring, measured from the base of the ring to the free water surface (inches).

APPENDIX 4E – SWALE FLOOD TEST

PURPOSE

The swale flood test verifies the path of flow into a swale and the drawdown time of a bio-infiltration swale. The flood test shall be conducted, when required, after the swale has been constructed and the vegetation has been established (i.e. is not in danger of being washed out when water is introduced into the swale).

PROCEDURE

1. Introduce clean water into the swale by directing the water (via hose from a hydrant or other clean water source) along the curb and gutter upstream of the swale inlet.

2. Raise the water level in the swale until it reaches 6 inches in depth (typically to the rim of the drywell or catch basin). Discontinue flow and note the time; this is the beginning of the flood test.

3. If the swale is draining rapidly, the progress is observed, and when the swale is empty, the time is documented, and the flood test has ended.

4. If the swale is not draining, measure the depth of water currently in the swale, documenting the time, and return to the swale site at a later time in order to verify that the swale has completely drained within 72 hours.

NOTE: Contact the local jurisdiction for specific requirements for this Test Method.

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APPENDIX 4F – POND FLOOD TEST

PURPOSE

The Pond Flood Test Method verifies drawdown time of a stormwater disposal facility, such as a detention pond. The pond flood test shall be conducted, when required, after the pond has been constructed, and after vegetation has been established (i.e. is not in danger of being washed out when water is introduced into the pond).

PROCEDURE

1. Introduce clean water into the pond. Use some form of splash-guard or diffuser device to prevent surface erosion of the pond.

2. Raise the water level in the pond until it reaches operational depth (i.e. to the invert elevation of the first outlet device (culvert, orifice, weir, etc.)). Discontinue flow.

3. Document the time and measure the depth of water in the pond; this is the beginning of the pond flood test.

4. The pond's ability to drain is observed. If the pond appears to be emptying rapidly, as soon as the pond is empty, the time is documented, and the flood test has ended.

5. If the pond is not draining, or is draining very slowly, measure the depth of water currently in the pond, documenting the time, and return to the pond site at a later time in order to verify that the pond has completely drained within 72 hours.

NOTE: Contact the local jurisdiction for specific requirements for this Test Method.

Some ponds will be large enough that a pond flood test may not be the most efficient method of determining drawdown time or infiltrative ability. Consideration may need to be given to other types of infiltrative test methods, such as the single-ring infiltrometer test. If the pond flood test is pursued for larger ponds, the local water purveyor must be contacted so that water service is not disrupted.

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