Applicant:
USA Waste of Texas Landfills, Inc.

PERMIT AMENDMENT APPLICATION

FAIRBANKS LANDFILL
PERMIT NO. MSW-1565B
HOUSTON, HARRIS COUNTY, TEXAS

Owner and Operator:
USA Waste of Texas Landfills, Inc.

Physical Site Address:
8205 Fairbanks N Houston Rd
Houston, Texas 77064
(713) 824-6867

VOLUME II OF III

Prepared by:

Geosyntec
consultants
Texas Board of Professional Engineers Firm Registration No. F-1182
3600 Bee Caves Road, Suite 101
Austin, Texas 78746
(512) 451-4003

August 2013

8/26/2013

SCOTT M. GRAVES
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VOLUME III of III

PART IV – SITE OPERATING PLAN

Applicant:
USA Waste of Texas Landfills, Inc.

PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN

FAIRBANKS LANDFILL
PERMIT NO. MSW-1565B
HOUSTON, HARRIS COUNTY, TEXAS

Owner and Operator:
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August 2013

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Prepared for:
USA Waste of Texas Landfills, Inc.

PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN

NARRATIVE REPORT

FAIRBANKS LANDFILL
MSW PERMIT NO. 1565B
HOUSTON, HARRIS COUNTY, TEXAS

Prepared by:
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3600 Bee Caves Road, Suite 101
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August 2013

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STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

8/26/2013

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TABLE

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

8/26/2013

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1. INTRODUCTION

1.1 Terms of Reference

USA Waste of Texas Landfills, Inc. is submitting a Permit Amendment Application to laterally and vertically expand the existing Fairbanks Landfill, a Type IV municipal solid waste (MSW) disposal facility (landfill) located in Houston, Harris County, Texas.

The complete Permit Amendment Application is divided into Parts I through IV as required by 30 TAC §330.57. Part I of the Permit Amendment Application presents site and applicant information. Part II presents an existing conditions summary and information on the character of the facility and surrounding area. Part III presents facility design information, detailed investigative reports, schematic designs of the facility, and required plans. Part IV presents the Site Operating Plan (SOP) which describes the general procedures for conducting day-to-day operations at the facility.

This report and accompanying attachments comprise Part III of the Permit Amendment Application for Permit No. MSW-1565B. Part III addresses the items required by 30 TAC §330.63 by discussing the criteria used in the selection and design of this facility for safeguarding the health, welfare, and physical property of the public and the environment. This Part III narrative report includes discussion of the geology, soil conditions, drainage, land use, zoning, adequacy of access roads and highways, and other considerations specific to this facility.

1.2 Existing Conditions

The facility is located on the northwest side of Houston, outside the Houston city limits (within the extraterritorial jurisdiction of the City of Houston) and approximately 14 miles north of downtown Houston. The facility is located approximately two and a half miles north of US 290 (the Northwest Freeway) and one mile east of Beltway 8 (the Sam Houston Tollway). The facility is located at 8205 Fairbanks N Houston Rd, Houston, Texas, 77064.

The facility is an existing Type IV MSW facility owned and operated by USA Waste of Texas Landfills, Inc., with a permit boundary of 118.1 acres and a disposal footprint of 81.6 acres. The facility initially began disposal operations in about 1984. In about 1990, Sanifill of Texas, Inc. became the permittee under then-Permit No. MSW-1565. In May 1998, the permittee changed its corporate name to USA Waste of Texas Landfills, Inc. In October 1998, Permit No. MSW-1565A was issued, which brought the facility area to a permit boundary of 118.1 acres and a waste disposal footprint consisting of a single landfill unit and an area of 84.1 acres.

Subsequently, in 2002, a minor permit amendment was granted that divided the facility into two landfill units and reduced the waste disposal footprint area to 80.0 acres. Presently, both landfill units (i.e., the entire 80-acre permitted waste disposal footprint) have been constructed, waste has been disposed in the landfill, and the facility is nearing its capacity.

The current facility has a minimum buffer distance from the permit boundary to the limit of waste disposal of 50 feet. The entire existing landfill has a liner meeting the regulatory design criteria for a Type IV landfill facility. Also, the final cover system has been installed over approximately 30.6 acres of the existing landfill, (generally along the west, north, and east sides of the landfill) where final filling grades of Permit MSW-1565A have been reached.

Current ancillary site facilities located outside the permitted waste disposal areas are the entrance facilities (entrance/exit road, scales and scale house/office area), perimeter access roads, surface water drainage features, groundwater monitoring wells, and landfill gas monitoring and control systems. Also, the current permit (MSW-1565A), in addition to waste disposal, authorizes the following processing facilities on-site: (i) a special area to collect large/heavy/bulky items (e.g., appliances) for recycling or salvaging; (ii) a composting operation for leaves, grass clippings, or wood waste (no putrescible waste); and (iii) a wood chipping operation.

1.3 Proposed Expansion

A facility layout plan is presented in Part III, Attachment 3, Drawing 3-1. Inspection of Drawing 3-1 shows that the permit boundary and landfill footprint is proposed to increase towards the east and south. The northern and western limits of the landfill have been constructed, and no changes these existing waste limits are proposed. A minor reduction in the permit boundary is proposed on the west side of the site, to eliminate a small area where facility operations have not occurred and will not occur. No changes are proposed to the existing site entrance/exit location. Table III-1, presented below, summarizes the current permit conditions and the proposed changes.

TABLE III-1

SUMMARY OF CURRENT PERMIT AND PROPOSED EXPANSION - FAIRBANKS LANDFILL

Item	Units	Current Condition (Permit 1565A)	Increase due to Expansion	New Condition (Permit 1565B)
Permit Boundary Area	(acres)	118.1	70.9	188.95
Waste Disposal Footprint Area	(acres)	80.0	57.3	137.3
Buffer/Other Area	(acres)	38.1	13.6	51.7
Buffer/Other Area as a Percentage of Permit Boundary	(percent)	32.3%	19.1%	27.3%
Total Waste Disposal Capacity	(cubic yards)	8,326,000	17,886,000	26,212,000
Remaining Capacity as of 26 March 2012 Aerial Flyover	(cubic yards)	98,000	17,886,000	17,984,000
Projected Remaining Site Life	(years)	0.3	26.7	27.0
Maximum Elevation of Final Cover	(ft, msl)	154.0	96.0	250.0
Elevation of Deepest Excavation	(ft, msl)	51.0	No Change	51.0

As indicated on Attachment 3, Drawing 3-1, the two existing waste disposal units will be joined together to form one combined landfill footprint as part of the expansion. The entire combined landfill footprint will have a contiguous tied-in liner (see Attachment 3, Drawing 3-3) meeting the regulatory-prescribed design criteria for a Type IV landfill facility. Details of the liner system design are discussed subsequently in Section 4 of this report.

Table III-1 indicates that of the proposed 188.95-acre permit boundary, the waste footprint of the landfill will occupy approximately 137.3 acres, and the remaining area of about 52 acres will be used as buffers and other site features (e.g., perimeter access road, surface water ponds, main access road with scales and scale-house/office, etc.).

For Permit MSW-1565B, the filling pattern for waste disposal will start by continuing to fill the existing northern landfill area to higher elevations as the geometry allows for this expansion. Construction of new landfill sectors and subsequent waste filling in those sectors will then progress in the numerical sequence of sectors identified on Attachment 3, Drawing 3-1. More detailed phasing plans showing the excavation and filling sequences was previously presented in a series of drawings in Part II, Appendix IIA of this Permit Amendment Application.

As previously discussed in Part II of the Permit Amendment Application (Section 14.1.1 of the Part II narrative report), there is an existing pipeline easement that crosses the site in a southwest-northeast orientation. This pipeline easement will be relocated to be adjacent to the southern and eastern permit boundaries (see Attachment 3, Drawing 3-1), and the existing easement and associated pipelines will be abandoned. No solid waste unloading, storage, disposal, or processing operations will occur within any easement, buffer zone, or right-of-way that crosses the site. No solid waste disposal will occur within 25 feet of the center line of any utility line or pipeline easement (but no closer than the easement), unless otherwise authorized by the Executive Director.

Right-of-ways (R.O.W.s) as related to compliance with location restrictions were discussed in Section 14.1.1 of the Part II Narrative Report. As discussed, a 100-ft wide corridor on the southern portion of the site has an outdated R.O.W. that was previously established for an older version of a possible road extension called “West Mount Houston Road”. West Mount Houston Road was never built, and is no longer part of the Houston Planning Commission’s *2012 Major Thoroughfare and Freeway Plan*. Instead, this *Major Thoroughfare and Freeway Plan* shows a different road alignment of a future roadway called “West Road” that will pass adjacent to the south portion of the site. Land acquisition for this new West Road has not taken place yet, so the new R.O.W. does not yet exist. The outdated West Mount Houston Road R.O.W. on the southern portion of the site will be abandoned (i.e., swapped to the new West Road location). The permit boundary will not encroach on the new West Road R.O.W. Documentation of coordination with the Harris County Public Infrastructure Department-Architecture and Engineering Division on this issue to establish an agreed-upon West Road alignment to replace the outdated R.O.W. is presented in Part II, Appendix IIM.

Ancillary site facilities located outside the permitted waste disposal areas are the entrance facilities (entrance/exit road, scales and scale house/office area), perimeter access roads, surface water drainage features, groundwater monitoring wells, and landfill gas monitoring and control systems. In addition to waste disposal, the following processing facilities will occur on-site: (i) a special area to collect large/heavy/bulky items (e.g., appliances) for recycling or salvaging; (ii) a wood processing area; and (iii) a construction and demolition (C&D) waste recycling area. These areas are described in the Section 2.3, and their operations are discussed in Part IV (the SOP).

1.4 Land Use and Zoning

An analysis of land use and zoning, and potential impact on the area surrounding the facility, was prepared by the specialty planning firm, TBG Partners Inc. (TBG), Houston, Texas. TBG’s Land Use Study is presented in Part II, Appendix IIB.

1.5 Adequacy of Access Roads and Highways

A Transportation Study evaluating the adequacy of roads and highways and related traffic evaluation was performed by HDR Engineering Inc. (HDR) of Houston and Austin, Texas for this project. The Transportation Study and related documentation of coordination with the Texas Department of Transportation (TxDOT) and other local agencies and school districts is provided in Part II, Appendix IIC.

Access will continue to be provided to the landfill at the existing site entrance/exit on Fairbanks North Houston Road. Regional access to the site is primarily from nearby highways US 290 to the south, or Beltway 8 to the north – both of which lead to Fairbanks N Houston Road, which leads to the site. There are no known weight restrictions on these roads in proximity to the facility, other than the maximum legal weight limit of 80,000 pounds.

1.6 Organization of Part III (Site Development Plan)

The remainder of this report is organized as follows:

- the general facility design is presented in Section 2;
- the facility surface water drainage design is discussed in Section 3;
- the waste management unit design is discussed in Section 4;
- geology and soils topics are addressed Section 5;
- groundwater topics are addressed in Section 6;
- the landfill gas management plan is discussed in Section 7;
- the facility closure plan is discussed in Section 8;
- the facility post-closure plan is discussed in Section 9; and
- cost estimates for closure and post-closure care are discussed in Section 10.

The attachments to the Site Development Plan are organized as follows:

- Attachment 1 provides drawings that present additional information on the general facility design (related to waste movement and access) and the on-site processing facilities and disposal areas;

- Attachment 2 is the Facility Surface Water Drainage Report, with related drawings and calculations;

- Attachment 3 provides the Waste Management Unit Design and related drawings, plans, and calculations for the landfill;

- Attachment 4 is the Geology Report;

- Attachment 5 is the Groundwater Monitoring Plan;

- Attachment 6 is the Landfill Gas Management Plan;

- Attachment 7 is the Closure Plan;

- Attachment 8 is the Post-Closure Plan; and

- Attachment 9 is the Cost Estimates for Closure and Post-Closure Care.

2. GENERAL FACILITY DESIGN

2.1 Introduction

Section 2 of this report has been prepared to address the general facility design topics required by 30 TAC §330.63(b).

2.2 Facility Access Control

This section describes how access will be controlled for the facility, pursuant to 30 TAC §330.63(b)(1). The access controls described below are designed to prevent the entry of livestock, protect the public from exposure to potential health and safety hazards, and to discourage unauthorized entry or uncontrolled disposal of solid waste or hazardous materials. Refer to Section 7 of Part IV (the SOP), for operating requirements related to access control, including the required inspection, maintenance, and notification procedures, as required by 30 TAC §330.131.

Access control to prevent unauthorized access, unauthorized dumping, and public exposure to the landfill is provided by: (i) fencing around the perimeter of the facility; (ii) control features at the main entrance/exit gates; (iii) locked gates at other secondary site access point(s) around the facility perimeter; and (iv) site personnel awareness and observations for maintaining access control. The layout of the fencing around the site perimeter and the location of the main entrance/exit gate are shown on Part III, Attachment 3, Drawing 3-1.

Fencing and gates will serve as the primary landfill access controls. To discourage unauthorized entry into the landfill facility, the perimeter of the facility will be protected by fencing that is at minimum composed of 4-ft high, three-strand barbed wire fence, field fence, or other fence materials.

The site is accessed through an entry gate at the main entrance. Entry to the landfill is restricted to only personnel whose entry is authorized by site management (e.g., the facility employees and contractors, authorized waste haulers, TCEQ personnel, properly identified visitors, etc.). Visitors entering the site are directed to the office location for check-in.

Landfill personnel will direct waste transport drivers to the proper disposal area. There, the drivers will be directed to a specific unloading area. Landfill personnel will also direct drivers needing access to other portions of the facility (e.g., construction contractors). Additionally, when appropriate, signs with directional arrows and/or barricades may be placed along site roads to direct traffic and control interior access.

During normal operating hours, facility personnel will be on duty at the scale house and in the vicinity of landfill operations to control access and disposal operations. When the site is closed, the entry gate will be closed to prevent site access, and locked when no personnel are present on site.

2.3 Waste Movement

2.3.1 Flow Diagram and Schematic Layout

The facility is a Type IV MSW Facility. In accordance with 30 TAC §330.5(a)(2) the facility may accept brush, construction waste, demolition waste, and/or rubbish. The facility may not accept putrescible wastes, conditionally exempt small-quantity generator waste, or household wastes. A more detailed description of the waste stream is included in the waste acceptance plan (Section 2 of the Part II narrative report).

Activities that may take place at the facility are: (i) disposal in the landfill; (ii) recycling or salvaging of large/heavy/bulky items (e.g., appliances); (iii) wood processing; and (iv) recycling/salvaging of construction and demolition (C&D) materials.

A flow diagram indicating the storage, processing, and disposal sequence is presented on Attachment 1, Drawing 1-1.

A schematic layout of the facility, showing the areas dedicated for waste disposal and identifying the processing/storage activities and their locations, is presented on Attachment 1, Drawing 1-2.

2.3.2 Solid Waste Disposal Facility (Landfill)

Drawing 1-2 in Attachment 1 presents an overview of the site layout and identifies the areas dedicated for waste disposal (i.e., the landfill). The landfill is designed, and will be constructed and operated, to meet all applicable TCEQ requirements for Type IV landfills. Section 4 of this report describes the “Waste Management Unit Design”, including the liner and cover system, and related construction details, specifications, and engineering analyses. Additional engineering plans, drawings, specifications, and calculations for the waste management unit design are also referenced in Section 4 and provided as various attachments to Part III. Operational requirements for the landfill are described in Part IV (the SOP).

2.3.3 Solid Waste Storage and Processing Facilities

Special Area to Collect Large/Heavy/Bulky Items (e.g., Appliances). As allowed by Permit MSW-1565A and proposed to continue to be allowed, a special area to stage and store received or salvaged large/heavy/bulky items (e.g., appliances, white goods) may be maintained at the site. This area will either be located on waste within the current landfill footprint, or in areas within the future landfill footprint, as noted on Drawing 1-2. Due to the changing location of access roads and ongoing waste placement, the location of this area may vary over time. The size of the special area to collect these materials may vary, depending on the amount of materials received at a given time. The items will be removed often enough to prevent them from becoming a nuisance or hazard, to preclude the discharge of any pollutants from the area, and to prevent an excessive accumulation of the material at the site. The collected materials will be recycled within 180 days or less, or disposed of at the working face within 180 days of acceptance at the facility. Collected materials that are inert may be reused by the facility.

Wood Processing Area. A wood processing area may be maintained at the site separate from the working face, to facilitate segregation of wood materials (e.g., brush, leaves, grass clippings, other wood materials) and subsequent on-site processing. This area will either be located on waste within the current landfill footprint, or in areas within the future landfill footprint, as noted on Drawing 1-2. Due to the changing location of access roads and ongoing waste placement, the location of this area may vary over time. The stockpile sizes of these materials may vary, depending on the amount of materials received at a given time. The items will be removed often enough to prevent them from becoming a nuisance or hazard, to preclude the discharge of any pollutants from the area, and to prevent an excessive accumulation of the material at the site. The wood materials will be processed and removed from the site within 180 days or less, or disposed of at the working face within 180 days of acceptance at the facility. Wood materials may be reused by the facility.

Potentially-Recyclable Construction and Demolition (C&D) Materials Area. A special area to stage and store potentially-recyclable C&D materials received/salvaged at the facility will be established in an area of the site either located on waste within the current landfill footprint, or in areas within the future landfill footprint, as noted on Drawing 1-2. Due to the changing location of access roads and ongoing waste placement, the location of this area may vary over time. Examples of potentially-recyclable C&D materials include but are not limited to metal, cardboard, plastic, concrete, bricks, shingles, sheetrock, tires, land clearing debris, wood pallets, or other inert materials. The stockpile sizes of these materials may vary, depending on the amount of materials received at a given time. The items will be removed often enough to prevent them from becoming a nuisance, to preclude the discharge of any pollutants from the area, and to prevent an excessive accumulation of the material at the site. The collected materials will be recycled within 180 days or less, or disposed of at the working face within 180 days of acceptance at the facility. Inert C&D materials may be reused by the facility.

2.4 Sanitation and Water Pollution Control at Processing Areas

As described above in Section 2.3, the solid waste processing facilities at the site are the special area for large/heavy/bulky items; the wood processing area; and the C&D recycling area. These areas are associated with materials that are basically inert, which are not expected to result in the need for washing or other cleaning operations (other than general housekeeping for tidiness, fire prevention, and control of storm water runon and runoff). Also, the materials in these areas will be kept in stockpiles on the ground surface, so there will be no appreciable infrastructure constructed (e.g., there are no floors, walls, structures, sump drains, etc.).

Each of these areas is designed to control surface water drainage in the vicinity of the areas, to prevent runoff onto and off of these areas, and will be operated and maintained to manage runon and runoff during peak discharge from the 25-year, 24-hour storm event and to prevent the off-site discharge of waste and contaminated water. This will be accomplished through the installation of runon diversion berms up-gradient from the processing facilities in the same manner as for the active working face – in accordance with the Contaminated Water Management Plan (Appendix IV-A of the SOP). This will prevent excessive storm water from passing through the area and potentially causing any washouts of the areas or the generation of contaminated water. The facility will implement necessary steps to control and prevent the discharge of contaminated water in accordance with the Contaminated Water Management Plan. No discharge of contaminated water shall occur without obtaining specific written authorization from the TCEQ prior to the discharge. The landfill will be operated consistent with §330.15(h) regarding discharge of solid wastes or pollutants into waters of the United States.

Operational requirements for these areas are described in Part IV (the SOP), including additional discussion of surface water controls, fire protection, and contaminated water management.

2.5 Endangered Species Protection

Pursuant to 30 TAC §330.61(n) and §330.551, a site-specific endangered and threatened species assessment was conducted in 2012 by Berg-Oliver Associates, Inc. (Berg-Oliver) of Houston, Texas for this project. The assessment included a review of state and federal reference information and a field survey for threatened or endangered species and their habitats. Berg-Oliver also corresponded with the United States Fish and Wildlife Service (USFWS) and the Texas Parks and Wildlife Department (TPWD) regarding the project and Berg-Oliver's findings. Berg-Oliver's assessment, and related correspondence with the USFWS and TPWD are provided in Part II, Appendix II-I.

Berg-Oliver’s site-specific field survey by a qualified biologist was conducted to check for listed species or suitable habitats for listed species. No federal- or state-listed endangered or threatened species, or any critical habitats for such species, were found at the site. Berg-Oliver’s findings show that ongoing facility development and operation is not expected to cause or result in the destruction or adverse modification of critical habitats or contribute to the taking or harming of any endangered or threatened species.

3. FACILITY SURFACE WATER DRAINAGE REPORT

Pursuant to 30 TAC §330.63(c), a Facility Surface Water Drainage Report is included with Part III. This Report is provided in Part III, Attachment 2. The Facility Surface Water Drainage Report has been prepared to demonstrate that the facility design complies with the requirements of 30 TAC §330.303, and to address the applicable requirements of 30 TAC Chapter 330, Subchapter G. The Report includes a narrative description of the drainage conditions and features at the site under pre-development and post-development conditions and addresses flood protection; and is accompanied by engineering design drawings and supporting hydrology calculations and hydraulic structural design calculations for the site drainage features.

4. WASTE MANAGEMENT UNIT DESIGN

4.1 Introduction

Section 4 of this report presents waste management unit design information, pursuant to 30 TAC §330.63(d)(4). The general facility design was previously addressed in Section 2. Attachment 3 of this SDP provides the supporting engineering drawings, plans, specifications, and calculations for the design of the landfill unit.

4.2 Drawings

A series of engineering drawings presenting details of the waste management unit design are included in Attachment 3, and are listed below.

Drawing 3-1	Facility Layout Plan;
Drawing 3-2	Overall Base Grading Plan;
Drawing 3-3	Overall Final Cover Grading Plan
Drawing 3-4	Landfill Entrance Plan;
Drawing 3-5	Landfill Cross-Section Location Map;
Drawing 3-6	Landfill Cross-Section A-A’;
Drawing 3-7	Landfill Cross-Section B-B’;
Drawing 3-8	Landfill Cross-Section C-C’;
Drawing 3-9	Landfill Cross-Section D-D’;
Drawing 3-10	Landfill Cross-Section E-E’;
Drawing 3-11	General Landfill Construction Design Details I; and
Drawing 3-12	General Landfill Construction Design Details II.

4.3 Provisions for All-Weather Operation

All-weather roadways will be used to provide access during wet weather from the site entrance along Fairbanks North Houston Road (public roadway) to the waste unloading area being used during wet weather. An all-weather road will also be provided around the landfill perimeter. From the site entrance/exit driveway on Fairbanks North Houston Road up to just past the scale area, the site access road is an all-weather asphalt-paved road. After the scale area, the road transitions to an all-weather gravel surface that continues as an internal access road on the landfill to the waste unloading area being used during wet weather. The layout of the entrance facilities and related access roads is shown on Attachment 3, Drawing 3-4. The landfill perimeter access road around the final landfill configuration is shown on Attachment 3, Drawing 3-3.

Additional interior access roads needed to access waste unloading areas will be established by the facility to provide waste vehicle access and facilitate site operations as waste filling progresses. Portions of these interior access roads are shown on the phase development drawings presented previously in the Permit Amendment Application, in Part II Appendix IIA. These interior access roads will lead from the facility entrance road described above and will continue on to the active working face; accordingly their locations will vary as development progresses. Interior roads that will be used by waste vehicles and landfill operations vehicles during wet weather conditions will be surfaced with all-weather material, such as gravel, so that continuous access to waste disposal areas is provided during both wet and dry weather.

The rough gravel road surfacing on the internal roads used to access the active working face will reduce the amount of mud tracked from the disposal area by shaking and pulling mud off the vehicle tires as they exit the disposal area. Then, the paved entrance roads will further minimize tracking of mud from the site onto public roads.

Access road maintenance requirements, including specific provisions addressing control of mud tracking, dust control, and general road cleaning and safety, are provided as required in Part IV (the SOP).

4.4 Proposed Landfill Method

The facility currently operates, and proposes to continue operating, as a multi-level, modified aerial fill landfill, with above and below-grade filling. The general site layout plan is shown in Attachment 1 on Drawing 3-1. Attachment 1, Drawings 3-2 and 3-3 show the liner system base grades and final cover system grades, respectively. Previously in the Permit Amendment Application, in Part II Appendix IIA, phase development drawings were presented showing the sequence of excavation and filling at various points in time during upcoming landfill development.

The excavation side slopes will be configured at 3 horizontal:1 vertical (3H:1V) down to the cell floor, which is generally flat. The final aerial fill side slopes (i.e., above-grade final slopes) will be configured at 4H:1V slopes (i.e., a 25% grade) up to a landfill top deck area sloped upward at three (3) percent to a ridgeline, as shown on Drawing 3-3. The final cover system will be installed incrementally with the landfill development progression as fill areas reach their maximum final waste grade elevations.

4.5 Landfill Depth and Height Statistics

The elevation of deepest excavation is 51 feet above mean sea level (ft, MSL). The maximum elevation of waste is 248 ft, MSL. The maximum elevation of the final cover is 250 ft, MSL.

4.6 Estimated Rate of Solid Waste Deposition and Site Life

The landfill volume, estimated rate of solid waste deposition, and the resulting site life estimate is presented in Attachment 3B. For reference, a description of the waste characteristics, anticipated facility service area, and a five-year projection of the estimated maximum annual waste acceptance rate is presented in the “waste acceptance plan” in Part II of the Permit Amendment Application as required by 30 TAC §330.61(b).

4.7 Landfill Cross Sections

A series of landfill cross sections is provided in Attachment 3A (see Drawings 3-6 through 3-10). These cross sections have been selected to pass through key site features so as to accurately depict the existing and proposed depths of all fill areas within the site. The sections show the top of the perimeter berm; top of the proposed fill (top of the final cover); maximum elevation of proposed waste fill; top of the wastes; existing ground; bottom of the excavations; side slopes of trenches and fill areas; gas monitoring probes; groundwater monitoring wells, plus the initial and static levels of any water encountered. The cross-sections also show the logs of soil borings that pass near the profile. The 100-year flood elevation in Rolling Fork Creek is identified on the sections that pass through the west side of the site next to the creek.

4.8 Landfill Construction Design Details

Landfill construction design details are also presented in Attachment 3A (see Drawings 3-11 and 3-12), to accompany the previously mentioned cross section. The cross sections call-out the design details (e.g., liner system, cover system, perimeter berm), which are then presented on the construction design details drawings.

4.9 Liner System Design and Liner Quality Control Plan

The proposed liner system for the facility is shown on an engineering detail on Attachment 3A, Drawing 3-11, and is described as follows (from bottom to top):

- 3-ft thick recompacted clay liner having a coefficient of permeability no greater than 1 x 10^{-7} cm/sec (i.e., $k \leq 1 \times 10^{-7}$ cm/sec); and
- 1-ft thick protective cover layer.

The existing landfill sectors have already been constructed and approved with either the above type of liner system, or for older sectors, in-situ liner on floor areas. Therefore the entire combined landfill footprint, once constructed, will form a contiguous tied-in liner beneath the facility meeting TCEQ's liner design criteria for a Type IV landfill facility.

Pursuant to 30 TAC §330.63(d)(4)(G), a Liner Quality Control Plan (LQCP), prepared to meet the applicable requirements of 30 TAC §330.339, is presented in Attachment 3C.

4.10 Geotechnical Analyses of Landfill Design

Geotechnical engineering analyses of the landfill design have been conducted to evaluate the structural integrity of the landfill and underlying foundation. These analyses are as follows (with their location within Attachment 3D noted in parentheses):

- Geotechnical Report (Attachment 3D.1), presenting the soils data collected during site investigations, the results of geotechnical laboratory testing, describing the findings on the suitability of soil conditions, and describing the selection of relevant geotechnical parameters. This attachment has been prepared to include, among other things, the geotechnical information required by 30 TAC §330.63(e)(5).
- Slope Stability (Attachment 3D.2), analyzing the ability of the landfill features and foundation materials to resist driving forces which could have the potential to induce sliding of slopes at the site, and the calculated factors of safety against these events.
- Settlement (Attachment 3D.3), calculating the predicted foundation settlements caused by the landfill loads, and evaluating the magnitude of total and differential settlements and whether they are within acceptable tolerances.

- Liner Uplift, Dewatering System, and Ballast Evaluation (Attachment 3D.4), evaluating the conditions that may lead to special liner design constraints and the design of these associated features.

4.11 Final Cover System Design and Quality Control Plan

The proposed final cover system for the facility is shown on an engineering detail on Attachment 3A, Drawing 3-11, and is described as follows (from bottom to top):

- 1.5-ft thick compacted soil layer composed of clayey soil, classified by the Unified Soils Classification System (USCS) as "SC" (sandy clay), "CL" (lean clay), or "CH" (fat clay); and

- A 6-inch or 12-inch thick topsoil layer(1) capable of sustaining native plant growth, and seeded immediately following the application of final cover.

(1)If the underlying compacted soil layer is classified as SC or CL, the minimum topsoil thickness is 6-inches. If the underlying compacted soil layer is classified as CH, the minimum topsoil thickness is 12-inches.

Other types of soil may be used with prior written approval from the Executive Director.

To date, approximately 30.6 acres of the existing landfill have been covered and approved as final capped with a final cover system meeting the above requirements. Approval of the landfill expansion for Permit MSW-1656B will result in the ability to fill additional waste to higher elevations, which will result in some of the existing final cover being sacrificed and filled over. A portion of the existing final cover along the perimeter edges of the northern and western slopes will remain in-place. As adjacent areas of the landfill achieve final waste grades, the final cover system will be installed incrementally and tied-in to adjacent completed areas. Once completed, the entire landfill will be capped with a contiguous final cover system of the same type, and that meets TCEQ's standard prescribed final cover system for a Type IV landfill facility.

A Final Cover Quality Control Plan (FCQCP) has been prepared and is included in Attachment 7 (Closure Plan), providing the design and specifications for the final cover, to meet the applicable requirements of 30 TAC §330.453.

4.12 Final Cover Erosion Protection

The final cover system has been designed to minimize soil loss from erosion. The surface of the final cover system will be vegetated. Drainage terraces are specified as part of the surface water management system (see Attachment 2A, Drawing 2-1) to intercept surface water runoff and limit the length of overland sheet flow. The terraces will direct the runoff into downchutes which will convey the runoff into the perimeter ditch/pond system. These surface water conveyance features are designed to handle the calculated design flow rates, velocities, and tractive stresses (design details and calculations are presented in the Facility Surface Water Drainage Report in Attachment 2). Also, a calculation of the predicted soil erosion loss on the final cover system, with results demonstrating that the final cover is designed with adequate resistance to erosion, is presented in Attachment 3E.

It is also noted that the final cover will be periodically inspected for signs of erosion and ponding of water, and maintained/repaired as necessary during the active life and post-closure care period of the site, as described in Part IV (the SOP) and Part III, Attachment 8 (Post-Closure Plan), respectively.

5. GEOLOGY REPORT

A Geology Report is presented in Part III, Attachment 4. This Geology Report was prepared by the professional geoscientist-of-record for the application, with the firm Biggs & Mathews, Inc., Ft. Worth, Texas. The Geology Report addresses the information required in 30 TAC §330.63(e) with the exception of the geotechnical data required by 30 TAC §330.63(e)(5)(A) and (B), which was prepared by Geosyntec's geotechnical engineer and is presented in Part III, Attachment 3D.1.

In summary, the Geology Report includes descriptions of the regional geology and hydrogeology, geologic processes, regional aquifers, subsurface investigations, and addresses geologic faults and seismicity.

The Geotechnical Report prepared by Geosyntec and presented in Part III, Attachment 3D.1 includes data on the geotechnical properties of the subsurface soil materials and a discussion on the suitability of the soils and strata for the uses for which they are intended.

6. GROUNDWATER MONITORING PLAN

A Groundwater Monitoring Plan is presented in Part III, Attachment 5. This Plan was prepared by the professional geoscientist-of-record for the application, with the firm Biggs & Mathews, Inc., Ft. Worth, Texas. The Groundwater Monitoring Plan addresses the information required in 30 TAC §330.63(f) and the applicable requirements of 30 TAC §330.401 through §330.421 for Type IV Landfills. The Plan includes identification of the point of compliance; an analysis of potential contaminant pathways; details of the required groundwater monitoring program; and the groundwater sampling and analysis plan.

7. LANDFILL GAS MANAGEMENT PLAN

Pursuant to 30 TAC §330.63(g), a facility Landfill Gas Management Plan is included with Part III. This Plan is provided in Part III, Attachment 6. The Landfill Gas Management Plan has been prepared to meet the requirements of 30 TAC §330.371 for Type IV Landfills. This includes the requirements for landfill gas monitoring at the perimeter permit boundary and in on-site structures, and procedures to be followed if excessive methane gas levels are measured.

8. CLOSURE PLAN

Pursuant to 30 TAC §330.63(h), a facility Closure Plan is included with Part III. This Plan is provided in Part III, Attachment 7. The Closure Plan has been prepared to meet the requirements of 30 TAC §330.453 (closure requirements for Type IV Landfills). This includes a description of the final cover system, a discussion of closure activities, drawings and sections, and closure specifications for the construction of the landfill final cover.

9. POST-CLOSURE PLAN

Pursuant to 30 TAC §330.63(i), a facility Post-Closure Plan is included with Part III. This Plan is provided in Part III, Attachment 8. The Post-Closure Plan has been prepared to meet the requirements of 30 TAC §330.463. This includes discussions on post-closure care activities to maintain the facility following closure, persons responsible for the activities, and planned post-closure use of the facility.

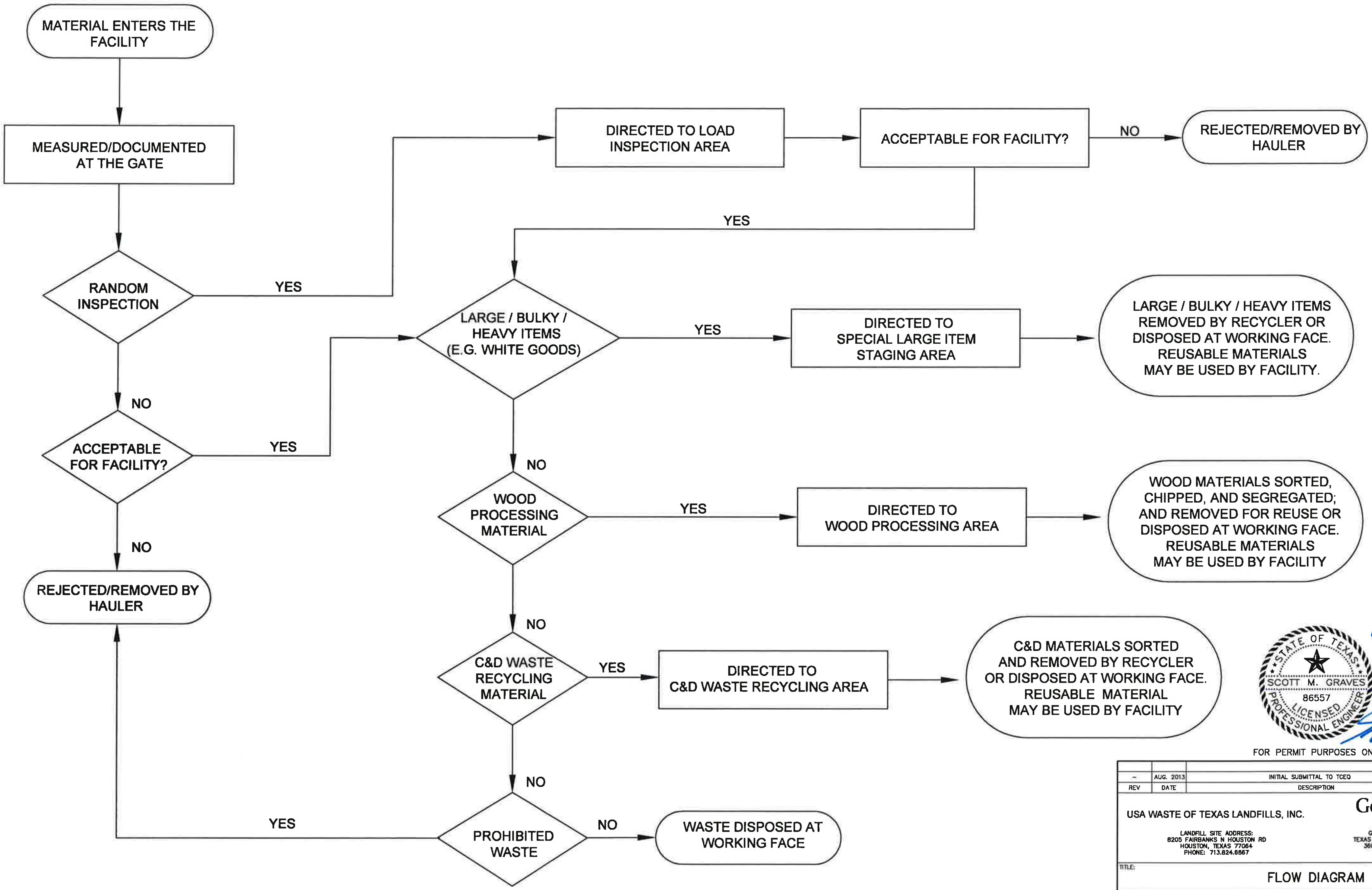
10. COST ESTIMATES FOR CLOSURE AND POST-CLOSURE CARE

Pursuant to 30 TAC §330.63(j), cost estimates for closure and post-closure care are included with Part III. This information is provided in Part III, Attachment 9. The closure cost estimate has been prepared to meet the requirements of 30 TAC §330.503, and the post-closure care cost estimate has been prepared to meet the requirements of 30 TAC §330.507. Documentation on financial assurance is included with Attachment 9.

ATTACHMENT 1

GENERAL FACILITY DESIGN

LIST OF DRAWINGS		
Drawing No.	Title	Drawing Date (latest revision)
1-1	Flow Diagram	August 2013
1-2	Schematic Plan of General Facility Design	August 2013



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8/26/2013

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REV	DATE	DESCRIPTION	DRN	APP
–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

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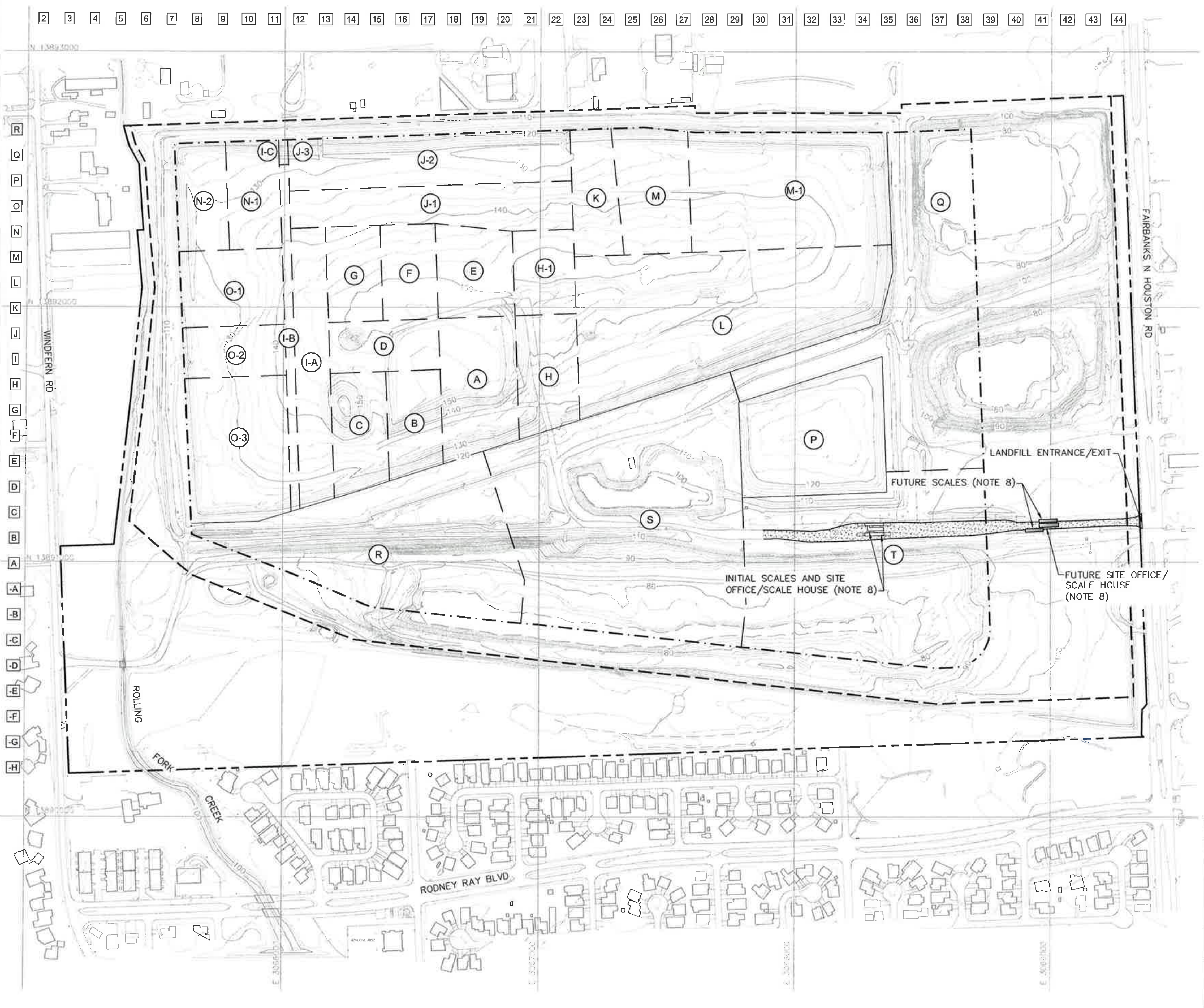
TITLE:
FLOW DIAGRAM

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.:	TXL0263	DESIGN BY:	SMG	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P1-1	DRAWN BY:	JJV	APPROVED BY:	SMG	III	1–1

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P1-1.dwg PLOTTED: Aug 19, 2013 – 11:01am



LEGEND

- 100 — EXISTING GROUND ELEVATION (FT, MSL) (NOTE 1)
- EXISTING ROAD (NOTE 7)
- EXISTING WATER LINE
- N 13893000 E 3053000 — STATE PLANE COORDINATES (NOTE 2)
- 44 — SITE GRID
- PROPERTY BOUNDARY
- EXISTING (PERMIT MSW-1565A) LANDFILL FOOTPRINT
- EXISTING ASPHALT-PAVED SITE ACCESS ROAD (NOTE 7)
- PERMIT BOUNDARY
- PROPOSED LANDFILL FOOTPRINT
- SECTOR BOUNDARY
- Ⓠ SECTOR DESIGNATION

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED BY THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD-83).
3. EACH LANDFILL DISPOSAL SECTOR WILL RECEIVE THE SAME TYPE OF WASTES, WHICH ARE THOSE WASTES ALLOWED FOR DISPOSAL AT A TYPE IV MSW LANDFILL FACILITY AND AS INDICATED IN THE PERMIT MSW-1565B.
4. THE ACTIVE WASTE DISPOSAL AREA WILL MOVE AS LANDFILLING PROGRESSES. SECTORS A-P ARE ALREADY CONSTRUCTED AND FILLING IS IN PROGRESS. SECTORS Q-T ARE PROPOSED SECTORS FOR THE LATERAL EXPANSION. LANDFILL DEVELOPMENT (EXCAVATION, LINING, AND FILLING) SEQUENCE OF PROPOSED NEW SECTORS WILL BE IN THE ALPHABETICAL ORDER OF THE SECTORS SHOWN. REFER TO DRAWINGS IIA-13 THROUGH IIA-16 FOR PHASE DEVELOPMENT LAYOUT PLANS SHOWING THE FILLING SEQUENCE AND CONFIGURATION. SECTORS MAY BE FURTHER SUBDIVIDED AT THE FACILITY'S DISCRETION.
5. THE WASTE PROCESSING AND STORAGE FACILITIES AT THIS SITE ARE:
   - SPECIAL AREA FOR LARGE/HEAVY/BULKY ITEMS (E.G. APPLIANCES) FOR RECYCLING OR SALVAGING.
   - WOOD PROCESSING AREA.
   - CONSTRUCTION AND DEMOLITION (C & D) WASTE RECYCLING AREA.
6. THE WASTE PROCESSING AND STORAGE FACILITIES INDICATED ON NOTE 5 WILL MOVE AS LANDFILLING PROGRESSES, BUT WILL ALWAYS BE LOCATED WITHIN THE LIMITS OF THE PROPOSED LANDFILL FOOTPRINT SHOWN ON THIS DRAWING, TO MAINTAIN THE SET-BACK DISTANCES FROM SITE BUFFERS.
7. MAIN ENTRANCE ROAD IS ASPHALT-PAVED WHERE SHOWN. FROM WHERE THE ASPHALT ENDS, THE ROADS USED TO ACCESS FILL AREAS ARE ALL-WEATHER (E.G. GRAVEL).
8. SCALES AND SITE OFFICE/SCALE HOUSE WILL BE RELOCATED FROM INITIAL LOCATION TO FUTURE LOCATION WHEN LANDFILL DEVELOPMENT AFFECTS THE INITIAL LOCATION (AT THE LATEST). REFER TO PART III, DRAWING 3-4 FOR MORE INFORMATION.

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8/26/2013

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PERMIT DRAWING

-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG
REV	DATE	DESCRIPTION	DRN	APP

USA WASTE OF TEXAS LANDFILLS, INC.

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TITLE:
SCHEMATIC PLAN OF GENERAL FACILITIES DESIGN

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.: TXL0263	DESIGN BY: SMG	REVIEWED BY: SMG	PART NO.: III	DRAWING: 1-2
FILE: 0263P1-2	DRAWN BY: JJV	APPROVED BY: SMG		

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P1-2.dwg PLOTTED: Aug 23, 2013 - 8:44am

ATTACHMENT 2

FACILITY SURFACE WATER DRAINAGE REPORT

Prepared for:
USA Waste of Texas Landfills, Inc.

PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN
ATTACHMENT 2

FACILITY SURFACE WATER DRAINAGE REPORT

FAIRBANKS LANDFILL
PERMIT NO. MSW-1565B
HOUSTON, HARRIS COUNTY, TEXAS

Prepared by:

Geosyntec consultants

Texas Board of Professional Engineers Firm Registration No. F-1182
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8/26/2013

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August 2013

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8/26/2013

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STATE OF TEXAS
SCOTT M. GRAVES
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8/26/2013

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ATTACHMENTS

Attachment 2A	Surface Water Management System Drawings
Attachment 2B	On-Site Drainage Analysis - Hydrology
Attachment 2C	On-Site Design – Surface Water Pond Appurtenances Design Calculations
Attachment 2D	On-Site Design – Drainage Terraces and Downchute Channels
Attachment 2E	On-Site Design – Culvert and Perimeter Drainage Channels
Attachment 2F	On-Site Design – Active Face Surface Water Controls
Attachment 2G	HCFCD Determination – No Adverse Impacts to Off-Site Watershed
Attachment 2H	Intermediate Cover Erosion and Sediment Control Plan (ICESCP)

1. INTRODUCTION

1.1 Purpose

Pursuant to 30 TAC §330.63(c), this Facility Surface Water Drainage Report (Drainage Report) has been developed as part of the Permit Amendment Application for the proposed expansion of the Fairbanks Landfill, Houston, Texas. This Drainage Report has been prepared to demonstrate that the facility design complies with the requirements of 30 TAC §330.303, and to address the applicable requirements of 30 TAC Chapter 330, Subchapter G. The Report includes a narrative description of the drainage conditions and features at the site under pre-development and post-development conditions and addresses flood control; and is accompanied by engineering design drawings and supporting hydrology calculations and hydraulic structural design calculations for the site drainage features. Specific goals of this Drainage Report are to:

- present an overview of the project, site/watershed setting, and information on the site in relation to the 100-year floodplain;

- describe the current-permitted site conditions and establish the pre-development drainage conditions;

- summarize the proposed surface water management system design and describe the drainage features and components within the facility area;

- describe the post-development drainage conditions;

- describe the hydrologic method and design parameters used to estimate peak flow rates and runoff volumes;

- compare pre-development versus post-development discharges from the site and provide discussion and analyses to demonstrate that the existing pre-development drainage patterns will not be adversely altered as a result of the proposed landfill development;

- describe the hydraulic methods and design parameters used to size the features and components of the surface water management system, and present the structural design of these facilities;

- present the erosion and sediment control information, including requirements for surface water inspections and maintenance;

- address protection from 100-year frequency flooding; and
- present overall conclusions that summarize the results of the drainage analysis and design.

1.2 Project Overview

The Fairbanks Landfill is an existing Type IV Municipal Solid Waste (MSW) Facility located on the northwest side of Houston, outside the Houston city limits and approximately 14 miles north of downtown Houston. The facility is located approximately two and a half miles north of US 290 (the Northwest Freeway) and one mile east of Beltway 8 (the Sam Houston Tollway). Location maps are presented elsewhere in the Permit Amendment Application (e.g., Part II, Appendix IIA). The current-permitted facility (Permit No. MSW-1565A) has a permit boundary of 118.1 acres and a waste disposal footprint occupying 80 acres.

A lateral and vertical expansion of the facility is proposed in this Permit Amendment Application (MSW-1565B). The permit boundary is proposed to increase to 188.95 acres, and the waste disposal footprint area is proposed to increase to approximately 137.3 acres. The remaining acreage not used for waste disposal will be utilized for buffer zones, entrance facilities (entrance/exit road, scales and scale house/office area), perimeter access roads, surface water drainage features, groundwater monitoring wells, and landfill gas monitoring and control systems.

A series of engineering drawings are presented in Attachment 2A of this Drainage Report to present the surface water management system design and associated drainage features. Drawing 2-1 in Attachment 2A introduces the proposed facility drainage design, by presenting the "Surface Water Management System Plan", and shows the location of the landfill and identifies the associated drainage facilities and features.

1.3 Site Setting and Watershed Information

The site is located in central Harris County. In Harris County, the Harris County Flood Control District (HCFCD) manages watershed-wide surface water drainage and flood control issues. The site is part of the White Oak Bayou watershed. White Oak Bayou originates northwest of the site area and flows generally toward the southeast. The Bayou drains areas in northwest portions of the county as well as the City of Jersey Village and portions of the City of Houston. White Oak Bayou joins Buffalo Bayou near downtown Houston. The watershed covers about 111 square miles and includes three primary streams: White Oak Bayou, Little White Oak Bayou, and Cole Creek.

More specifically, Rolling Fork Creek (HCFCD Unit No. E125-00-00) flows in a southerly direction on the western side of the site. Rolling Fork Creek is a tributary of White Oak Bayou (HCFCD Unit No. E100-00-00), and joins White Oak Bayou approximately 1.4 miles south of the site.

Clean surface water runoff from the existing facility is managed through drainage terraces, downchute channels, and perimeter channels which are routed towards an on-site surface water pond; after passing through the surface water pond, the surface water runoff is discharged to Rolling Fork Creek. The proposed landfill expansion will have similar surface water management features, and will continue to route surface water in this same general manner, to pass through surface water ponds and discharge into Rolling Fork Creek in the southwest portion of the site very near the existing site outfall location.

1.4 100-Year Floodplain Information

TCEQ rules for the siting of landfills include a location restriction in 30 TAC §330.547, which specifies that no solid waste disposal operations shall be permitted in Federal Emergency Management Agency (FEMA)-defined 100-year floodways; and that new municipal solid waste management units, existing municipal solid waste units, and lateral expansions that are located in 100-year floodplains must meet certain additional requirements. The facility will meet this location restriction and will not be located in a 100-year floodway, nor will the landfill unit be located in 100-year floodplains. A demonstration of compliance with this location restriction is provided in Part II of the Permit Amendment Application (see Part II Narrative Report, Section 10.1) as required by 30 TAC §330.61(m)(1). An overview of this information is presented below.

The site and vicinity are part of FEMA Flood Insurance Rate Map (FIRM) Panel Number 48201C0445L (June 18, 2007). Map revisions have been subsequently approved, but the 2007 version of the full FIRM panel has not yet been physically revised by FEMA to reflect the post-2007 revisions. These previously approved revisions include the following relevant approved map revisions in the site vicinity:

- Conditional Letter of Map Revision (CLOMR) Case No. 97-06-307R (issued August 25, 1997); and
- Letter of Map Revision (LOMR) Case No. 08-06-1925P (issued February 26, 2009).

A map showing the resulting FEMA defined 100-year floodplain location in relation to the existing Fairbanks Landfill is presented in Part II (see Drawing IIG-1, in Appendix IIG). The conclusions of the floodplain evaluation are as follows:

- the facility's landfill disposal limits are not and will not be within the 100-year floodway;
- the 100-year flood profile elevations in Rolling Fork Creek adjacent to the site range from an elevation of about 108 ft above mean sea level (ft, MSL) next to northern portions of the site, to 105 ft, MSL next to southern portions of the site;
- neither the existing constructed landfill, nor the proposed expansion landfill disposal limits are within the 100-year floodplain; and
- additionally, the limit of fill construction of not just the landfill itself, but also the ancillary landfill-related features proposed by this Permit Amendment Application (e.g., the landfill perimeter berms, the surface water pond berms), are outside of the 100-year floodplain.

Additional information on protection of the facility from flooding is discussed in Section 7 of this Report, after details of the proposed design and resulting analyses are presented.

2. DESCRIPTION OF THE PRE-DEVELOPMENT CONDITION

From review of USGS maps showing the topography of the natural conditions of the site prior to development/disturbance activities (e.g., Part II, Appendix IIA, Drawing IIA-3), the conditions before the landfill existed can be described as generally flat, with gradual mild slopes that tend towards the west towards Rolling Fork Creek. The natural ground elevations of the site ranged from approximately an elevation of 115 feet above mean sea level (ft, MSL) in the northeastern part of the site, to just under an elevation of 100 ft, MSL at the downstream side of Rolling Fork Creek in the southwestern portion of the site. As mentioned previously, the existing landfill has been largely developed, which has changed the conditions within the current permit boundary to be those permitted rather than the pre-landfill natural conditions.

Therefore, the pre-development drainage areas encompass the existing facility, the expansion area, and off-site drainage areas that contribute runoff to the site. This will allow a proper comparison to post-development conditions at the common point-of-interest (the discharge point where water exits the site to Rolling Fork Creek), as discussed later in this report. Accordingly, the pre-development conditions are defined as follows:

- Within the current permit boundary (MSW-1565A), the pre-development conditions are the permitted condition.

- Within the expansion areas being added by Permit MSW-1565B, the pre-development conditions are the natural conditions described above, taken from the USGS topographic map.

- Other off-site areas that contribute runoff onto the site are also delineated using the existing topography of those conditions.

The pre-development conditions and resulting drainage areas are delineated on Drawing 2-2, presented in Attachment 2A of this Drainage Report. Inspection of Drawing 2-2 shows that the pre-development drainage area is 205.2 acres, which flows to a single exit point to Rolling Fork Creek in the southwest portion of the site.

Drawing 2-2 also indicates the calculated peak flow rate and the volume of runoff discharged from the site for the 25-year, 24-hour storm event under pre-development conditions. A description of the hydrologic method and design parameters is presented subsequently in this Report.

3. PROPOSED SURFACE WATER MANAGEMENT SYSTEM

3.1 General

This section summarizes the proposed surface water management system design and describes the drainage features and components within the facility. The facility will have above and below grade waste filling over lined areas. A series of drawings presenting the liner base (excavation) grades, the site configuration during phased development and waste filling, and the landfill completion plan, are presented in Part II of the Permit Amendment Application (see Drawings IIA-12 through IIA-17). As described below, certain permanent components of the overall site surface water management system will be constructed during initial development of a cell, while other components will be installed as portions of the landfill reach final grade or at the time of closure.

As mentioned, specific to this Drainage Report, a series of engineering drawings are presented in Attachment 2A to present the surface water management system design and associated drainage features. Drawing 2-1 in Attachment 2A of this Drainage Report presents the final configuration of the landfill and the related surface water management system features. As shown, the landfill will have overall sideslopes inclined at 4 horizontal to 1 vertical (4H:1V) (i.e., 25%). At the crest of the final cover sideslopes, the final cover grades then continue up at a shallower top-deck grade of three percent (3%), up to a peak (ridgeline) elevation. In this Drainage Report, final cover slope areas with grades of 3% are designated as top deck areas, and final cover slopes with overall grades of 4H:1V are designated as sideslope areas.

3.2 Surface Water Management System Components

Various surface water management system components collect and convey surface water from the final cover system to the discharge point from the site, as described below. The sizing and hydraulic design of these features is described later in this Drainage Report, in Section 5 (which references detailed calculation packages presented as attachments included with this Drainage Report).

Drainage Terraces and Downchutes. Sideslope drainage terraces installed as “tack-on” berms on the final cover sideslope will intercept surface water runoff (i.e., sheet flow) along the up-gradient sideslope areas of the final cover, and convey runoff to downchute channels. Similar drainage terraces will be constructed at the crest of the landfill sideslope, on the top deck of the final cover, to collect and convey sheet flow runoff from the 3% slope top deck surfaces to the downchute channels. Trapezoidal shaped downchute channels oriented essentially perpendicular to the landfill slopes (i.e., down-slope) will collect the runoff from the top deck and sideslopes and convey this runoff to the landfill perimeter at the toe of the cover system sideslopes. These downchute channels will be lined with an articulated concrete block (ACB) material, or equal, to resist hydraulic forces from the water flowing in these channels.

<u>Perimeter Channel</u>. The western and northern sides of the landfill are existing, and include perimeter channels to convey runoff from drainage terraces and downchutes, and any contributing sheet flow, around the landfill and into surface water ponds. The proposed expansion will continue to route runoff from the western and northern sides of the landfill in this manner, using the same alignment and slopes as the existing perimeter channels. Due to the additional drainage areas contributing to these perimeter channels, they will need to convey larger peak flows than the existing perimeter channels and therefore in some cases will be widened to provide the additional capacity requirements. The perimeter drainage channels around the west and north sides of the site have a single high-point (see Drawing 2-4), approximately mid-way along the northern side of the site. One side of the channel high-point will convey flow eastward, into the Northeast Surface Water Pond. The other side of the channel high-point will convey flow westward and then southward around the landfill perimeter and into the South Surface Water Pond.

<u>Surface Water Ponds</u>. Two surface water ponds are proposed (see Drawing 2-1): a Northeast Surface Water Pond; and a South Surface Water Pond. It is noted that the term “surface water pond” is used because the ponds are intended to provide a detention function (controlling the rate of surface water release from the site), as well as provide a sediment control/water quality function.

The two surface water ponds will be hydraulically connected by a culvert beneath the site access road to effectively form a single surface water pond. As mentioned, the perimeter channel along the western and northern sides of the site will convey runoff into these ponds. Additionally, runoff collected by the drainage terraces and downchutes on the eastern and southern portions of the landfill will convey flow into these ponds. At the eastern end of the perimeter channel where it enters the Northeast Surface Water Pond, a grouted riprap apron will be used for erosion protection. At the southwestern end of the perimeter channel, a culvert will be used to connect the perimeter channel to the South Surface Water Pond (and will also have erosion protection). Where the downchutes flow directly into the ponds, the ACB-lined (or equivalent) downchute channels will cross the perimeter road by way of low water crossings, and will connect with the ponds (with the ACB-lining continuing into the pond for erosion protection). The hydraulically-connected surface water ponds are designed to be “wet ponds” – that is, portions of the pond will extend deeper than the lowest outlet point at elevation 99.5 ft MSL. This will result in what is often referred to as a “permanent pool” elevation of the pond of 99.5 ft, MSL (although it is noted that the water surface elevation is not necessarily permanent, and may fluctuate lower than this elevation during, for example, seasonally dry periods). The final discharge point of the facility surface water management system will occur at the outlet location in the southwest portion of the South Surface Water Pond, through a 60-inch corrugated metal pipe. The geometry and appurtenances of the surface water ponds will detain and release the surface water runoff at rates equal to or less than the pre-development discharge rates from the site as described later in this Report.

Active-Area Surface Water Controls. During ongoing landfill development and prior to final cover installation and closure, the site will utilize temporary diversion berms and contaminated water holding areas to maintain the separation of clean runoff from potentially-contaminated water. Temporary diversion berms will be placed up-gradient from active waste areas (i.e., the working face) to intercept clean runoff and route it around active areas to the surface water management system. Also, containment berms will be used to create holding areas down-gradient from the working face to hold any contaminated water that is generated, and prevent its runoff and discharge from the site. The requirements regarding active-area surface water controls are presented in the Contaminated Water Management Plan (Part IV, Appendix IV-A). The calculations for sizing of the active-area surface water controls are presented in this Drainage Report, in Attachment 2F.

Interim Erosion and Sediment Control Measures. Erosion and sediment control is addressed in Section 6 of this Drainage Report. In addition, an Intermediate Cover Erosion and Sediment Control Plan (ICESCP), is provided in Attachment 2H to this Drainage Report, and includes a description of the measures to be utilized during interim conditions at the site.

4. DESCRIPTION OF THE POST-DEVELOPMENT CONDITION

The post-development drainage areas will encompass the proposed permit boundary (i.e., existing facility and the expansion area), and off-site drainage areas that contribute runoff to the site, as follows:

- Within the proposed permit boundary (MSW-1565B), the post-development conditions are the final conditions that incorporate the proposed landfill and the surface water management features described in Section 3.
- Other off-site areas that contribute runoff onto the site are also delineated using existing topography of those conditions.

The post-development conditions and resulting drainage areas are delineated on Drawing 2-3, presented in Attachment 2A of this Drainage Report. The post-development surface water management features at the site and the routing sequence will be as discussed in Section 3. Inspection of Drawing 2-3 shows that the post-development drainage area is 205.2 acres (the same area as the pre-development drainage area), and there is a single exit point to Rolling Fork Creek in the southwest portion of the site (a few feet away from the pre-development exit point).

Drawing 2-3 also indicates the calculated peak flow rate and the volume of runoff discharged from the site for the 25-year, 24-hour storm event under post-development conditions. A description of the hydrologic method and design parameters is presented subsequently in this Report. Also, in Section 5.5.1, comparisons of the pre-development and post-development conditions are made.

5. DRAINAGE CALCULATIONS

5.1 General

In accordance with 30 TAC §330.303(a), the surface water management system has been designed to be capable of passing the peak discharges from the 25-year, 24-hour rainfall event. Design calculations are made to demonstrate that post-development peak discharges exiting the facility are less than pre-development flows exiting the facility. Calculations have been performed to size the drainage features, and to verify that flow velocities and tractive stresses in conveyance components will not cause erosion of the drainage terraces, downchute channels, perimeter channels, culvert outlets, etc. These calculations related to the site surface water management features are presented as additional attachments to the Drainage Report, and are as follows:

- Hydrology calculations (i.e., calculations of peak runoff rates and total runoff volumes for the pre-development conditions and post-development conditions) are presented in Attachment 2B. This attachment also includes the storm routing through the on-site surface water ponds, and the resulting hydrology and hydraulics associated with the detention capabilities of the ponds.

- Hydraulic calculations for sizing and design of the surface water pond appurtenances (i.e., outlet aprons and anti-seep collars) are presented in Attachment 2C.

- Hydraulic calculations for sizing and design of the drainage terraces and downchute channels are presented in Attachment 2D.

- Hydraulic calculations for sizing and design of culverts and perimeter drainage channels are presented in Attachment 2E.

- Hydrology and hydraulics calculations for active-area surface water controls are presented in Attachment 2F.

It is also noted that an additional calculation package for predicting soil loss and sizing of interim erosion and sediment controls is presented in Attachment 2H.

5.2 Design Storm

As indicated above and pursuant to 30 TAC §330.63(c)(1)(D)(i), the 25-year, 24-hour rainfall depth was utilized as the design storm for the surface water management system design. The rainfall depth-duration frequency relationships for Harris County were obtained from HCFCD (2009). A rainfall depth of 9.6 inches was chosen to represent the 25-year, 24-hour rainfall, as determined by the HCFCD for the Harris County Hydrologic Region 2 for White Oak Bayou (HCFCD, 2009). Additional information concerning the design storm parameters is presented in Attachment 2B to this Drainage Report.

5.3 Hydrologic Methods

The U.S. Army Corps of Engineers Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) computer program was used to model the pre-development conditions and the post-development conditions. HEC-HMS is the successor to and replacement for the HEC-1 program. Modeling was used to calculate surface water runoff volumes, peak flow rates, routing of rainfall event hydrographs through perimeter channels and surface water ponds, and runoff discharge quantities. Attachment 2B of this Drainage Report presents detailed drainage calculations, including a detailed discussion of the parameters used in the analyses and results of the hydrologic modeling efforts.

5.4 Hydraulics

Principles of open channel flow using Manning’s equation (Chow, 1959) were used to size the perimeter drainage channels, top deck drainage terraces, sideslope drainage terraces, drainage downchute channels, and drainage culverts based on the peak flows, derived from the HEC-HMS hydrologic modeling.

Manning’s Equation in its general form is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S_o^{1/2}$$

where: Q = discharge (cfs);

n = manning’s roughness coefficient;

A = area of cross-section of flow (ft^2);

P = wetted perimeter (ft);

R = hydraulic radius (ft) = A/P; and

S_0 = longitudinal slope (ft/ft).

The average tractive stress for a given depth of flow in a channel is calculated by:

$$\tau_o = \gamma_w RS$$

where:

τ_o = average tractive stress (lb/ft^2);

γ_w = unit weight of water (lb/ft^3);

R = hydraulic radius (ft); and

S = channel slope (ft/ft).

Tractive stresses, as well as flow velocities resulting from peak flows, were calculated to select the type of channel lining that would be required to prevent erosion of the drainage features.

Elevation-area relationships were developed for the surface water ponds and subsequently input to the HEC-HMS model for post-development conditions. The elevation-area relationship is calculated based on the size, depth, and shape of the ponds, while the elevation-outflow relationship is calculated based on the configuration of the outflow control structure.

As mentioned, the computations for sizing surface water management system components are found in the following attachments to this Drainage Report:

- Attachment 2B – Hydrology;
- Attachment 2C – Surface Water Pond Appurtenances Design Calculations;
- Attachment 2D – Drainage Terraces and Downchute Channels; and
- Attachment 2E – Culverts and Perimeter Drainage Channels.

5.5 Calculation Results Summary

5.5.1 Discharge Comparisons

Table 5.5.1-1 summarizes the pre- and post-development peak discharges, total discharge volume, and the time to the peak discharge rate. The pre- and post-development drainage area contributing to the discharge at the site outfall is 205.2 acres.

TABLE 5.5.1-1

SUMMARY OF PEAK DISCHARGE CONDITIONS AT SITE OUTFALL (PRE- VS. POST-DEVELOPMENT COMPARISON)

	PRE-DEVELOPMENT		POST-DEVELOPMENT	
	25-YEAR	100-YEAR	25-YEAR	100-YEAR
PEAK DISCHARGE (CFS)	173.0	271.1	129.8	156.4
TOTAL RUNOFF VOLUME (AC-FT)	122.7	181.8	121.4	179.0
TIME TO PEAK DISCHARGE (MIN)	55	45	50	74
PEAK DISCHARGE VELOCITY (FT/SEC)	13.8	21.6	6.6	8.0

A more detailed description of the analysis and modeling results summarized above are included in Attachment 2B. Examination of the table above indicates that the predicted peak post-development discharge rates are less than the peak pre-development discharge rates at the site outfall. The runoff volumes are similar for pre-development and post-development conditions. The times to peak discharge are also not substantially different between pre- and post-development conditions, and the peak discharge velocities at the site outfall are less under proposed conditions than under pre-development existing conditions.

Additionally, since the facility is located within the White Oak Bayou watershed, HCFCD manages watershed-wide surface water drainage and flood control issues, a regional watershed drainage evaluation was performed on USA Waste Landfills of Texas, Inc.'s behalf for the proposed expansion design by Jones & Carter, Inc., Houston, Texas. Jones & Carter's drainage impact analysis independently assessed the potential effects of the proposed expansion on the surrounding watershed area and in consideration of HCFCD drainage criteria, and was submitted to the HCFCD for their review. HCFCD reviewed the evaluation and issued a finding that they have no objections to the conclusions that the project will cause no adverse impact to the receiving waterways in storm events up to and including the 100-year event. Documentation from the HCFCD is provided in Attachment 2G of this Drainage Report.

In summary, the proposed outfall will be in the same location as the existing outfall, and surface water runoff under proposed post-development conditions is generally routed towards this outfall in a similar manner to pre-development conditions. The proposed drainage areas and patterns of runoff will be similar to the existing permitted pre-development drainage patterns. The lower peak discharge rates under post-development conditions are viewed as a benefit given the importance of attenuating runoff in the urban and relatively low-lying Houston area, as confirmed by HCFCD's concurrence with the findings of no adverse impacts to off-site areas.

This information demonstrates that the existing pre-development drainage patterns will not be adversely affected by the proposed expansion.

5.5.2 Surface Water Ponds

Surface water generated at the site is routed through the surface water ponds, and the post-development information presented above in Section 5.5.1 represents information at the site outfall (i.e., the outlet of the South Surface Water Pond). The surface water ponds were sized to adequately detain and pass the 25-year, 24-hour storm event while maintaining at least one foot of freeboard, and to hold the 100-year, 24-hour rainfall event without overtopping. Also, while not a TCEQ requirement, Geosyntec adopted an additional design criterion that is specified by HCFCD – namely, that site surface water ponds should have a detention storage capacity of not less than 0.55 acre-feet (ac-ft) per acre of new developed area.

TABLE 5.5.2-1

SURFACE WATER POND WATER LEVELS AND DETENTION CAPACITY

	25-Year Event		**100-Year Event**	
	Northeast Pond	**South Pond**	**Northeast Pond**	**South Pond**
Peak Water Surface Elevation (ft)	102.2	105.7	103.3	107.7
Available Freeboard to Pond Crest (ft)	8.8	5.3	7.7	3.3
Peak Storage Capacity per Pond (ac-ft)	62.0	47.3	80.0	65.3
Combined Peak Storage Capacity (ac-ft)	109.3		145.3	
Minimum HCFCD Required Storage Capacity (ac-ft)	104.8		104.8	

As shown in the above table, adequate freeboard is provided for the 25-year, 24-hour storm. Additionally, the 100-year, 24-hour storm event is maintained below the crest of the ponds and below the elevation of the specified emergency spillway.

5.5.3 Perimeter Channels

Perimeter channels have been designed to convey the peak flows from the 25-year, 24-hour rainfall while maintaining at least one foot of freeboard. Additionally, perimeter channels were designed with the capacity to convey the 100-year, 24-hour rainfall event. Predicted tractive stresses and velocities for peak flows during the 25-year, 24-hour rainfall have been evaluated and channel linings have been selected accordingly. Drawing 2-4, Perimeter Drainage Channel Plans With Stationing, shows the designation and layout of the perimeter drainage channels. Drawing 2-5 presents the perimeter drainage channel profiles. A table summarizing channel widths, depths, and slopes is provided on Drawing 2-10, and calculations pertaining to the perimeter drainage channel design are presented in Attachment 2E to this Drainage Report. Table 5.5.3-1 summarizes the peak 25-year, 24-hour and peak 100-year, 24-hour design flows in the proposed perimeter channels.

TABLE 5.5.3-1

PERIMETER DRAINAGE CHANNEL RESULTS

Channel Segment Designation	25-Yr Peak Flow Rate (ft^3/s)	25-Yr Peak Flow Depth (ft)	25-Yr Peak Flow Velocity (ft/s)	25-Yr Peak Tractive Stress (lb/ft^2)	Freeboard (ft)	Proposed Channel Lining Material
R1	160.89	3.79	2.44	0.21	1.21	Native Vegetation
R2	160.8	3.79	2.44	0.21	1.21	Native Vegetation
R3	323.9	4.67	2.89	0.27	1.33	Native Vegetation
R4	146.5	3.90	2.39	0.20	1.10	Native Vegetation
R5	146.5	3.90	2.39	0.20	1.10	Native Vegetation
R6	262.9	4.02	2.72	0.24	1.23	Native Vegetation

Note: Channel segments R1 and R4 were assumed to be equivalent to channel segments R2 and R5, respectively. These channel segments are immediately down gradient of the perimeter channel highpoint, and subsequently other drainage structures do not discharge directly into these channel segments.

5.5.4 Drainage Terraces

The top deck and sideslope drainage terrace layout is presented on the Facility Surface Water Management Plan, Drawing 2-1. Details of both the top deck and sideslope drainage terraces are presented on Drawing 2-7, and calculations pertaining to the design of these structures are presented in Attachment 2D to this Drainage Report. Drainage terraces have been designed to convey the peak flows from the 25-year, 24-hour storm while maintaining a minimum of one foot of freeboard. Additionally, the drainage terraces have been designed with the capacity to convey the 100-year, 25-year rainfall event. Based on the calculated peak tractive stresses, grass lining will be adequate to resist erosion of the channel during a 25-year rainfall event. Table 5.5.4-1 summarizes the peak 25-year, 24-hour design flows for the each of the top deck drainage terraces.

TABLE 5.5.4-1

TOP DECK DRAINAGE TERRACE RESULTS

Terrace Designation	25-Yr Peak Flow Rate (ft^3/s)	25-Yr Peak Flow Depth (ft)	25-Yr Peak Flow Velocity (ft/s)	25-Yr Peak Tractive Stress (lb/ft^2)	Freeboard (ft)	Proposed Channel Lining Material
TD_1	62.7	1.66	1.27	0.08	1.34	Native Vegetation
TD_3	52.5	1.55	1.21	0.07	1.45	Native Vegetation
TD_5	52.9	1.55	1.22	0.07	1.45	Native Vegetation
TD_7	77.5	1.79	1.34	0.08	1.21	Native Vegetation
TD_9	18.3	1.04	0.93	0.05	1.96	Native Vegetation
TD_11	37.0	1.36	1.11	0.06	1.64	Native Vegetation

The sideslope drainage terraces were calculated to convey the peak flows for the 25-year and 100-year rainfall events. Calculations indicate that one foot of freeboard will be maintained during the 25-year rainfall event. The following ranges of results were calculated for all the sideslope drainage terraces:

- Peak 25-Year Design Discharge = 3.37 to 31.51 cfs
- Peak 100-Year Design Discharge = 4.51 to 42.19 cfs
- Channel Slope = 1.99% to 6.25%
- Calculated 25-Year Depth of Flow = 0.51 to 1.47 ft
- Calculated 100-Year Depth of Flow = 0.57 to 1.64 ft
- ***Calculated 25-Year Depth of Flow plus Freeboard < Available Depth of Flow [confirmed acceptable]***
- ***Calculated 100-Year Depth of Flow < Available Depth of Depth of Flow [confirmed acceptable]***
- Allowable Tractive Stress = 1.0 psf
- Calculated 25-Year Tractive Stress = 0.54 to 1.00 psf
- ***Calculated 25-Year Tractive Stress ≤ Allowable Tractive Stress [confirmed acceptable]***

5.5.5 Downchute Channels

Downchute channels have been designed to convey the peak flows from the 25-year, 24-hour rainfall event while maintaining a minimum of one foot of freeboard and the 100-year, 24-hour rainfall event for the layout presented on the Facility Surface Water Management Plan, Drawing 2-1. Details of the downchute channels are presented on Drawings 2-7 through 2-9, and calculations pertaining to the downchute channel designs are presented in Attachment 2D to this Drainage Report. Table 5.5.5-1 summarizes the peak 25-year, 24-hour design calculations for each of the downchute channels.

TABLE 5.5.5-1

DOWNCHUTE CHANNEL RESULTS

Downchute Designation	25-Yr Peak Flow Rate (ft^3/s)	25-Yr Peak Flow Depth (ft)	25-Yr Peak Flow Velocity (ft/s)	25-Yr Peak Tractive Stress (lb/ft^2)	Freeboard (ft)	Proposed Channel Lining Material
D1	160.8	0.94	19.44	10.81	1.06	ACB [1]
D2	231.8	0.90	20.16	11.42	1.10	ACB [1]
D3	181.9	0.88	19.40	10.78	1.12	ACB [1]
D4	227.5	0.90	20.04	11.31	1.10	ACB [1]
D5	156.0	0.92	19.27	10.67	1.08	ACB [1]
D6	223.6	0.99	20.67	11.85	1.01	ACB [1]
D7	146.5	0.89	18.92	10.37	1.11	ACB [1]

Note: [1] Channel lock articulating concrete block (ACB) system, or a lining system having equivalent resistance to tractive stress, may be used as the lining material for downchute channels.

6. EROSION AND SEDIMENT CONTROL

6.1 General

The facility has been designed to minimize soil erosion losses, thereby providing effective erosional stability to top dome surfaces and external embankment side slopes during all phases of landfill operation, closure, and post-closure care. The surface water management system design described in this Drainage Report accomplishes this utilizing properly-sized and designed drainage terraces, downchute channels, perimeter drainage channels, culverts, and surface water ponds. These features provide for positive drainage of runoff from the final cover system and surrounding site areas and within acceptable tolerances for stresses that could cause erosion. As described in Section 3.2 of this Drainage Report, perimeter drainage channels, surface water ponds, and drainage terraces will be utilized during development and operation of the facility and will ultimately transport any sediment from the final cover or intermediate cover slopes to surface water ponds.

Additionally, temporary grassing/stabilization, diversions, and other best management practices (BMPs) will be used to minimize soil erosion and sedimentation during intermediate conditions. These BMPs along with other measures utilized while landfill slopes have intermediate cover are discussed in the Intermediate Cover Erosion and Sediment Control Plan (ICESCP), which is provided in Attachment 2H to this Drainage Report. As areas of the landfill reach final grade, the final cover system, which includes vegetation and other final long-term surface water management system components located on the sideslopes and the top deck areas, will be installed.

6.2 Soil Loss Minimization

The long-term effects of erosion have been evaluated using the Revised Universal Soil Loss Equation (RUSLE) for the intermediate and final cover surfaces. These analyses are more thoroughly discussed for the intermediate cover and final cover surfaces in Appendix 2H-1 of Attachment 2H and in Attachment 3E of the Site Development Plan, respectfully. When landfill slopes contain intermediate cover prior to receiving final cover, measures will be taken to minimize soil erosion and loss. These measures are discussed in the ICESCP located in Attachment 2H of this Drainage Report. Surface water conveyance structures have been designed for landfill areas with both intermediate and final cover systems. Flow velocities have been estimated for these conveyance structures to determine if erosion controls, other than grassing, are required (e.g., concrete lining, geomembranes, geosynthetic erosion control materials, riprap lining materials, etc.). As suggested in TxDOT Highway Design Manual, flow conveyance structures with velocities in excess of 5 feet per second have been specified to utilize erosion control materials.

6.3 Seeding and Stabilization Activities

Temporary and permanent stabilization will be used during the construction and operation of the facility to minimize soil erosion and sedimentation. Temporary stabilization will be performed as described in the ICESCP (see Attachment 2H).

Permanent stabilization will be performed in conjunction with final cover system construction (for the landfill) and final closure of the facility (for other disturbed areas), as described in the Closure Plan (Part III, Attachment 7).

6.4. Surface Water Maintenance Plan

6.4.1 General

During site construction activities and site operations, inspection and maintenance of disturbed areas and their surface water management system features will be conducted in accordance with the facility’s Texas Pollutant Discharge Elimination System (TPDES) Multi-Sector General storm water permits. Written records of these inspections and maintenance activities will be maintained as required by the TPDES permits, as further discussed in Part IV – Site Operating Plan (SOP), Section 24.

During the post-closure care period for the facility, inspections will be performed as indicated in Section 3 of the Post-Closure Plan located in Attachment 8 to the SDP.

6.4.2 Site Maintenance Activities

In general, the following procedures will be followed when deemed necessary by the inspections performed as part of the TPDES permit and as further discussed in Section 24 of the SOP, to maintain and ensure functionality of the surface water management system and erosion and sedimentation controls:

- Eroded areas or areas with ponding water will be regraded to their original slopes and reseeded or covered with an erosion resistant material. Upgrades to the original design specifications can be considered at this remedial stage depending upon the severity of systems degradation.

- Additional temporary erosion protection and sediment control measures using established BMPs will be implemented (seeding, temporary berms, ditches, silt fences, erosion mat, check dams, silt traps, etc.), as necessary, during operation to minimize the amount of erosion and sedimentation. These measures can be eliminated once the need is gone (i.e., once long-term vegetation is established and permanent conveyances are in place).

- Piped structures (culverts, pond outlets, etc.) will be kept clean of debris to ensure optimal flow capabilities.

- Vegetated water conveyance areas will be mowed periodically to encourage healthy growth and to maintain design flow capacities and erosion resistance.

- Temporary diversion berms will be constructed up gradient of the active working face to limit surface water run-on to waste operations. The temporary containment berms downslope of working areas, interphase berms, or temporary cell berms in interim areas (as appropriate) will also serve to contain surface water runoff down gradient of active working areas. Any surface water that comes in contact with waste will be handled as contaminated water and kept separate from clean runoff.

- Erosion control structures such as surface water ponds will be cleaned periodically (removal of debris and sediment) in order to maintain design capacity. The surface water ponds will be cleaned by removing sediment using a backhoe, front-end loader, dozer or other similar equipment. The excavated sediment will be transported to designated areas of the site for spreading and drying (must be surrounded by adequate temporary erosion controls).

- Areas of distressed vegetation will be identified and revegetated.

- Broken or washed-out drainage terraces, downchute channels, perimeter channels, and culverts will be repaired.

- Excess silt, weeds and other debris from drainage channels and other conveyances will be removed to restore their design configuration, followed by re-vegetating the disturbed areas as appropriate.

The decision on whether or not maintenance or repairs of site surface water features are needed and the timing on implementing any remedies is based on the severity of the problem compared to the disturbance that will be caused by the repair and seasonal factors (weather patterns, growing season, etc.).

7. PROTECTION FROM FLOODING

As described previously in Section 1.4 of this Drainage Report, the landfill will not be within the 100-year floodway, nor will it be located within the 100-year floodplain. Additionally, the limit of fill construction of not just the landfill itself, but also the perimeter landfill-related features proposed by this Permit Amendment Application (e.g., the landfill perimeter berms, the surface water pond berms), is outside of the 100-year floodplain. Furthermore, the portion of the site closest to Rolling Fork Creek has already been constructed and stabilized with vegetation, and since it is outside of the floodplain, by definition it is not expected to restrict the flow and storage capacity of the 100-year frequency flood; nor are other constructed features at the site.

The FEMA floodplain map and backup information (Part II, Appendix IIG) show that the 100-year flood profile elevations in Rolling Fork Creek adjacent to the site range from an elevation of about 108 ft, MSL next to northern portions of the site, to 105 ft, MSL next to southern portions of the site. All proposed landfill expansion areas are designed with outside-edge of the perimeter berm elevations that are 111.0 ft, MSL or higher. The lowest perimeter elevation of the existing landfill is slightly lower, at elevation 110.6 ft, MSL. In all cases, more than 3-ft of freeboard between the 100-year flood elevation and the limit of waste elevation at the edges of the landfill. Drawing 2-1 shows the location of the 100-year floodplain, and also identifies the calculated flood protection freeboard at the landfill perimeter were it is adjacent to the 100-year floodplain. This is provided as further confirmation that >3-ft of freeboard is provided.

8. CONCLUSION

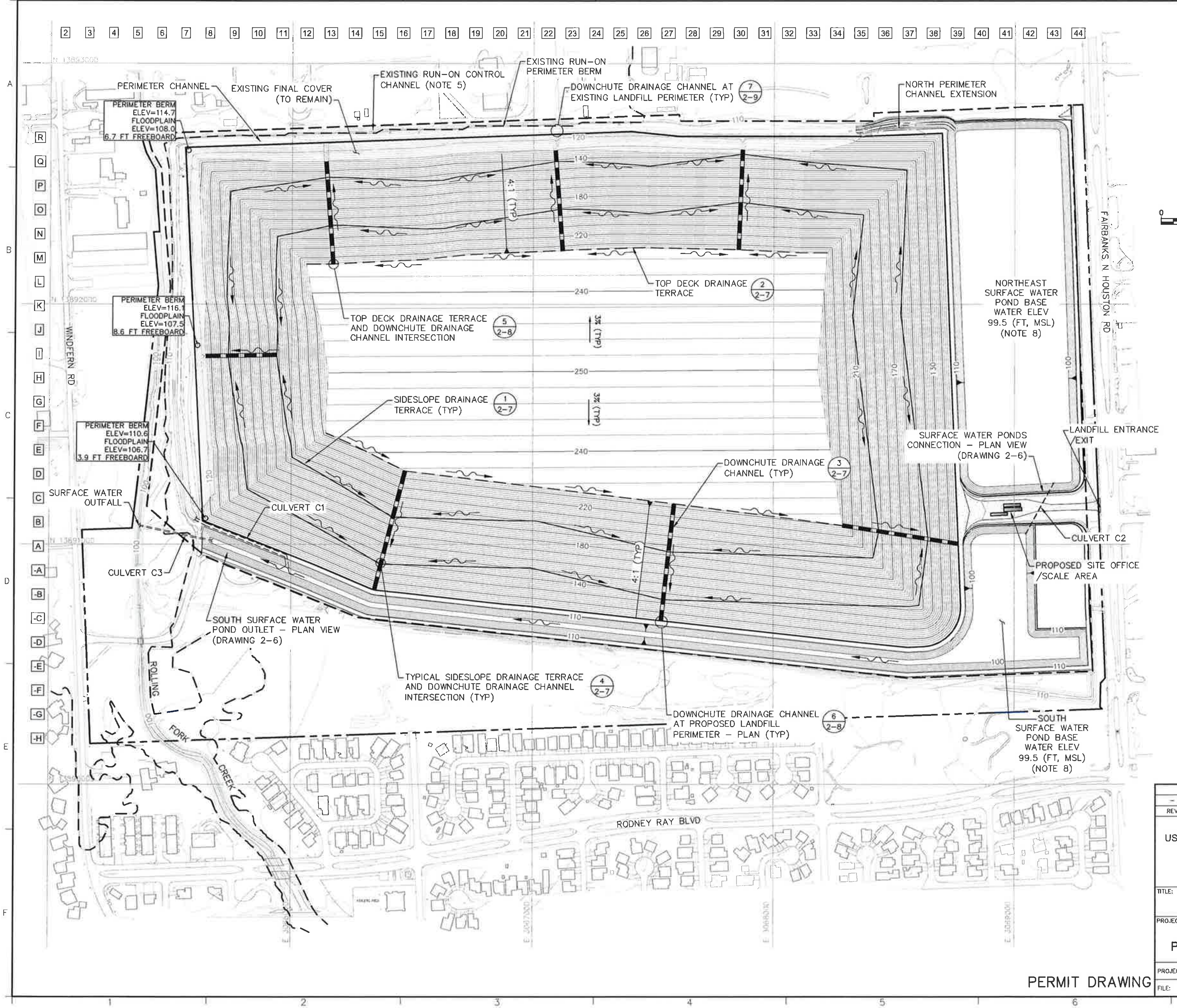
This Drainage Report has been prepared to demonstrate that the facility design complies with the requirements of 30 TAC §330.303, and to address the applicable requirements of 30 TAC Chapter 330, Subchapter G. The Report is accompanied by engineering design drawings and supporting hydrology calculations and hydraulic structural design calculations for the site drainage features. The following conclusions summarize the results of the drainage analysis and design:

- The drainage design criteria selected meet the requirements of 30 TAC Chapter 330.
- The surface water management system drainage structures (terraces, downchutes, ditches, and culverts) are designed to adequately convey peak flows from the 25-year rainfall event.
- The surface water pond capacities and outlet structure are designed in accordance with the rules for the 25-year rainfall event and with erosion protection to attenuate the velocity and dissipate the energy at the outfall.
- Erosion will be minimized through the interim and permanent design features and best management practices described herein.
- The post-development discharge rates from the site are less than the pre-development discharge rates, and the discharge volumes and time-to-peak discharge are similar.
- The HCFCD has determined that the regional watershed will not be adversely impacted.
- The landfill is not within the 100-year floodway or 100-year floodplain, nor will filling occur in the 100-year floodplain. The landfill is protected from the 100-year frequency flood event.
- The post-development drainage patterns will be similar to the existing pre-development permitted drainage patterns and will direct surface water runoff to the same outfall location. The existing pre-development drainage patterns will not be adversely altered.

ATTACHMENT 2A

SURFACE WATER MANAGEMENT SYSTEM DRAWINGS

LIST OF DRAWINGS		
Drawing No.	Title	Date
2-1	Facility Surface Water Management Plan	August 2013
2-2	Pre-Development Plan With Drainage Patterns	August 2013
2-3	Post-Development Plan With Drainage Patterns	August 2013
2-4	Perimeter Drainage Channel Plan With Stationing	August 2013
2-5	Perimeter Drainage Channel Profile	August 2013
2-6	Surface Water Ponds – Plan View	August 2013
2-7	Surface Water Management System Details I	August 2013
2-8	Surface Water Management System Details II	August 2013
2-9	Surface Water Management System Details III	August 2013
2-10	Surface Water Management System Details IV	August 2013



LEGEND

100	EXISTING GROUND ELEVATION (FT, MSL) (NOTES 1,2)
	EXISTING ROAD
	EXISTING WATER LINE
N 13893000 E 3069300	STATE PLANE COORDINATES (NOTE 2)
44	SITE GRID
	PROPERTY BOUNDARY
	PROPOSED PERMIT BOUNDARY
	OVERALL LIMIT OF FINAL COVER
	TOP DECK DRAINAGE TERRACE
	SIDESLOPE DRAINAGE TERRACE
	DOWNCHUTE DRAINAGE CHANNEL
	DRAINAGE FLOW DIRECTION
200	PROPOSED GROUND ELEVATION (FT, MSL) (NOTE 3)
	100-YEAR FLOODPLAIN (NOTE 7)

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. TOP OF FINAL COVER SYSTEM REFERS TO THE PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF THE FINAL COVER SYSTEM). LIMIT OF FINAL COVER SYSTEM REFERS TO THE TOE OF SLOPE OF THE TOPSOIL LAYER.
4. OUTSIDE OF THE LIMIT OF FINAL COVER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
5. EXISTING RUN-ON CONTROL CHANNEL IS LOCATED AT TOE OF NORTHERN SLOPE PERIMETER BERM, WITHIN PERMIT BOUNDARY AND WILL BE MAINTAINED AS NEEDED FOR POSITIVE DRAINAGE.
6. INFORMATION ON SURFACE WATER POND APPURTENANCES IS PROVIDED ON SHEET 2-6.
7. 100-YEAR FLOODPLAIN LIMITS ARE FROM FEMA MAPS, AS DESCRIBED IN PART II, NARRATIVE REPORT, SECTIONS 10.1.2 AND 10.1.3.
8. SURFACE WATER PONDS WILL BE "WET" PONDS. ACCORDINGLY, THE BASE WATER ELEVATION REFERS TO THE OUTFALL ELEVATION. THUS, THE DETENTION VOLUME OF THE PONDS IS CALCULATED AS THE STORAGE VOLUME ABOVE THIS BASE WATER ELEVATION.

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG
REV	DATE	DESCRIPTION	DRN	APP

USA WASTE OF TEXAS LANDFILLS, INC.

LANDFILL SITE ADDRESS:
8205 FAIRBANKS N HOUSTON RD
HOUSTON, TEXAS 77064
PHONE: 713.824.6867

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NO. 1182
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

TITLE:

FACILITY SURFACE WATER MANAGEMENT PLAN

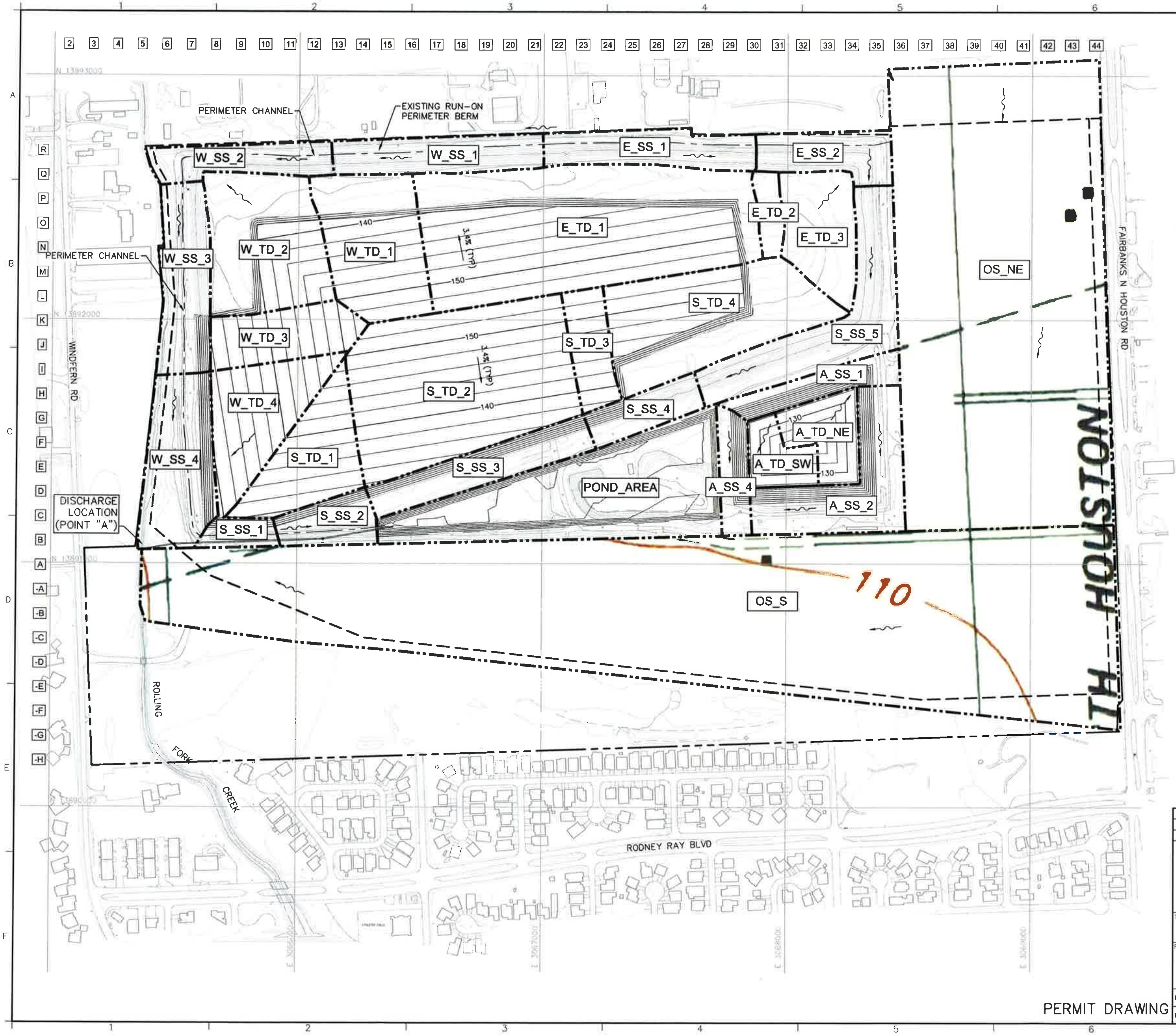
PROJECT:

FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PERMIT DRAWING

PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2-1	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2-1

DRAWING: Austin P:\CADD\Projects\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-1.dwg PLOTTED: Aug 23, 2013 - 10:39am



N

0 200' 400'
SCALE IN FEET

LEGEND

100	EXISTING GROUND ELEVATION (FT, MSL) (NOTES 1,2)
	EXISTING ROAD
	EXISTING WATER LINE
N 13893000 E 3069000	STATE PLANE COORDINATES (NOTE 2)
44	SITE GRID
	PROPERTY BOUNDARY
	PROPOSED PERMIT BOUNDARY
	DRAINAGE FLOW DIRECTION
200	PERMITTED GROUND ELEVATION (FT, MSL) (NOTE 2)
S_SS_4	DRAINAGE AREA DESIGNATION
	DRAINAGE AREA

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. CURRENT PERMITTED SURFACE WATER MANAGEMENT SYSTEM PLAN TAKEN FROM MSW PERMIT 1565A ATTACHMENT 1-H, DRAWING 1-H.
4. THE PURPOSE OF THIS DRAWING IS TO PRESENT THE DRAINAGE AREAS MODELED IN THE RUNOFF CALCULATION PACKAGE, ATTACHMENT 2B, FOR THE PRE-DEVELOPMENT CONDITION.
5. UNITED STATES GEOLOGICAL SURVEY (USGS) TOPOGRAPHIC MAP USED TO MODEL THE NATURAL CONDITIONS ADJACENT TO THE CURRENTLY PERMITTED LANDFILL BOUNDARY.

PRE-DEVELOPMENT DRAINAGE CALCULATIONS

			25 YR, 24-HR STORM		
DISCHARGE POINT	CONTRIBUTING DRAINAGE AREAS	WATERSHED AREA (AC)	FLOW RATE (CFS)	FLOW VOLUME (AC-FT)	VELOCITY (FT/S)
A	ALL DESIGNATED	205.2	173.0	122.7	13.8

SCOTT M. GRAVES
86557

8/26/2013

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REV	DATE	DESCRIPTION	DRN	APP
-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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consultants
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3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

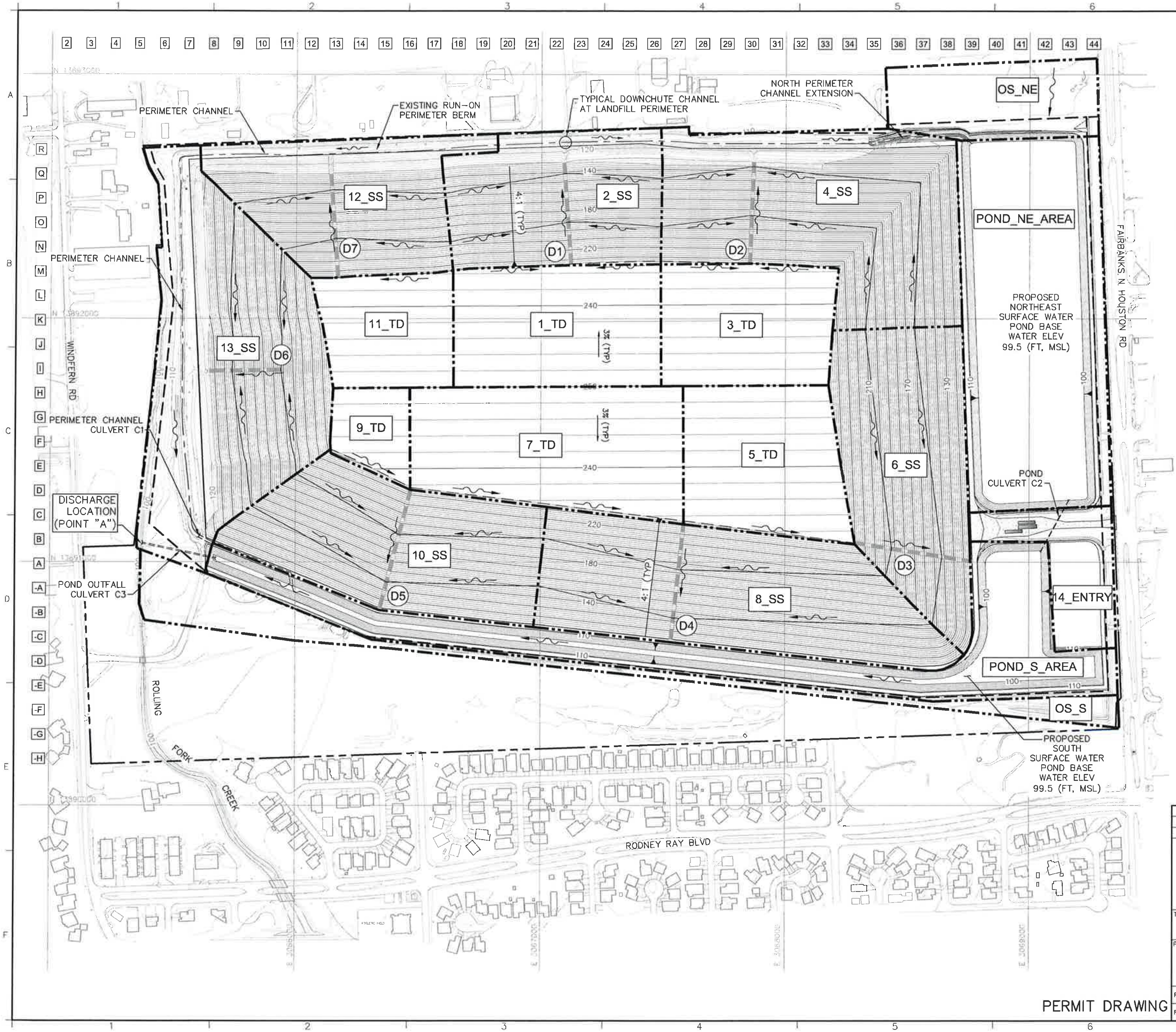
TITLE:
PRE-DEVELOPMENT PLAN WITH DRAINAGE PATTERNS

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2-2	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2-2

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-2.dwg PLOTTED: Aug 20, 2013 - 2:22pm



PERMIT DRAWING

LEGEND

—100—	EXISTING GROUND ELEVATION (FT, MSL) (NOTES 1,2)
═══	EXISTING ROAD
— — — —	EXISTING WATER LINE
N 13893000 E 3069000	STATE PLANE COORDINATES (NOTE 2)
44	SITE GRID
——— — — — ———	PROPERTY BOUNDARY
— — — — — —	PROPOSED PERMIT BOUNDARY
— — — — — —	TOP DECK DRAINAGE TERRACE
———————	SIDESLOPE DRAINAGE TERRACE
▬ ▬ ▬ ▬	DOWNCHUTE DRAINAGE CHANNEL
D5	DOWNCHUTE CHANNEL DESIGNATION
∿→	DRAINAGE FLOW DIRECTION
—200—	PROPOSED GROUND ELEVATION (FT, MSL) (NOTE 2)
5_TD	DRAINAGE AREA DESIGNATION
▬ · ▬ · ▬	DRAINAGE AREA

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. THE PURPOSE OF THIS DRAWING IS TO PRESENT THE DRAINAGE AREAS MODELED IN THE RUNOFF CALCULATION PACKAGE, ATTACHMENT 2BI, FOR THE POST-DEVELOPMENT CONDITION.
4. SEE DRAWING 2-4 FOR PERIMETER CHANNEL DESIGNATIONS USED IN RUNOFF CALCULATION PACKAGE, ATTACHMENT 2B AND 2E.

POST-DEVELOPMENT DRAINAGE CALCULATIONS

			25 YR, 24-HR STORM		
DISCHARGE POINT	CONTRIBUTING DRAINAGE AREAS	WATERSHED AREA (AC)	FLOW RATE (CFS)	FLOW VOLUME (AC-FT)	VELOCITY (FT/S)
A	ALL DESIGNATED	205.2	129.8	121.4	6.6

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

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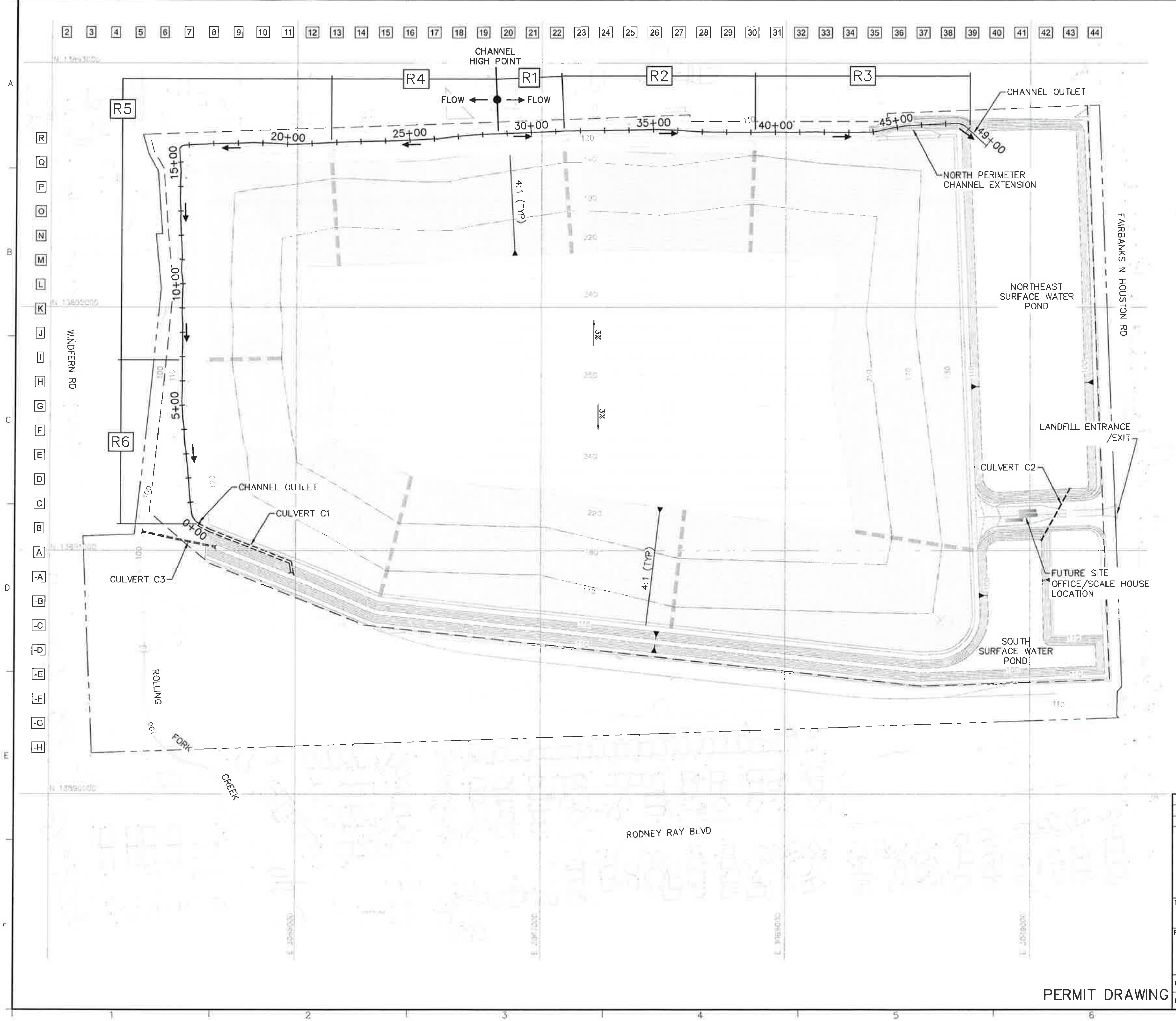
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

TITLE:
POST-DEVELOPMENT PLAN WITH DRAINAGE PATTERNS

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.: TXL0263	DESIGN BY: BK	REVIEWED BY: SMG	PART NO.: III	DRAWING: 2-3
FILE: 0263P2-3	DRAWN BY: JJV	APPROVED BY: SMG		

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-3.dwg PLOTTED: Aug 23, 2013 - 10:45am



-N-

0 200' 400'
SCALE IN FEET

LEGEND

100	EXISTING GROUND ELEVATION (FT, MSL) (NOTES 1,2)
	EXISTING WATER LINE
	STATE PLANE COORDINATES (NOTE 2)
44	SITE GRID
	PROPERTY BOUNDARY
	PROPOSED PERMIT BOUNDARY
200	PROPOSED GROUND ELEVATION (FT, MSL) (NOTE 2)
R4	CHANNEL REACH DESIGNATION
→	PERIMETER CHANNEL FLOW DIRECTION
25+00	PERIMETER DRAINAGE CHANNEL CENTERLINE ALIGNMENT AND STATIONING

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. REFER TO PART III, ATTACHMENT 2, DRAWING 2-1 FOR THE SURFACE WATER MANAGEMENT FEATURES ON THE FINAL COVER SYSTEM (NOT SHOWN ON THIS DRAWING FOR CLARITY).
4. SEE ATTACHMENT 2E FOR DESIGN OF PERIMETER DRAINAGE CHANNELS.

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

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3600 BEE CAVES ROAD, SUITE 101
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PHONE: 512.451.4003

TITLE:
PERIMETER DRAINAGE CHANNEL PLAN WITH STATIONING

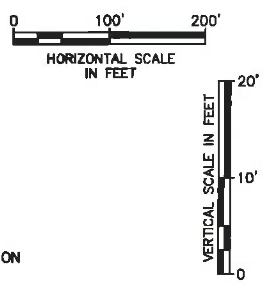
PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

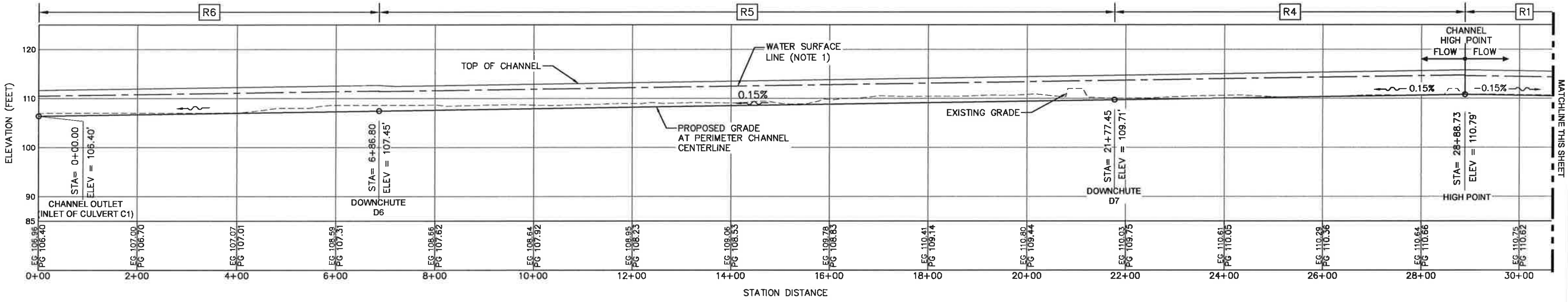
PROJECT NO.: TXL0263
FILE: 0263P2-4
DESIGN BY: BK
DRAWN BY: JJV
REVIEWED BY: SMG
APPROVED BY: SMG
PART NO.: III
DRAWING: 2-4

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-4.dwg PLOTTED: Aug 21, 2013 - 11:39am

LEGEND

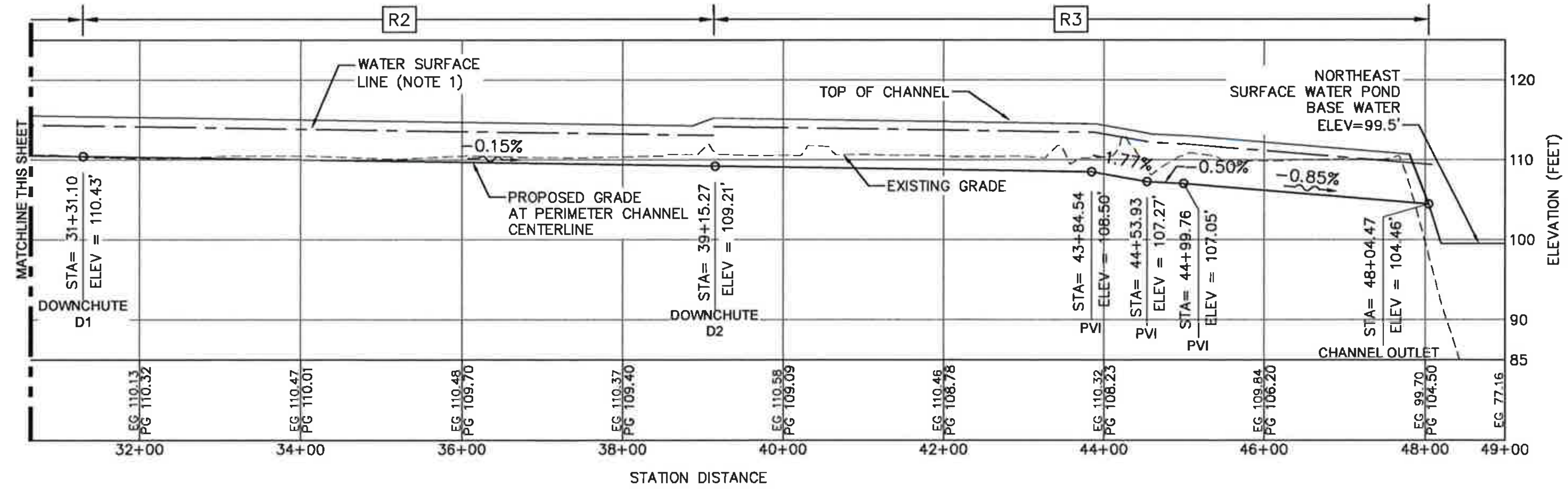
– – – – –	EXISTING GRADE ALONG CHANNEL CENTERLINE
———	PROPOSED GRADE ALONG CHANNEL CENTERLINE
——— – ———	WATER SURFACE LINE (NOTE 1)
R5	CHANNEL REACH DESIGNATION
PG 110.36	PROPOSED GRADE ELEVATION
EG 110.36	EXISTING GRADE ELEVATION
PVI	POINT OF VERTICAL INTERSECTION





NOTES:

1. WATER SURFACE LINE REPRESENTS THE 25-YEAR, 24-HOUR NORMAL DEPTH OF FLOW.
2. SEE DRAWING 2-10 FOR TABLE OF PERIMETER DRAINAGE CHANNEL DESIGNATIONS, DIMENSIONS (WIDTH, DEPTH), AND CHANNEL LINING TYPE. SEE ATTACHMENT 2E FOR PERIMETER CHANNEL SIZING DESIGN.



SCOTT M. GRAVES
86557

8/26/2013

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–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG
REV	DATE	DESCRIPTION	DRN	APP

USA WASTE OF TEXAS LANDFILLS, INC.

LANDFILL SITE ADDRESS:
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AUSTIN, TEXAS 78746
PHONE: 512.451.4003

TITLE:

PERIMETER DRAINAGE CHANNEL PROFILE

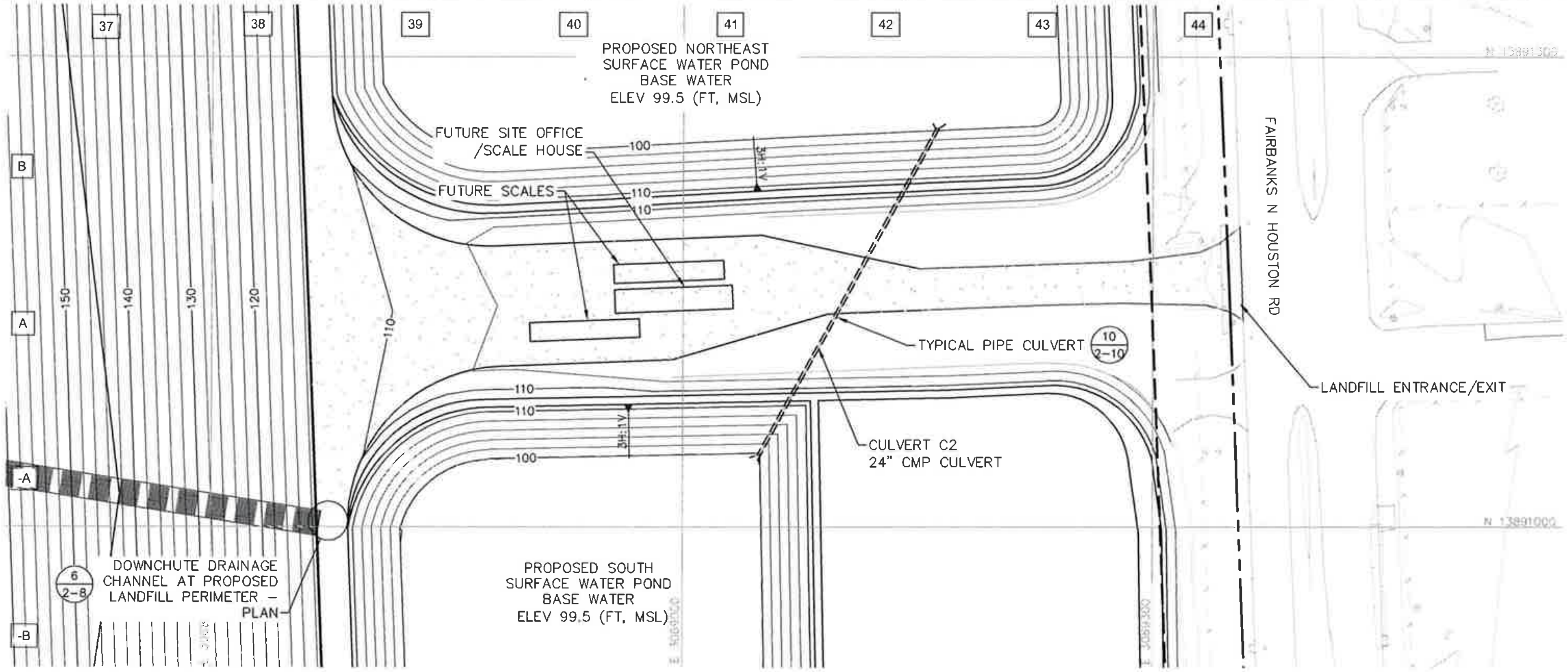
PROJECT:

FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

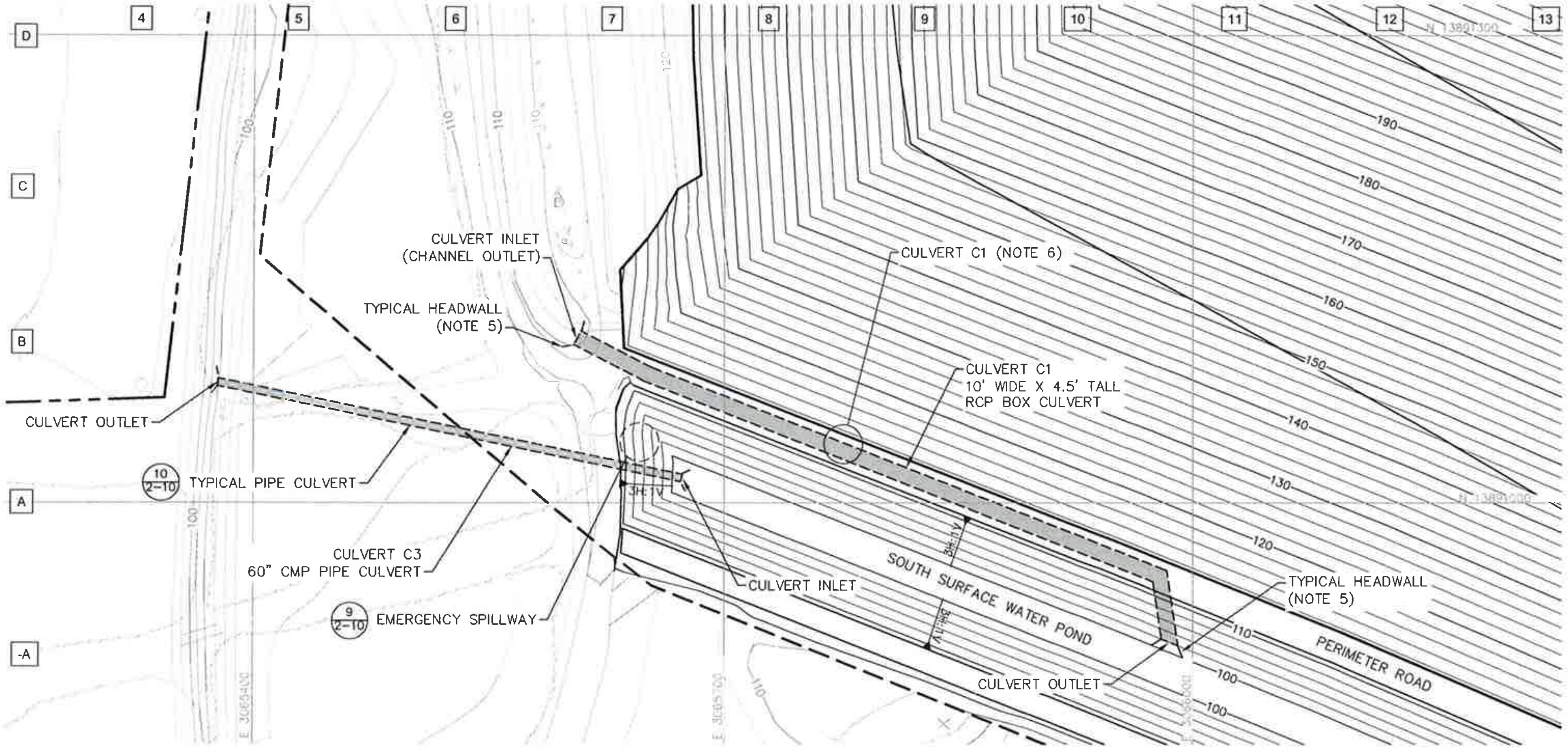
PERMIT DRAWING

PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2-5	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2-5

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-5.dwg PLOTTED: Aug 23, 2013 - 11:07am



PLAN
SURFACE WATER PONDS CONNECTION
SCALE: 1" = 50'



PLAN
SOUTH SURFACE WATER POND OUTLET
SCALE: 1" = 50'

LEGEND

100	EXISTING GROUND ELEVATION (FT, MSL) (NOTES 1,2)
	EXISTING ROAD
	EXISTING FENCE
	EXISTING VEGETATION
	EXISTING WATER LINE
N 13893100 E 3069000	STATE PLANE COORDINATES (NOTE 2)
44	SITE GRID
	PROPERTY BOUNDARY
	PROPOSED PERMIT BOUNDARY
	PROPOSED LIMIT OF FINAL COVER
200	PROPOSED GROUND ELEVATION (FT, MSL) (NOTE 3)

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. OUTSIDE OF THE LIMIT OF FINAL COVER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. SEE DRAWING 2-10 FOR SURFACE WATER POND FEATURE ELEVATIONS AND DESIGN PARAMETERS.
5. TEXAS DEPARTMENT OF TRANSPORTATION STANDARD DETAIL FW-0 AVAILABLE IN ATTACHMENT 2E TO BE USED FOR HEADWALL INSTALLATION.
6. CULVERT C1 DESIGN PER TEXAS DEPARTMENT OF TRANSPORTATION STANDARD DETAIL SCP-10 AVAILABLE IN ATTACHMENT 2E.

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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LANDFILL SITE ADDRESS:
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3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

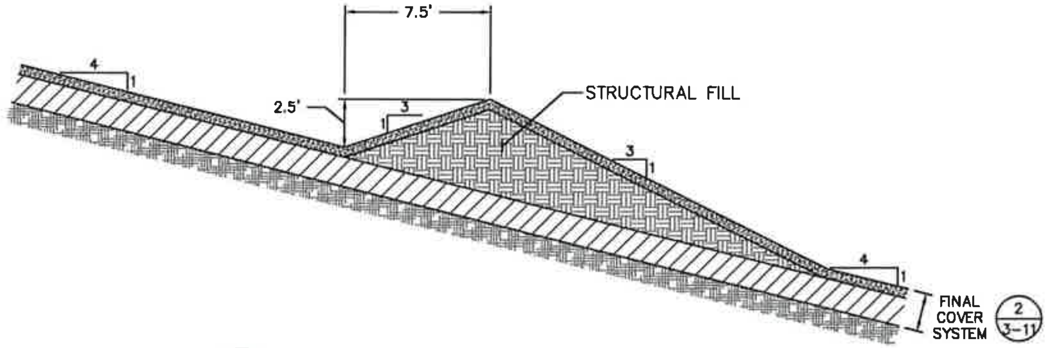
TITLE:
SURFACE WATER PONDS – PLAN VIEW

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW–1565B

PROJECT NO.: TXL0263	DESIGN BY: BK	REVIEWED BY: SMG	PART NO.: III	DRAWING: 2–6
FILE: 0263P2–6	DRAWN BY: JJV	APPROVED BY: SMG		

PERMIT DRAWING

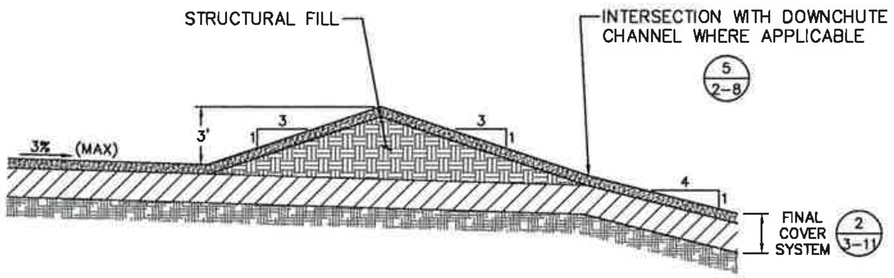
DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-6.dwg PLOTTED: Aug 23, 2013 - 11:02am



1 / 2-1 DETAIL
SIDESLOPE DRAINAGE TERRACE

SCALE: 1" = 10'

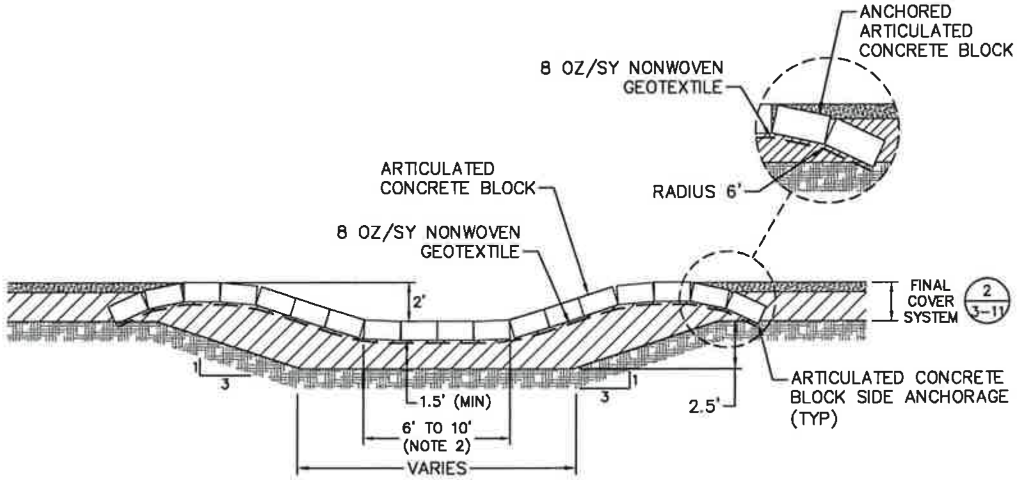
0 5' 10' SCALE IN FEET



2 / 2-1 DETAIL
TOP DECK DRAINAGE TERRACE

SCALE: 1" = 10'

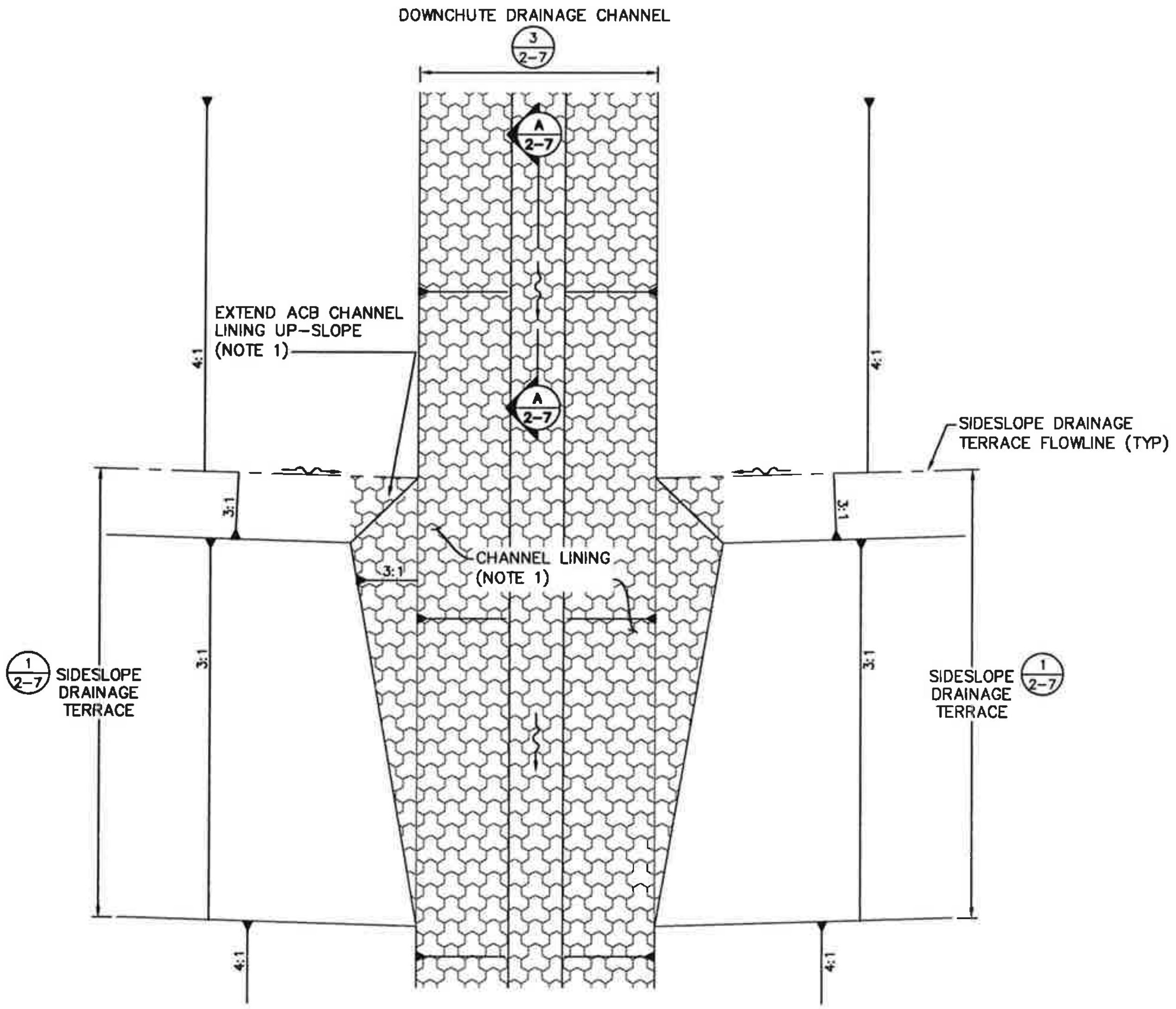
0 5' 10' SCALE IN FEET



3 / 2-1 DETAIL
DOWNCHUTE DRAINAGE CHANNEL (NOTE 1)

SCALE: 1" = 10'

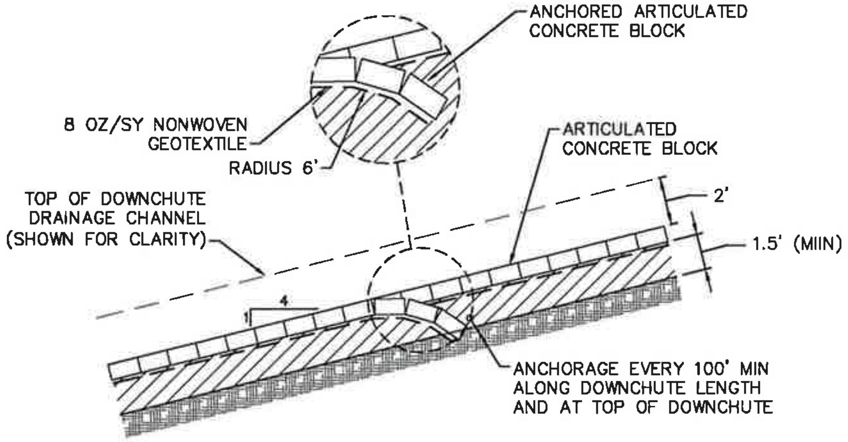
0 5' 10' SCALE IN FEET



4 / 2-1 DETAIL
TYPICAL SIDESLOPE DRAINAGE TERRACE AND DOWNCHUTE DRAINAGE CHANNEL INTERSECTION

SCALE: 1" = 20'

0 10' 20' SCALE IN FEET



A / 2-7 SECTION
DOWNCHUTE DRAINAGE CHANNEL SECTION (NOTE 1)

SCALE: 1" = 8'

0 4' 8' SCALE IN FEET

NOTES:

1. DOWNCHUTE CHANNEL LINING WILL BE ARTICULATED CONCRETE BLOCK (ACB) OR APPROVED EQUIVALENT ALTERNATE CHANNEL LINING SYSTEM (e.g., GABION/RENO-MATTRESS, RIPRAP, GEOMEMBRANE) WITH A PERMISSIBLE TRACTIVE STRESS OF GREATER THAN OR EQUAL TO 16.5 POUNDS PER SQUARE FOOT.
2. REFER TO PART III, ATTACHMENT 2D FOR DOWNCHUTE CHANNEL WIDTHS, AND DRAWING 2-3 FOR DOWNCHUTE DESIGNATIONS.

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

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AUSTIN, TEXAS 78746
PHONE: 512.451.4003

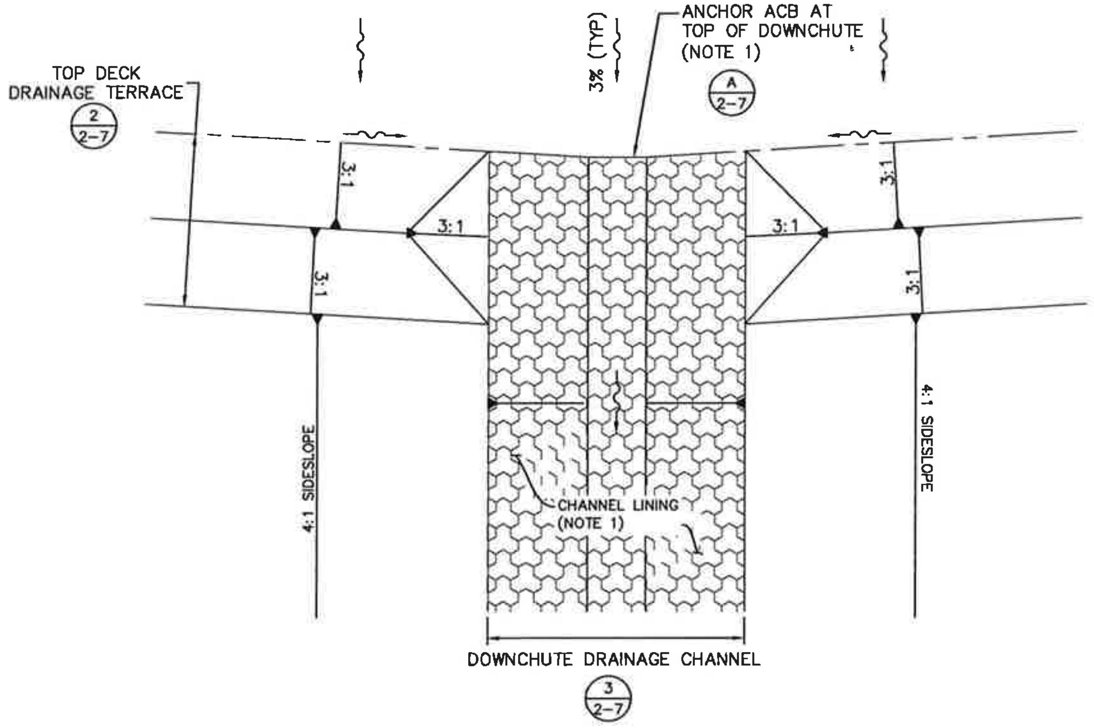
TITLE:
SURFACE WATER MANAGEMENT DETAILS I

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PERMIT DRAWING

PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2-8	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2-7

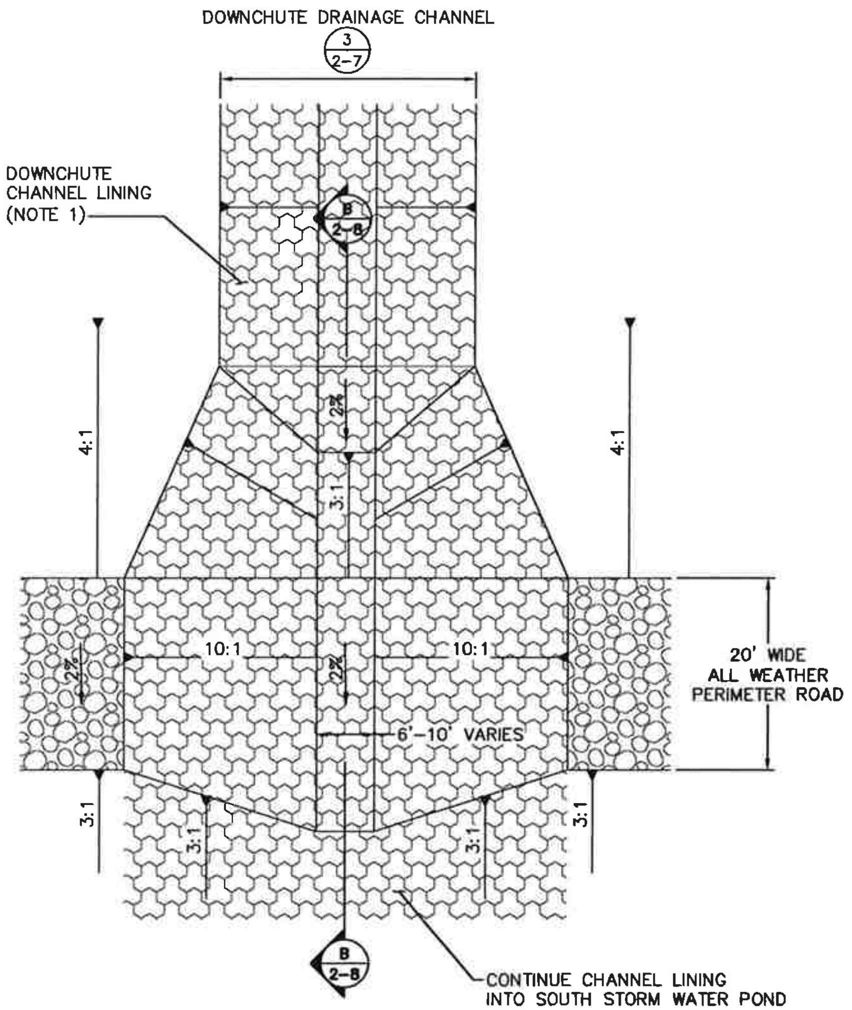
DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-8.dwg PLOTTED: Aug 23, 2013 - 4:08pm



5 / 2-1 DETAIL
TOP DECK DRAINAGE TERRACE AND DOWNCHUTE DRAINAGE CHANNEL INTERSECTION

SCALE: 1" = 20'

0 10' 20'
SCALE IN FEET



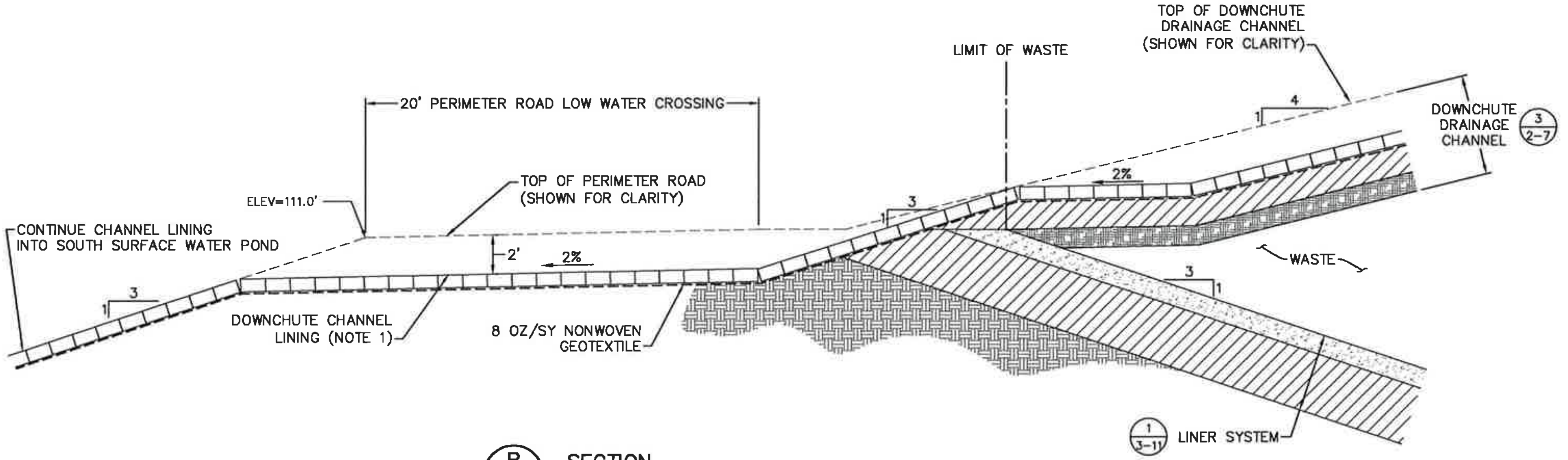
6 / 2-1 DETAIL
DOWNCHUTE DRAINAGE CHANNEL AT PROPOSED LANDFILL PERIMETER – PLAN

SCALE: 1" = 20'

0 10' 20'
SCALE IN FEET

NOTE:

1. DOWNCHUTE CHANNEL LINING WILL BE ARTICULATED CONCRETE BLOCK (ACB) OR APPROVED EQUIVALENT ALTERNATE CHANNEL LINING SYSTEM (e.g., GABION/RENO-MATTRESS, RIPRAP, GEOMEMBRANE) WITH A PERMISSIBLE TRACTIVE STRESS OF GREATER THAN OR EQUAL TO 16.5 POUNDS PER SQUARE FOOT



B / 2-8 SECTION
DOWNCHUTE DRAINAGE CHANNEL AT PROPOSED LANDFILL PERIMTER

SCALE: 1" = 8'

0 4' 8'
SCALE IN FEET

SCOTT M. GRAVES
86557

8/26/2013

FOR PERMIT PURPOSES ONLY

REV	DATE	DESCRIPTION	DRN	APP
-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

LANDFILL SITE ADDRESS:
8205 FAIRBANKS N HOUSTON RD
HOUSTON, TEXAS 77064
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Geosyntec
consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NO. 1182
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
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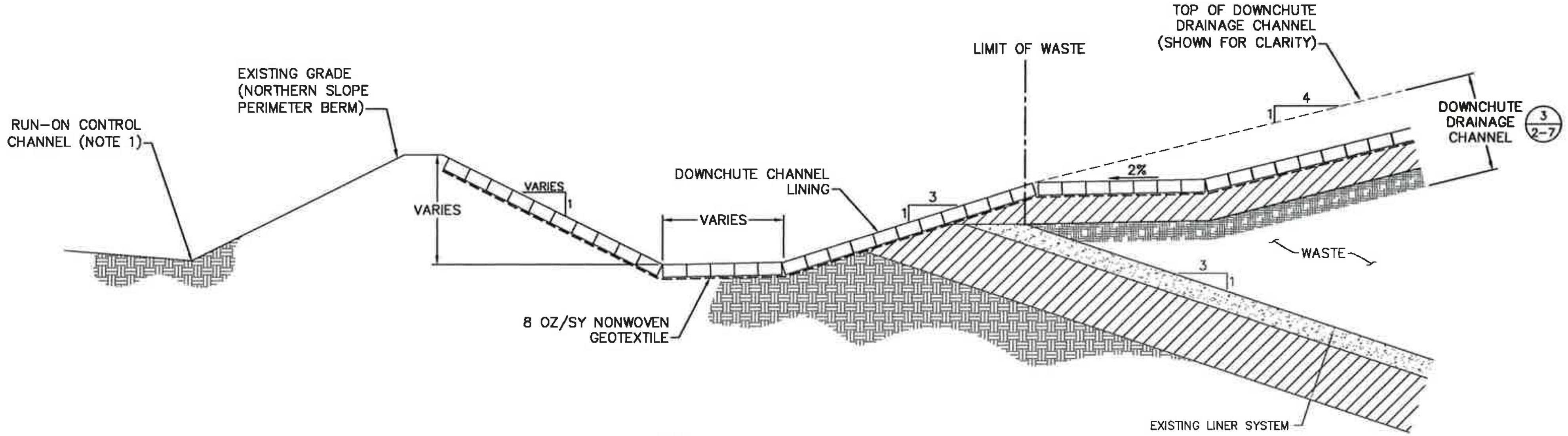
TITLE:
SURFACE WATER MANAGEMENT DETAILS II

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PERMIT DRAWING

PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.: III	DRAWING: 2-8
FILE:	0263P2-9	DRAWN BY:	JJV	APPROVED BY:	SMG		

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Reno\0263P2-8.dwg PLOTTED: Aug 23, 2013 - 4:07pm



7
2–1

DOWNCHUTE DRAINAGE CHANNEL AT EXISTING LANDFILL PERIMETER

SCALE: 1" = 8'

0 4' 8'
SCALE IN FEET

NOTE:

1. EXISTING RUN–ON CONTROL CHANNEL IS LOCATED AT TOE OF NORTHERN SLOPE PERIMETER BERM, WITHIN PERMIT BOUNDARY AND WILL BE MAINTAINED AS NEEDED FOR POSITIVE DRAINAGE.

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86557

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–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG
REV	DATE	DESCRIPTION	DRN	APP

USA WASTE OF TEXAS LANDFILLS, INC.

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3600 BEE CAVES ROAD, SUITE 101
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TITLE:
SURFACE WATER MANAGEMENT DETAILS III

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW–1565B

PERMIT DRAWING

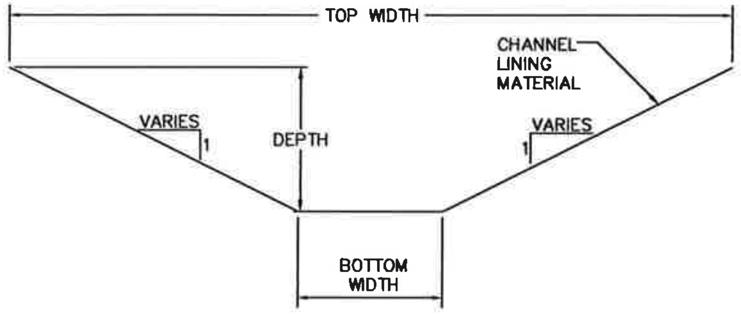
PROJECT NO.:	TXL0263	DESIGN BY:	BK	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2–10	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2–9

PERIMETER DRAINAGE CHANNEL SCHEDULE

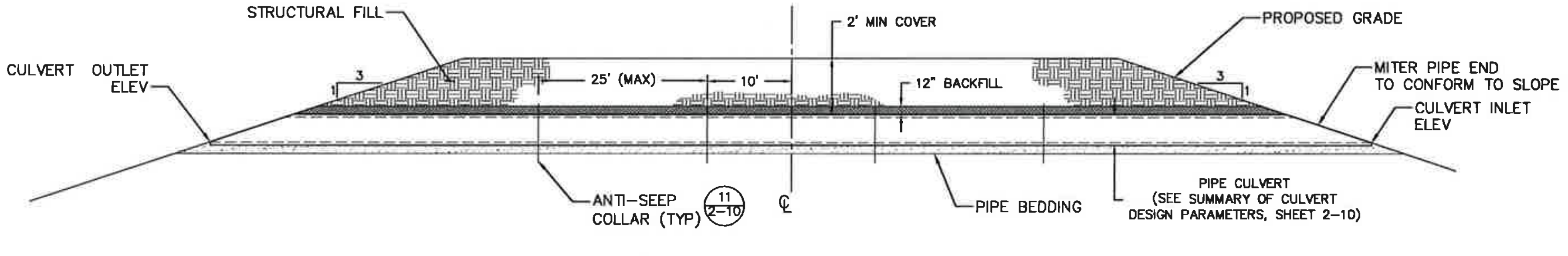
CHANNEL/CULVERT SEGMENT	CHANNEL SHAPE	CHANNEL SLOPE (%)	MANNING'S N VALUE	CHANNEL DIMENSIONS (MINIMUM)				25-YEAR, 24-HR PEAK FLOW, Q (CFS)	100-YEAR, 24-HR PEAK FLOW, Q (CFS)
				BOTTOM WIDTH (FT)	DEPTH (FT)	SIDE SLOPES (H: V)	TOP WIDTH (FT)		
R1	TRAPEZOIDAL	0.15	0.040	6.00	5.00	3:1	36.0	160.8	209.2
R2	TRAPEZOIDAL	0.15	0.040	6.00	5.00	3:1	36.0	160.8	209.2
R3	TRAPEZOIDAL	0.15	0.040	10.00	6.00	3:1	46.0	323.9	436.3
R4	TRAPEZOIDAL	0.15	0.040	4.00	5.00	3:1	34.0	146.5	190.0
R5	TRAPEZOIDAL	0.15	0.040	4.00	5.00	3:1	34.0	146.5	190.0
R6	TRAPEZOIDAL	0.15	0.040	12.00	5.25	3:1	43.5	262.9	333.8

SUMMARY OF CULVERT DESIGN PARAMETERS

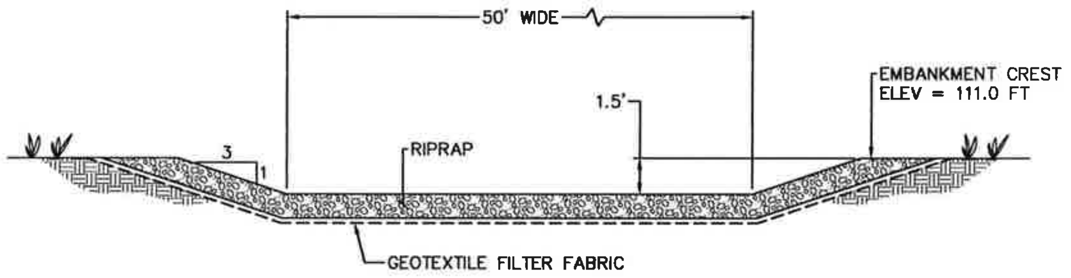
CULVERT	25-YEAR, 24-HR PEAK FLOW, Q (CFS)	APPROX. LENGTH (FT)	SLOPE (%)	DESCRIPTION	INLET ELEVATION (FT, MSL)	OUTLET ELEVATION (FT, MSL)
C1	258.2	440	1.0	1 – 10' X 4.5' BOX	106.4	102.0
C2	8.9	200	0.0	1 – 24" PIPE	99.5	99.5
C3	129.8	330	0.45	1 – 60" PIPE	99.5	98.0
SEE DRAWING 2-4 FOR CULVERT DESIGNATIONS						



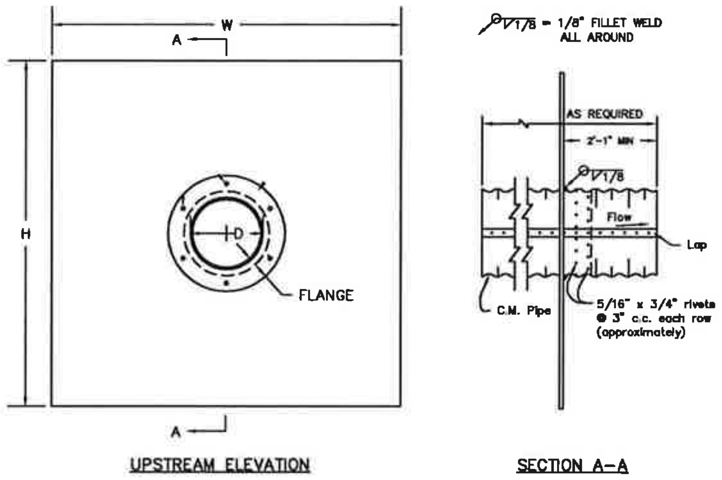
8
2-10
DETAIL
PERIMETER CHANNEL
SCALE: N.T.S.



10
2-6
DETAIL
TYPICAL PIPE CULVERT
SCALE: 1" = 20'



9
2-6
DETAIL
EMERGENCY SPILLWAY
SCALE: 1" = 8'



UPSTREAM ELEVATION

SECTION A-A

CULVERT	PIPE DIAM. (D) (INCHES)	SHEET HEIGHT (H) (INCHES)	SHEET WIDTH (W) (INCHES)
C2	24	72	72
C3	60	108	108

NOTES:

1. MAKE PIPE CONNECTIONS AS NEEDED TO ASSURE A WATERTIGHT SYSTEM.
2. APPLY SILICON CAULK ON THE SEAMS AS NEEDED TO INSURE A GOOD SEAL SO THAT THE COMPLETED INSTALLATION IS WATERTIGHT.

11
2-10
DETAIL
ANTI SEEP COLLAR
SCALE: N.T.S.

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86557

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REV	DATE	DESCRIPTION	DRN	APP
–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

USA WASTE OF TEXAS LANDFILLS, INC.

LANDFILL SITE ADDRESS:
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TITLE:
SURFACE WATER MANAGEMENT SYSTEM DETAILS IV

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PERMIT DRAWING

PROJECT NO.: TXL0263
FILE: 0263P2-11
DESIGN BY: BK
DRAWN BY: JJV
REVIEWED BY: SMG
APPROVED BY: SMG
PART NO.: III
DRAWING: 2-10

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2-11.dwg PLOTTED: Aug 23, 2013 - 11:55am

ATTACHMENT 2B

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY

ON-SITE DRAINAGE ANALYSIS – HYDROLOGY FAIRBANKS LANDFILL EXPANSION

8/26/2013

SCOTT M. GRAVES
86557

SEALED FOR PERMITTING PURPOSES;
CALCULATION PAGES 1 TO 61

GEOSYNTEC CONSULTANTS
TX ENG FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the hydrology analysis for the estimation of surface water runoff from the proposed expansion of the Fairbanks Landfill (Site) in Houston, Texas. The landfill will consist of both a vertical and lateral expansion at the Site. The specific goals of the analysis include calculating peak discharges and total runoff volumes from the Site for the: (i) pre-development conditions and (ii) post-development conditions. The calculated values of peak discharge and runoff volume of the proposed surface water system for the lateral and vertical expansion presented in this permit amendment application are compared against currently permitted pre-development conditions in order to verify that development of the expansion design does not adversely alter, to any significant degree, the drainage patterns of the watershed in the vicinity of the Site.

The following definitions pertain to the two conditions analyzed in this package:

- Pre-Development Conditions – currently permitted conditions of the landfill facility. The existing permitted surface water management system is analyzed, while incorporating the additional areas included in the expansion for this permit amendment application and off-site run-on areas.
- Post-Development Conditions – conditions of the Site once the expansion design has been fully developed, with the final cover and permanent surface water management system installed, while incorporating additional off-site run-on areas.

2 METHODOLOGY

2.1 HEC-HMS Computer Model

Surface water discharges for the two conditions are estimated using the Hydrologic Modeling System (HEC-HMS) computer program developed through the Hydraulic Engineering Center (HEC) of the United States Army Corps of Engineers (USACE). The program simulates natural and controlled precipitation-runoff and routing processes. HEC-HMS is the successor to and replacement for the HEC-1 program (USACE, 2000). For precipitation-runoff-routing simulation, HEC-HMS provides the following components:

- Precipitation-specification options can describe an historical precipitation event, a frequency-based hypothetical precipitation event, or an event that represents the upper limit of precipitation possible at a given location. For this analysis, the 25-year (4% annual chance), 24-hour duration hypothetical precipitation event was used to compare pre-development and post-development conditions. Additionally, the analysis is repeated for the 100-year (1% annual chance), 24-hour duration hypothetical precipitation event to verify that the proposed surface water ponds sizing and discharge structures will adequately route the runoff without overtopping the pond crest for that hypothetical event.

- Water loss models can estimate the volume of runoff given the precipitation and properties of the watershed. For this analysis, the Soil Conservation Service (SCS) Curve Number Loss Model was used (USDA, 1986).

- Direct runoff models can account for overland flow, storage, and energy losses as water runs off a watershed and into the stream channels. For this analysis, the Kinematic Wave Model was used.

- Hydraulic routing models account for storage and energy flux as water moves through stream channels. For this analysis, the Kinematic Wave Model was used.

- Hydraulic models of water-control measures such as surface water pond facility outfall structures.

HEC-HMS was used to model the pre-development conditions and the post-development conditions. More specifically, HEC-HMS modeling calculated surface water runoff volumes, peak flow rates, and flow characteristics for the perimeter channels and the surface water ponds.

2.2 Pre-Development Condition

Drawing 2-2 in Attachment 2A of the Facility Surface Water Drainage Report (Drainage Report) presents the final configuration of the currently permitted landfill and surface water management system design, together with the natural conditions for the expansion area. The United States Geological Survey (USGS) topographic map for the general site vicinity was used to model the natural conditions adjacent to the currently permitted landfill boundary. The pre-development drainage area of 205.2 acres incorporates the currently permitted surface water management system within the 118.1-acre facility permit boundary area as well as off-site areas and the proposed expansion area – so that the pre-development and post-development analysis results can be properly compared. The currently permitted surface water management system design utilizes drainage terraces, downchute channels, perimeter ditches, and a detention pond to control surface water runoff from the Site.

The currently permitted surface water management system maintains similar drainage patterns to the natural conditions. One discharge location is located at the detention pond outlet pipe in the southwest portion of the site, which discharges to Rolling Fork Creek, which flows along the west side of the site. This discharge location is used for evaluation of the pre-development conditions. 205.2 acres drain to the discharge location for pre-development conditions including the entire 118.1-acre existing facility permit boundary.

2.3 Post-Development Condition

Drawing 2-1 in Attachment 2A shows the final configuration of the expansion and the proposed surface water management system design. Like the currently permitted facility, the proposed surface water management system will utilize drainage terraces, downchute channels, and perimeter ditches to control surface water runoff from the Site. In addition, two hydraulically-connected surface water ponds are incorporated into the surface water management system for controlled release from the Site. The drainage areas flowing to each of the drainage features are delineated on Drawing 2-3 in Attachment 2A. The facility permit-boundary area associated with the proposed expansion (i.e., post-development conditions) is 188.95 acres.

The proposed surface water management system will maintain similar drainage patterns to the pre-development condition. One discharge location is located at the south surface water pond outlet pipe in the southwest portion of the site, which discharges to Rolling Fork Creek, which flows along the west side of the site. This discharge location is used for evaluation of the post-development conditions and coincides with the 205.2 acre drainage area for pre-development conditions. As mentioned, the post-development drainage area includes the entire proposed facility permit boundary area.

3 DESIGN PARAMETERS

The following engineering data were used in estimating surface water runoff.

3.1 Rainfall

- Rainfall Return Periods, Durations, and Depths – The Harris County Flood Control District (HCFCD) provides rainfall frequency and duration depths for the Harris County Hydrologic Regions. The Site is located in the White Oak Bayou Watershed, and outflow from the Site drains into the Rolling Fork Creek. Table 2B-1 provides a summary of the rainfall depths for various durations and return periods for Harris County Hydrologic Region 2 for White Oak Bayou (HCFCD, 2009).

3.2 Drainage Areas and Reaches

- Drainage Areas – The contributing watershed areas for each basin or reach in the pre-development and post-development models are divided into multiple subbasins. Subbasins are defined based on the receiving surface water drainage feature. Subbasins are delineated for the following areas: top deck surfaces draining to the top deck drainage terraces and the drainage downchutes, sideslope surfaces draining to the sideslope drainage terraces and the drainage downchutes and perimeter channel, off-site run-on areas, and surface water pond areas. The Soil Conservation Service (SCS) Curve Number Loss Model was used to estimate the volume of runoff from a given subbasin. The Kinematic Wave Model was used to estimate the direct runoff flow rates from the subbasins. Each subbasin is assigned a curve number representing the type of ground cover for a given soil for the area. The subbasin area, curve number, and Kinematic Wave Model input parameters are included in the HEC-HMS output in Appendix 2B-1.

- Hydrologic Soil Groups (HSG) – Figure 2B-1 shows the approximate footprint of the landfill superimposed on a soil map from the Soil Survey Geographic (SSURGO) Database (NRCS, 2012) for Harris County. The predominate soil types at the Site include a combination of Gessner loam (Ge), Addicks loam (Ad), and Wockley fine sandy loam (Wo) with the Gessner formation constituting the majority of the Site. These soil types have a range of HSG designations as shown in Table 2B-2. Due to the range of HSG designations, all soil types for the landfill permit area are conservatively assumed to have an HSG of type D, which generally provides the highest calculated runoff volumes. Off-site natural areas are assumed to have an HSG of type C.

- Curve Number (CN) – Curve numbers are obtained from the TR-55 (USDA, 1986). Table 2B-3 summarizes the CNs chosen for the analyses performed in the package. Proposed final cover is generally assumed to be open space with fair grass cover conditions (CN = 84), whereas off-site natural conditions are assumed to be open space with good grass cover conditions (CN = 74).

- Manning's Roughness Coefficients – Values of Manning's roughness coefficients used in the Kinematic Wave Model and reach routing calculations were obtained from the HCFCD guidance (HCFCD, 2010). Table 2B-4 summarizes the Manning's coefficients used in this calculation package. It should be noted that for design purposes, the culverts assume a Manning's coefficient for a corrugated metal pipe (CMP). Any culvert material type may be used provided that the Manning's coefficient is equal to or less than that for CMP.

- Perimeter Channel Reaches – Reaches represent perimeter channels that route surface water from upstream subbasins to junctions with downstream subbasins. Reaches also may route surface water from upstream reaches. The Kinematic Wave Model is used to model the reaches in HEC-HMS. The Kinematic Wave Model accounts for storage and energy flux as water moves through stream channels. Average geometric characteristics of the stream channel measured from the existing and proposed topography are input into HEC-HMS.

3.3 Surface Water Ponds

Proposed surface water ponds are incorporated in the post-development analysis to temporarily store surface water runoff and reduce discharge flow rates from the upstream areas. The surface water ponds are designed to maintain post-development discharge flow rates at or below pre-development discharge flow rates. Surface water ponds are input into HEC-HMS as “reservoir” nodes. The elevation-area relationship is input for each surface water pond. The elevation-area relationship was computed from the proposed geometry of the surface water ponds. Specifically, the surface area at various elevations throughout the ponds was used to compute the elevation-area relationship. Design characteristics of the outflow structures include culvert diameter and emergency spillway depth and breadth. Input and output files for the surface water ponds design are provided in Appendix 2B-1. The surface water ponds are hydraulically connected such that the northeast surface water pond discharges into the south surface water pond. The south surface water pond discharges to Rolling Fork Channel at the discharge location.

3.4 Nodal Network Diagrams

Nodal network diagrams used in HEC-HMS for the pre-development and post-development analyses are provided and correspond to the output files included in Appendix 2B-1.

- Pre-Development Nodal Network – Figure 2B-2 of this calculation package presents the nodal network drawing for the pre-development conditions. The pre-development nodal network diagram shows the subbasins, permitted detention pond, and discharge location. The nodal network diagram represents the existing permitted surface water management system and discharge point shown on Drawing 2-2 in Attachment 2A

- Post-Development Nodal Network – Figure 2B-3 of this calculation package presents the nodal network drawing for the post-development conditions. The post-development nodal network diagram shows the subbasins, reaches, surface water ponds, and discharge location. The nodal network diagram represents the proposed surface water management system and discharge point shown on Drawing 2-3 in Attachment 2A.

4 RESULTS

Modeling results from calculations presented in this calculation package indicate that post-development peak discharges from the facility are less than the pre-development peak discharge rates; thus the development should not adversely affect or significantly alter the drainage patters in the vicinity of the Site. Table 2B-5 and the results provided in Appendix 2B-1 summarize the pre- and post-development peak discharges and total discharge runoff volumes.

5 REFERENCES

HCFCD (2009). *Hydrology and Hydraulics Guidance Manual*, Harris County Flood Control District, December 2009.

HCFCD (2010). *Policy Criteria and Procedure Manual*, Harris County Flood Control District, December 2010.

NRCS (2012). Soil Data Mart, Natural Resources Conservation Service, United States Department of Agriculture, Soil Survey Geographic (SSURGO) Database, accessed 4 January 2012, http://soildatamart.nrcs.usda.gov.

USACE (2000). *Hydraulic Modeling System HEC-HMS Technical Reference Manual*, US Army Corps of Engineers, Hydrologic Engineering Center, CPD-74B, March 2000.

USDA (1986). *Urban Hydrology for Small Watersheds*, Technical Release 55 (TR-55), United States Department of Agriculture, Science and Education Administration, Agriculture Handbook Number 537.

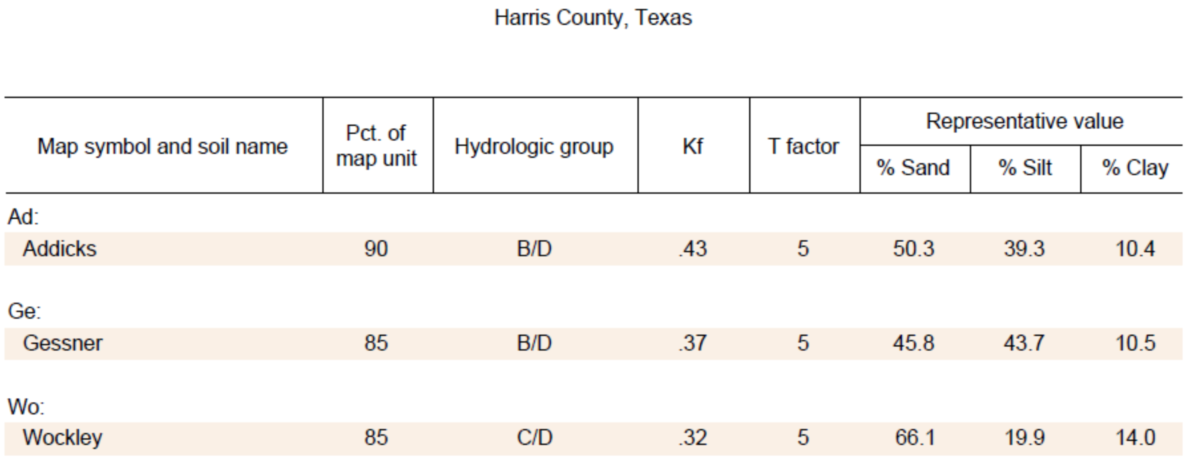
TABLES

Table 2B-1. Summary of Rainfall Parameters used in Analysis for Harris County Hydrologic Region 2

(from HCFCD, 2009)

Rainfall Duration	25-yr Rainfall Depth (in.)	100-yr Rainfall Depth (in.)
5 min	1.0	1.2
15 min	1.7	2.1
1 hr	3.4	4.3
2 hr	4.3	5.7
3 hr	5.0	6.7
6 hr	6.4	8.9
12 hr	7.8	10.8
24 hr	9.6	13.2

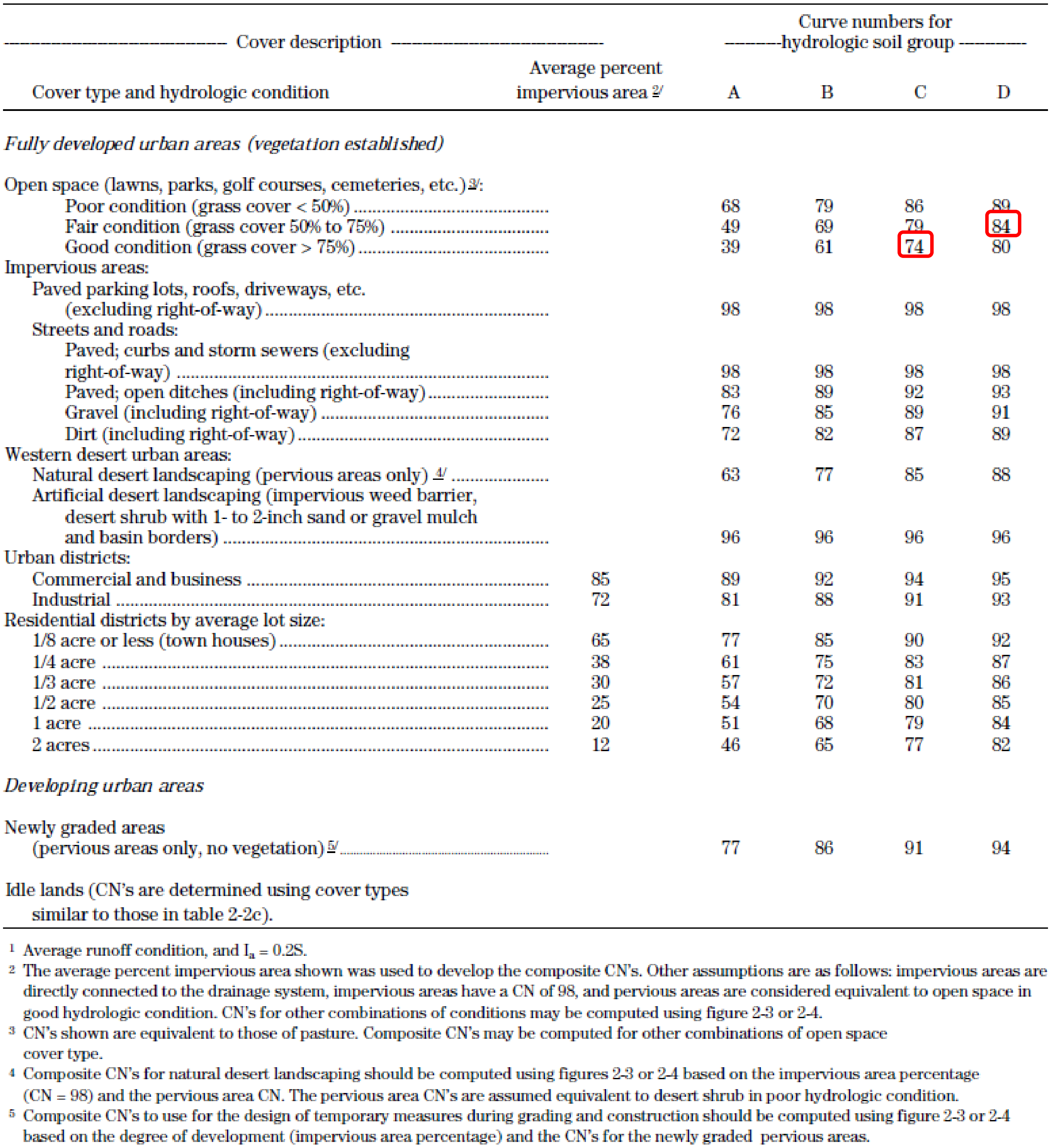
Table 2B-2. Hydrologic Soil Groups for On-Site Soils (from NRCS, 2012)



Harris County, Texas

Map symbol and soil name	Pct. of map unit	Hydrologic group	Kf	T factor	Representative value		
					% Sand	% Silt	% Clay
Ad:							
Addicks	90	B/D	.43	5	50.3	39.3	10.4
Ge:							
Gessner	85	B/D	.37	5	45.8	43.7	10.5
Wo:							
Wockley	85	C/D	.32	5	66.1	19.9	14.0

Table 2B-3. Summary of Curve Numbers used in Analysis[1] (from USDA, 1986)



Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

---

[1] Average runoff condition, and $I_a = 0.2S$.

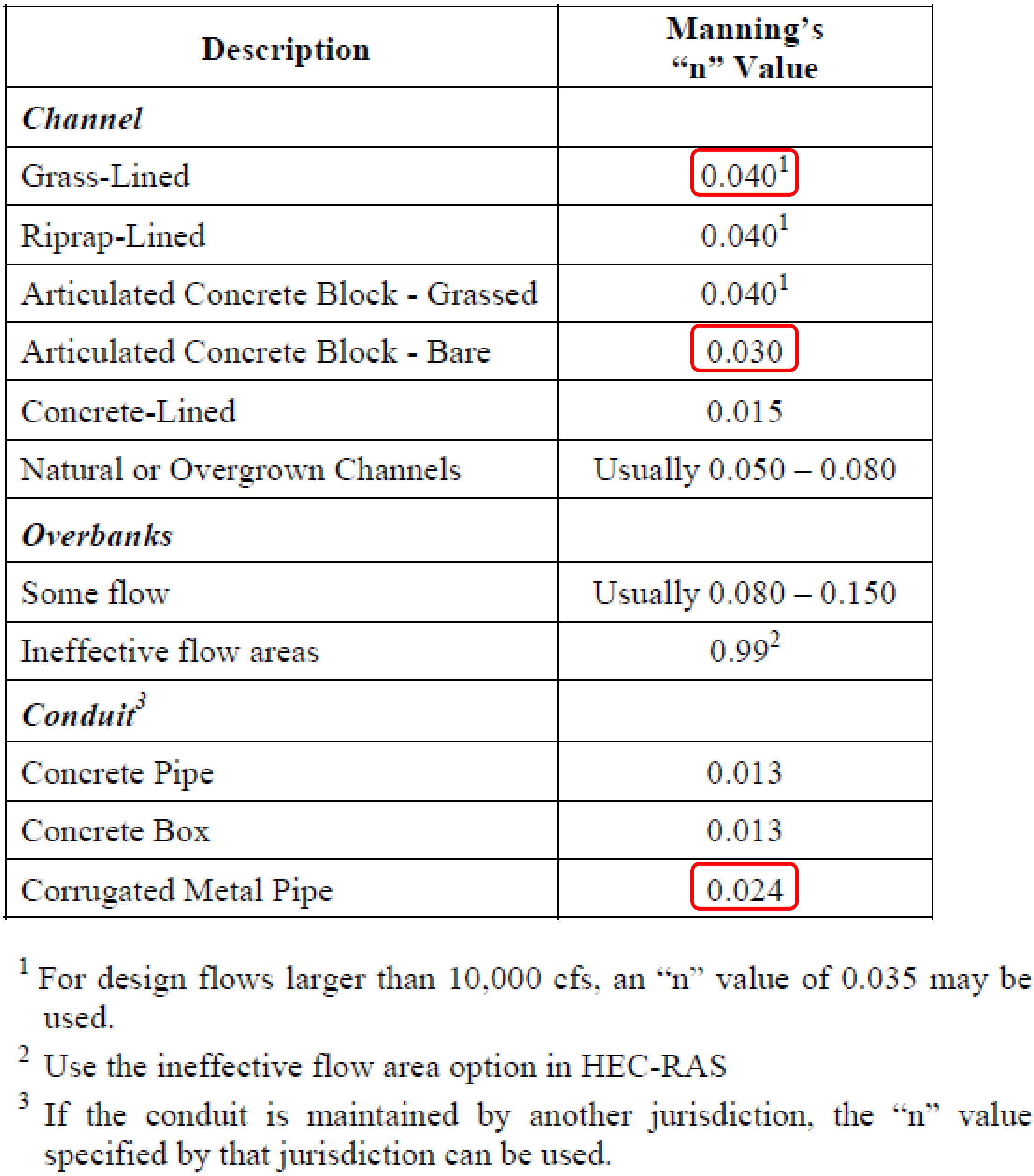
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2B-4. Manning's n Values
(from HCFCD, 2010)



Description	Manning's "n" Value
Channel	
Grass-Lined	0.040[1]
Riprap-Lined	0.040[1]
Articulated Concrete Block - Grassed	0.040[1]
Articulated Concrete Block - Bare	0.030
Concrete-Lined	0.015
Natural or Overgrown Channels	Usually 0.050 – 0.080
Overbanks	
Some flow	Usually 0.080 – 0.150
Ineffective flow areas	0.99[2]
Conduit[3]	
Concrete Pipe	0.013
Concrete Box	0.013
Corrugated Metal Pipe	0.024

[1] For design flows larger than 10,000 cfs, an "n" value of 0.035 may be used.

[2] Use the ineffective flow area option in HEC-RAS

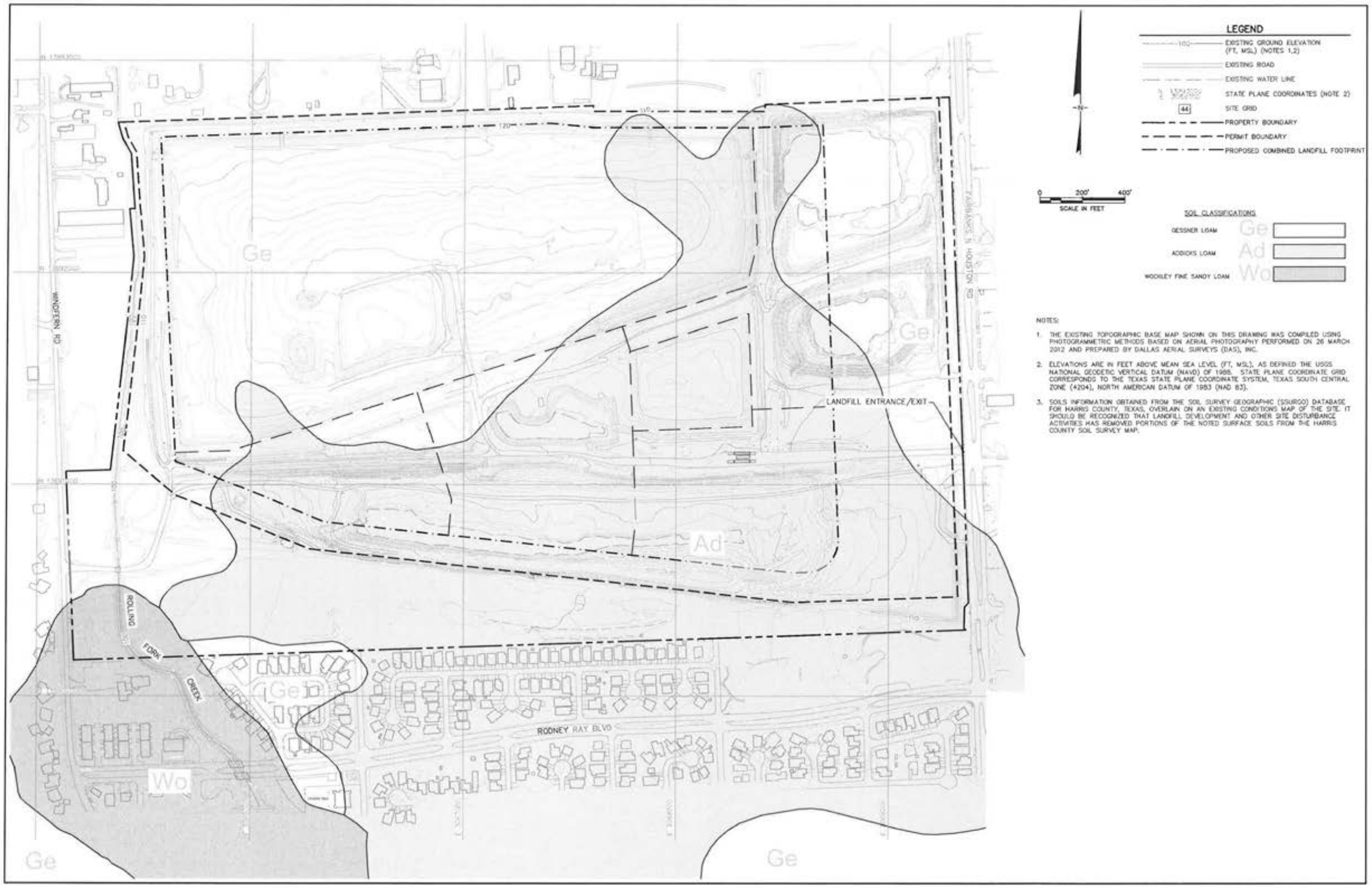
[3] If the conduit is maintained by another jurisdiction, the "n" value specified by that jurisdiction can be used.

Table 2B-5. Summary of Peak Discharge and Total Discharge Volumes at Site Outfall

	Pre-Development		Post-Development	
	25-year	**100-year**	**25-year**	**100-year**
Peak Discharge (cfs)	173.0	271.1	129.8	156.4
Total Runoff Volume (ac-ft)	122.7	181.8	121.4	179.0

FIGURES

Figure 2B-1. Soil Survey Map



NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL), AS DEFINED THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO THE TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (NAD 83).
3. SOILS INFORMATION OBTAINED FROM THE SOIL SURVEY GEOGRAPHIC (SSURGO) DATABASE FOR HARRIS COUNTY, TEXAS, OVERLAIN ON AN EXISTING CONDITIONS MAP OF THE SITE. IT SHOULD BE RECOGNIZED THAT LANDFILL DEVELOPMENT AND OTHER SITE DISTURBANCE ACTIVITIES HAS REMOVED PORTIONS OF THE NOTED SURFACE SOILS FROM THE HARRIS COUNTY SOIL SURVEY MAP.

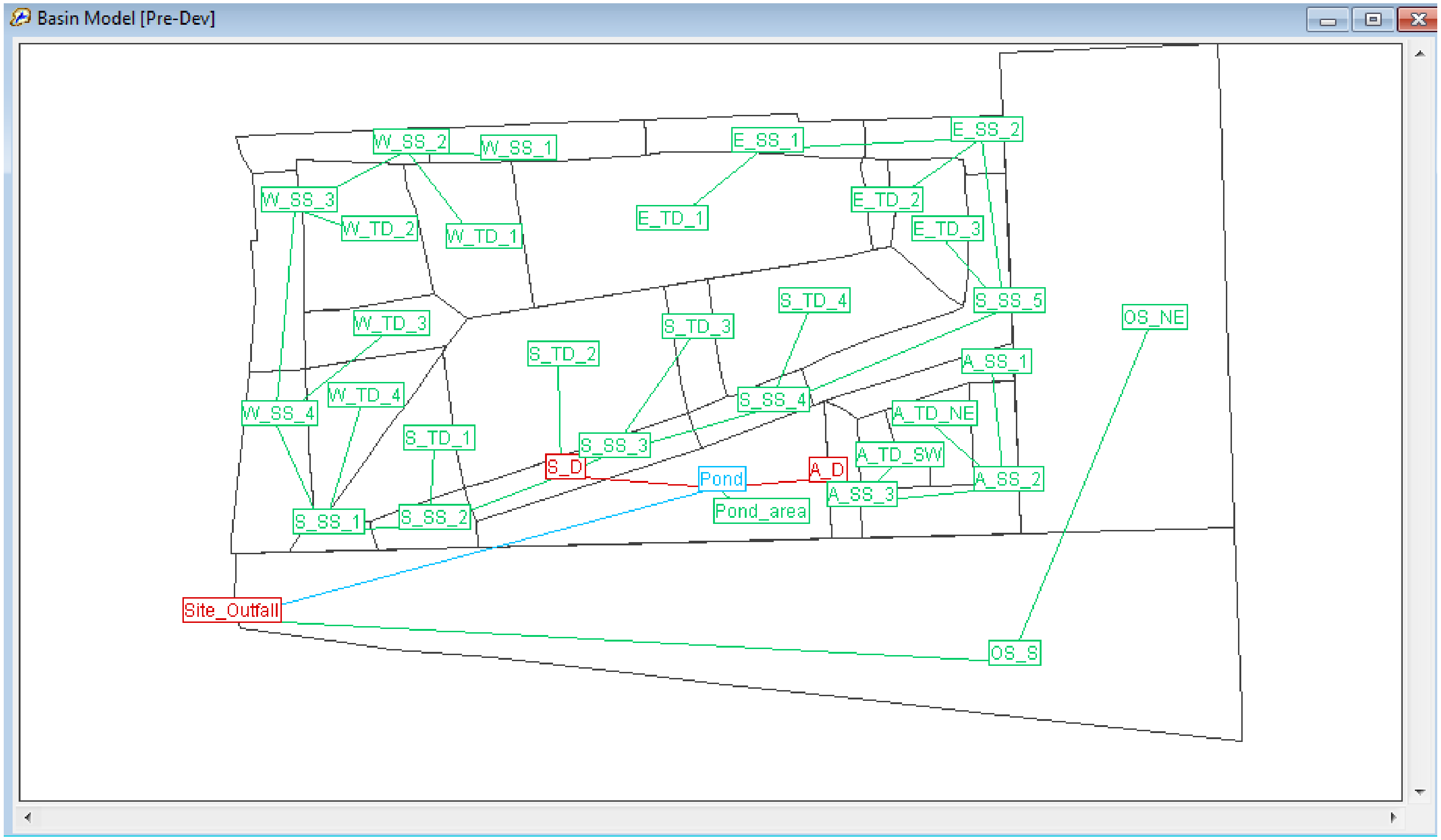


Figure 2B-2. Pre-Development HEC-HMS Nodal Network

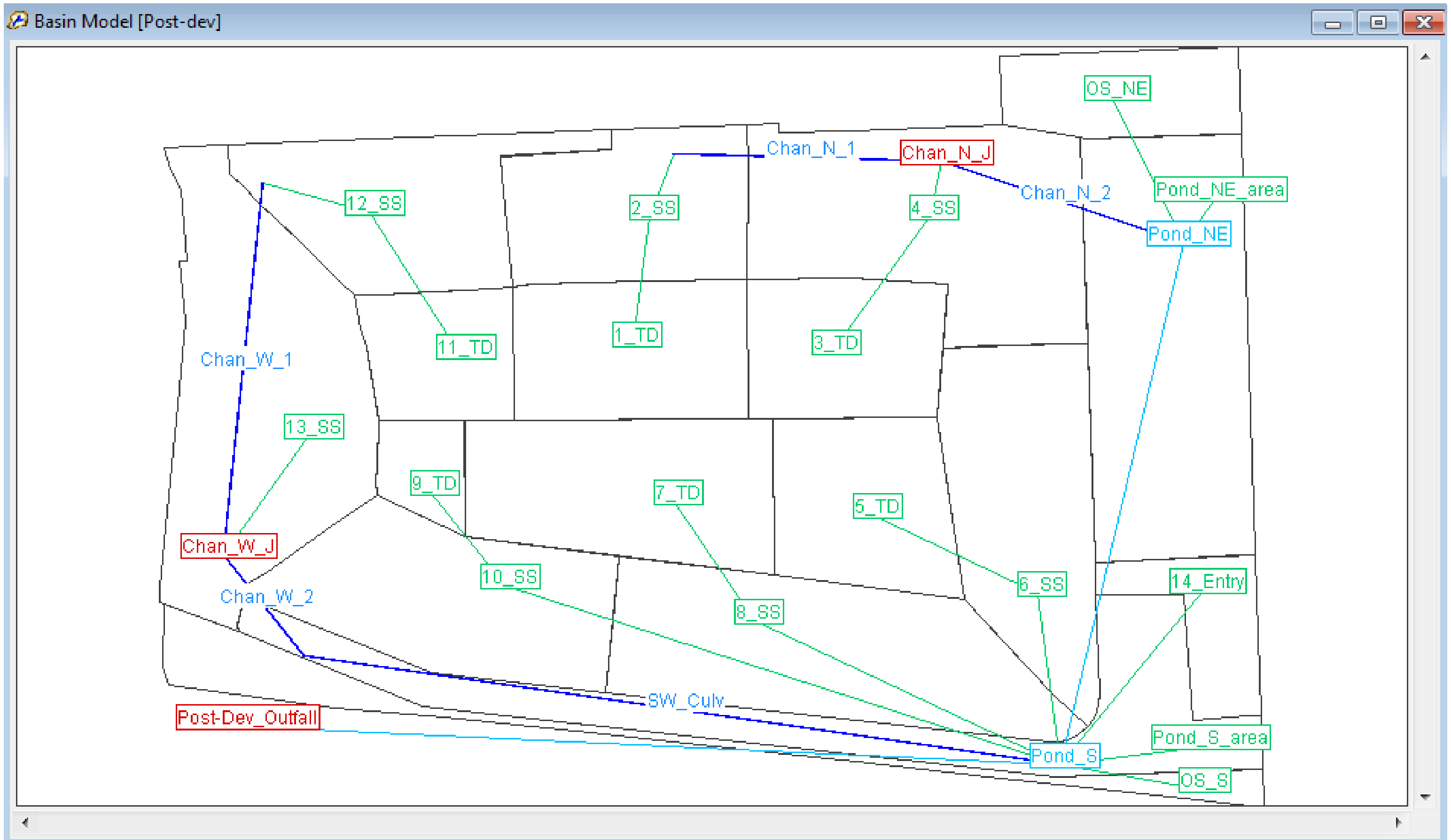
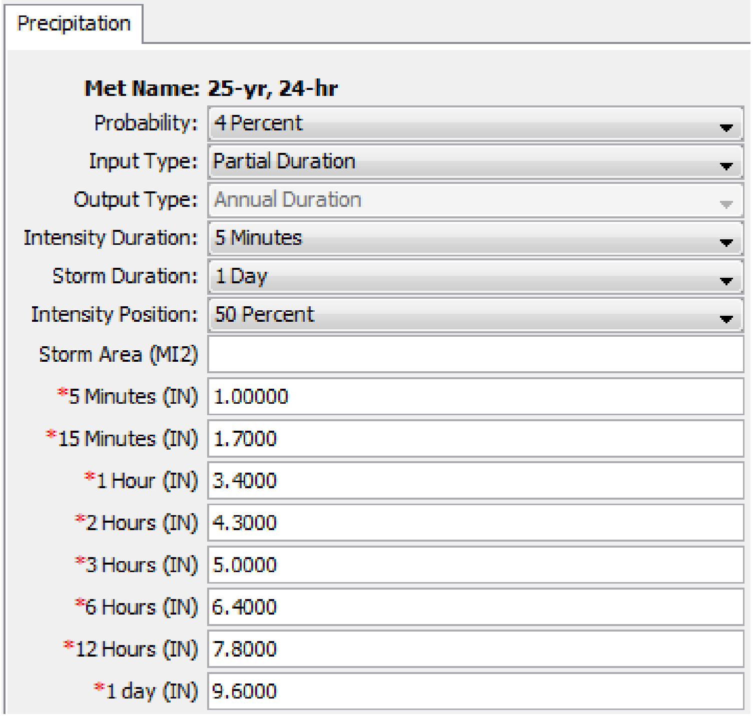


Figure 2B-3. Post-Development HEC-HMS Nodal Network

APPENDIX 2B-1

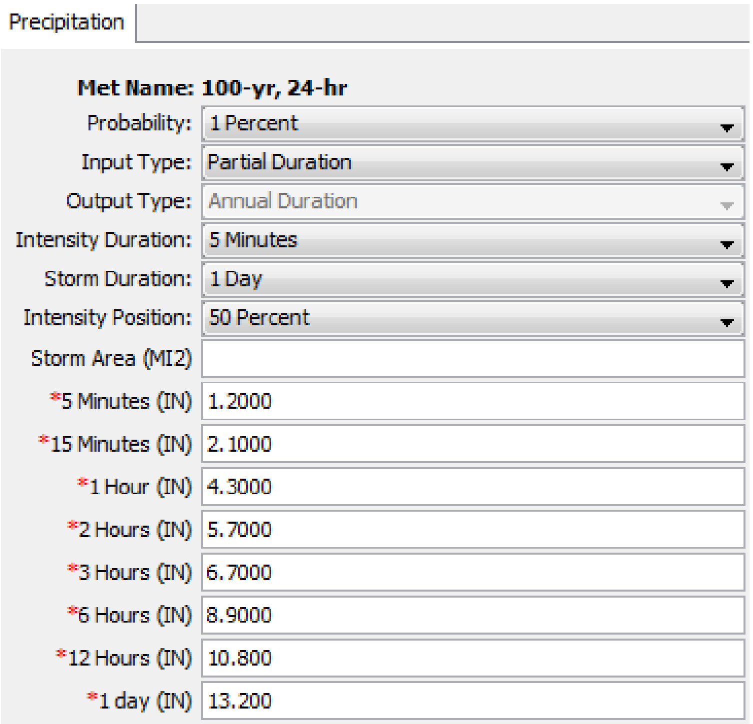
HEC-HMS HYDROLOGIC MODEL PARAMETERS

Table 2B-1-1. 25-Year, 24-Hour Frequency Storm Input



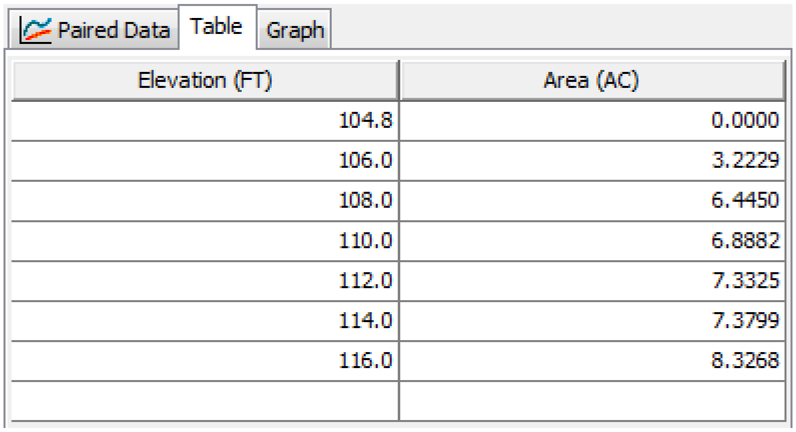
Met Name: 25-yr, 24-hr
Probability: 4 Percent
Input Type: Partial Duration
Output Type: Annual Duration
Intensity Duration: 5 Minutes
Storm Duration: 1 Day
Intensity Position: 50 Percent
Storm Area (MI2)
*5 Minutes (IN) 1.00000
*15 Minutes (IN) 1.7000
*1 Hour (IN) 3.4000
*2 Hours (IN) 4.3000
*3 Hours (IN) 5.0000
*6 Hours (IN) 6.4000
*12 Hours (IN) 7.8000
*1 day (IN) 9.6000

Table 2B-1-2. 100-Year, 24-Hour Frequency Storm Input



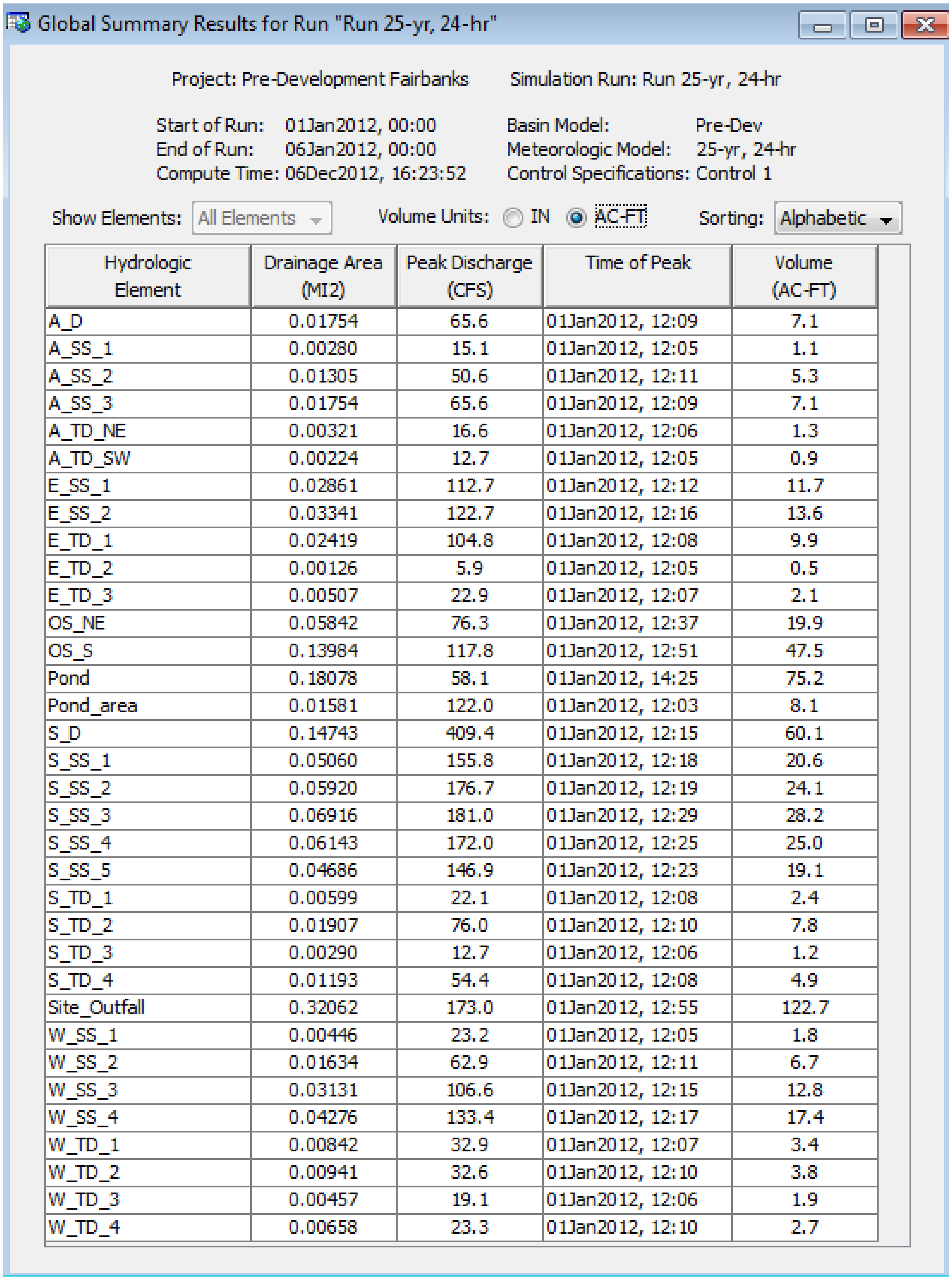
Met Name: 100-yr, 24-hr
Probability: 1 Percent
Input Type: Partial Duration
Output Type: Annual Duration
Intensity Duration: 5 Minutes
Storm Duration: 1 Day
Intensity Position: 50 Percent
Storm Area (MI2)
*5 Minutes (IN) 1.2000
*15 Minutes (IN) 2.1000
*1 Hour (IN) 4.3000
*2 Hours (IN) 5.7000
*3 Hours (IN) 6.7000
*6 Hours (IN) 8.9000
*12 Hours (IN) 10.800
*1 day (IN) 13.200

Table 2B-1-3. Pre-Development Permitted Pond Elevation-Area Relationship



Elevation (FT)	Area (AC)
104.8	0.0000
106.0	3.2229
108.0	6.4450
110.0	6.8882
112.0	7.3325
114.0	7.3799
116.0	8.3268

Table 2B-1-4. Pre-Development 25-Year, 24-Hour Storm Nodal Areas, Peak Flow Rates, and Runoff Volumes



Global Summary Results for Run "Run 25-yr, 24-hr"

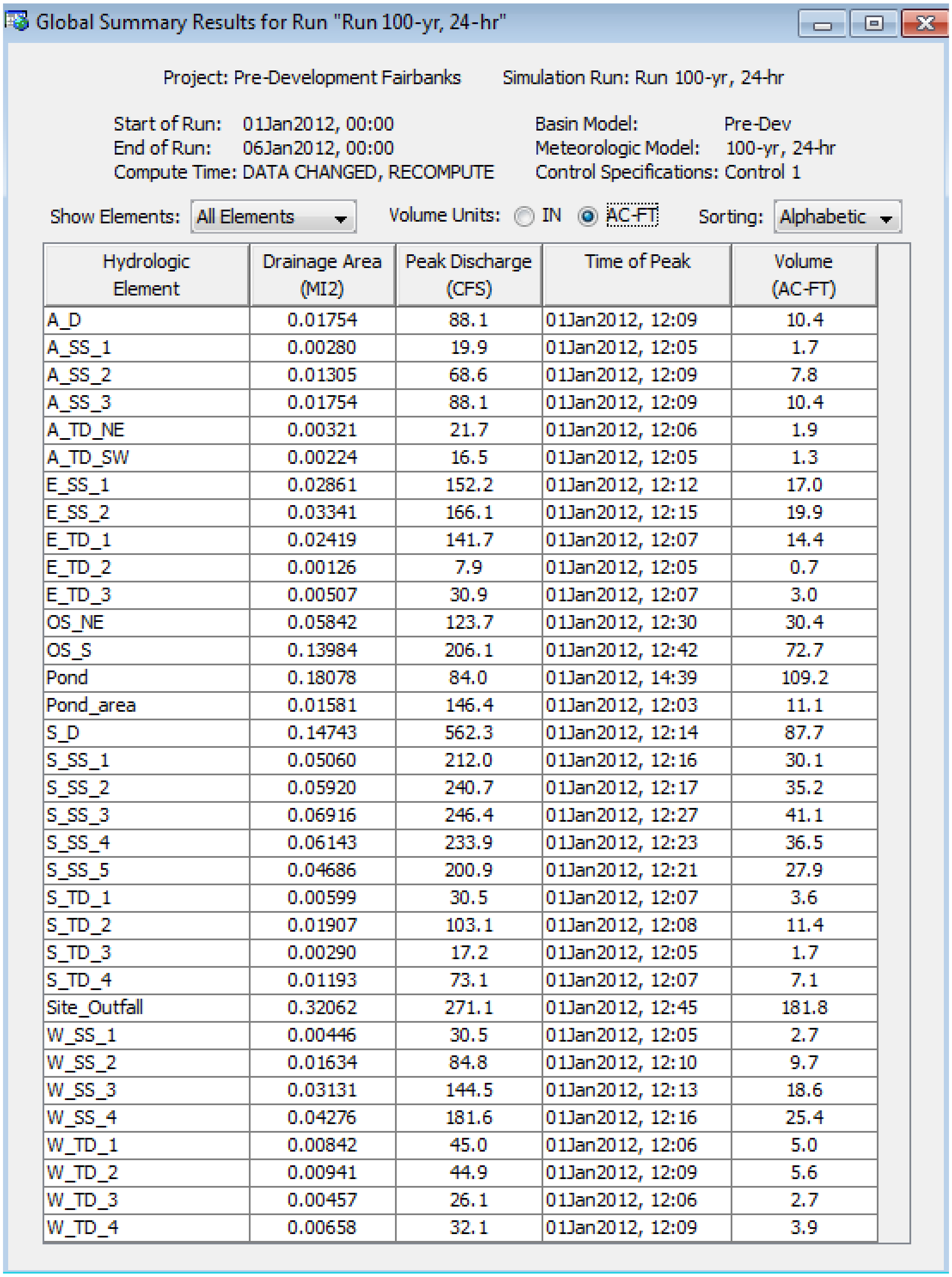
Project: Pre-Development Fairbanks   Simulation Run: Run 25-yr, 24-hr

Start of Run: 01Jan2012, 00:00   Basin Model: Pre-Dev
End of Run: 06Jan2012, 00:00   Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Dec2012, 16:23:52   Control Specifications: Control 1

Show Elements: All Elements   Volume Units: ○ IN ● AC-FT   Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
A_D	0.01754	65.6	01Jan2012, 12:09	7.1
A_SS_1	0.00280	15.1	01Jan2012, 12:05	1.1
A_SS_2	0.01305	50.6	01Jan2012, 12:11	5.3
A_SS_3	0.01754	65.6	01Jan2012, 12:09	7.1
A_TD_NE	0.00321	16.6	01Jan2012, 12:06	1.3
A_TD_SW	0.00224	12.7	01Jan2012, 12:05	0.9
E_SS_1	0.02861	112.7	01Jan2012, 12:12	11.7
E_SS_2	0.03341	122.7	01Jan2012, 12:16	13.6
E_TD_1	0.02419	104.8	01Jan2012, 12:08	9.9
E_TD_2	0.00126	5.9	01Jan2012, 12:05	0.5
E_TD_3	0.00507	22.9	01Jan2012, 12:07	2.1
OS_NE	0.05842	76.3	01Jan2012, 12:37	19.9
OS_S	0.13984	117.8	01Jan2012, 12:51	47.5
Pond	0.18078	58.1	01Jan2012, 14:25	75.2
Pond_area	0.01581	122.0	01Jan2012, 12:03	8.1
S_D	0.14743	409.4	01Jan2012, 12:15	60.1
S_SS_1	0.05060	155.8	01Jan2012, 12:18	20.6
S_SS_2	0.05920	176.7	01Jan2012, 12:19	24.1
S_SS_3	0.06916	181.0	01Jan2012, 12:29	28.2
S_SS_4	0.06143	172.0	01Jan2012, 12:25	25.0
S_SS_5	0.04686	146.9	01Jan2012, 12:23	19.1
S_TD_1	0.00599	22.1	01Jan2012, 12:08	2.4
S_TD_2	0.01907	76.0	01Jan2012, 12:10	7.8
S_TD_3	0.00290	12.7	01Jan2012, 12:06	1.2
S_TD_4	0.01193	54.4	01Jan2012, 12:08	4.9
Site_Outfall	0.32062	173.0	01Jan2012, 12:55	122.7
W_SS_1	0.00446	23.2	01Jan2012, 12:05	1.8
W_SS_2	0.01634	62.9	01Jan2012, 12:11	6.7
W_SS_3	0.03131	106.6	01Jan2012, 12:15	12.8
W_SS_4	0.04276	133.4	01Jan2012, 12:17	17.4
W_TD_1	0.00842	32.9	01Jan2012, 12:07	3.4
W_TD_2	0.00941	32.6	01Jan2012, 12:10	3.8
W_TD_3	0.00457	19.1	01Jan2012, 12:06	1.9
W_TD_4	0.00658	23.3	01Jan2012, 12:10	2.7

Table 2B-1-5. Pre-Development 100-Year, 24-Hour Storm Nodal Areas, Peak Flow Rates, and Runoff Volumes



Global Summary Results for Run "Run 100-yr, 24-hr"

Project: Pre-Development Fairbanks   Simulation Run: Run 100-yr, 24-hr

Start of Run: 01Jan2012, 00:00   Basin Model: Pre-Dev
End of Run: 06Jan2012, 00:00   Meteorologic Model: 100-yr, 24-hr
Compute Time: DATA CHANGED, RECOMPUTE   Control Specifications: Control 1

Show Elements: All Elements   Volume Units: ○ IN ● AC-FT   Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
A_D	0.01754	88.1	01Jan2012, 12:09	10.4
A_SS_1	0.00280	19.9	01Jan2012, 12:05	1.7
A_SS_2	0.01305	68.6	01Jan2012, 12:09	7.8
A_SS_3	0.01754	88.1	01Jan2012, 12:09	10.4
A_TD_NE	0.00321	21.7	01Jan2012, 12:06	1.9
A_TD_SW	0.00224	16.5	01Jan2012, 12:05	1.3
E_SS_1	0.02861	152.2	01Jan2012, 12:12	17.0
E_SS_2	0.03341	166.1	01Jan2012, 12:15	19.9
E_TD_1	0.02419	141.7	01Jan2012, 12:07	14.4
E_TD_2	0.00126	7.9	01Jan2012, 12:05	0.7
E_TD_3	0.00507	30.9	01Jan2012, 12:07	3.0
OS_NE	0.05842	123.7	01Jan2012, 12:30	30.4
OS_S	0.13984	206.1	01Jan2012, 12:42	72.7
Pond	0.18078	84.0	01Jan2012, 14:39	109.2
Pond_area	0.01581	146.4	01Jan2012, 12:03	11.1
S_D	0.14743	562.3	01Jan2012, 12:14	87.7
S_SS_1	0.05060	212.0	01Jan2012, 12:16	30.1
S_SS_2	0.05920	240.7	01Jan2012, 12:17	35.2
S_SS_3	0.06916	246.4	01Jan2012, 12:27	41.1
S_SS_4	0.06143	233.9	01Jan2012, 12:23	36.5
S_SS_5	0.04686	200.9	01Jan2012, 12:21	27.9
S_TD_1	0.00599	30.5	01Jan2012, 12:07	3.6
S_TD_2	0.01907	103.1	01Jan2012, 12:08	11.4
S_TD_3	0.00290	17.2	01Jan2012, 12:05	1.7
S_TD_4	0.01193	73.1	01Jan2012, 12:07	7.1
Site_Outfall	0.32062	271.1	01Jan2012, 12:45	181.8
W_SS_1	0.00446	30.5	01Jan2012, 12:05	2.7
W_SS_2	0.01634	84.8	01Jan2012, 12:10	9.7
W_SS_3	0.03131	144.5	01Jan2012, 12:13	18.6
W_SS_4	0.04276	181.6	01Jan2012, 12:16	25.4
W_TD_1	0.00842	45.0	01Jan2012, 12:06	5.0
W_TD_2	0.00941	44.9	01Jan2012, 12:09	5.6
W_TD_3	0.00457	26.1	01Jan2012, 12:06	2.7
W_TD_4	0.00658	32.1	01Jan2012, 12:09	3.9

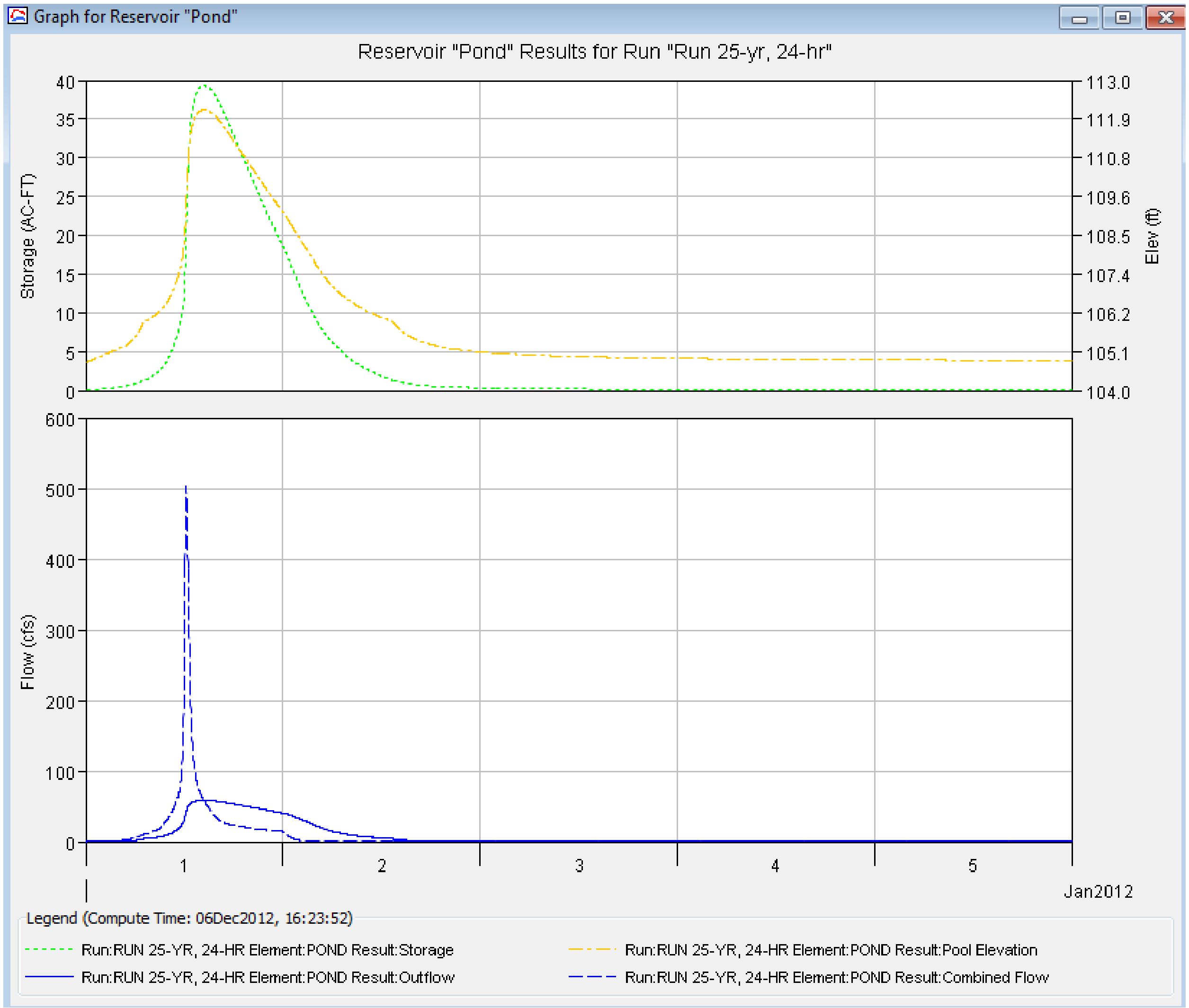


Figure 2B-1-1. Pre-Development 25-Year, 24-Hour Permitted Pond Hydrograph and Elevation/Storage Relationships

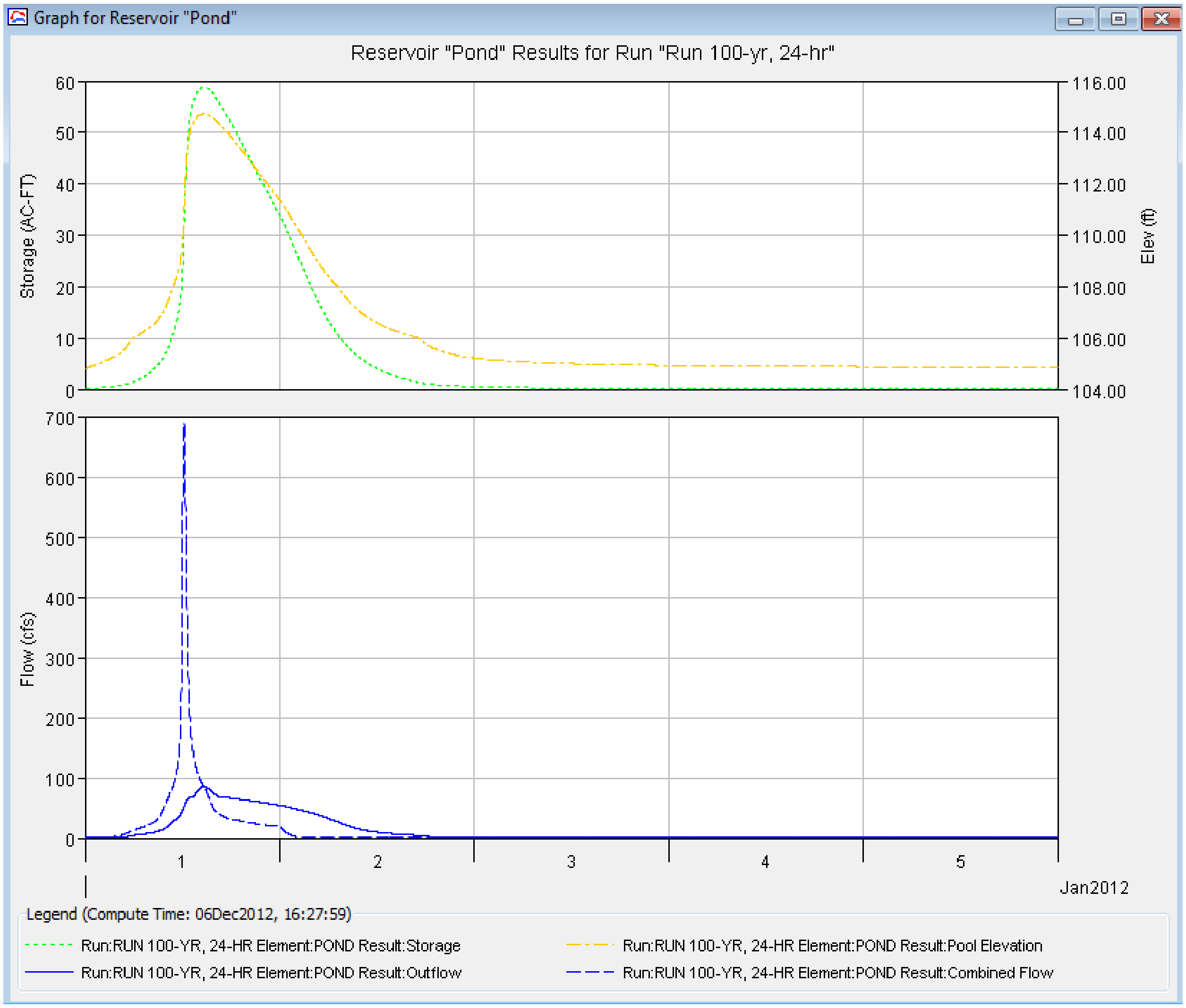


Figure 2B-1-2. Pre-Development 100-Year, 24-Hour Permitted Pond Hydrograph and Elevation/Storage Relationships

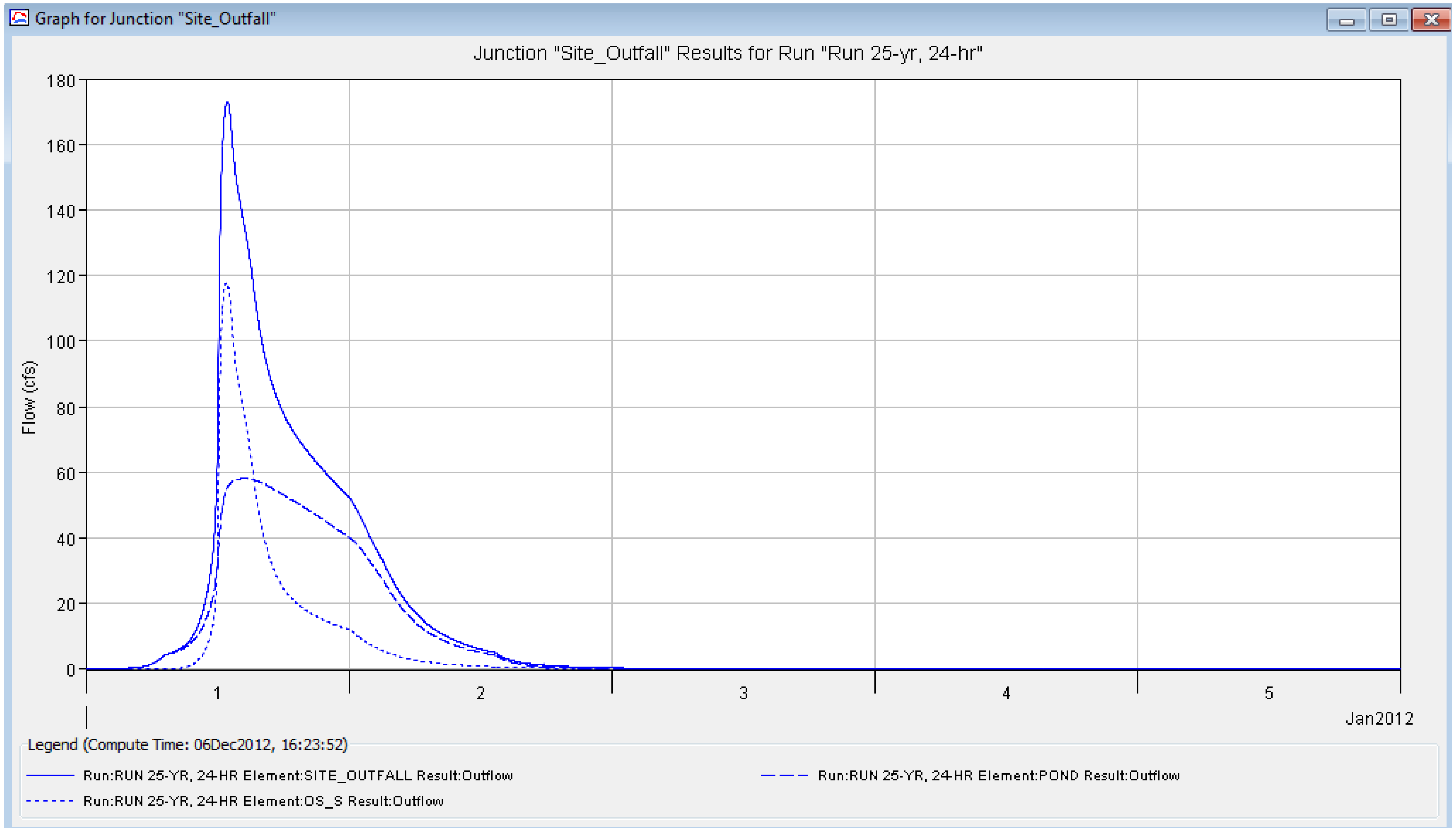


Figure 2B-1-3. Pre-Development 25-Year, 24-Hour Runoff Hydrograph at Site Outfall

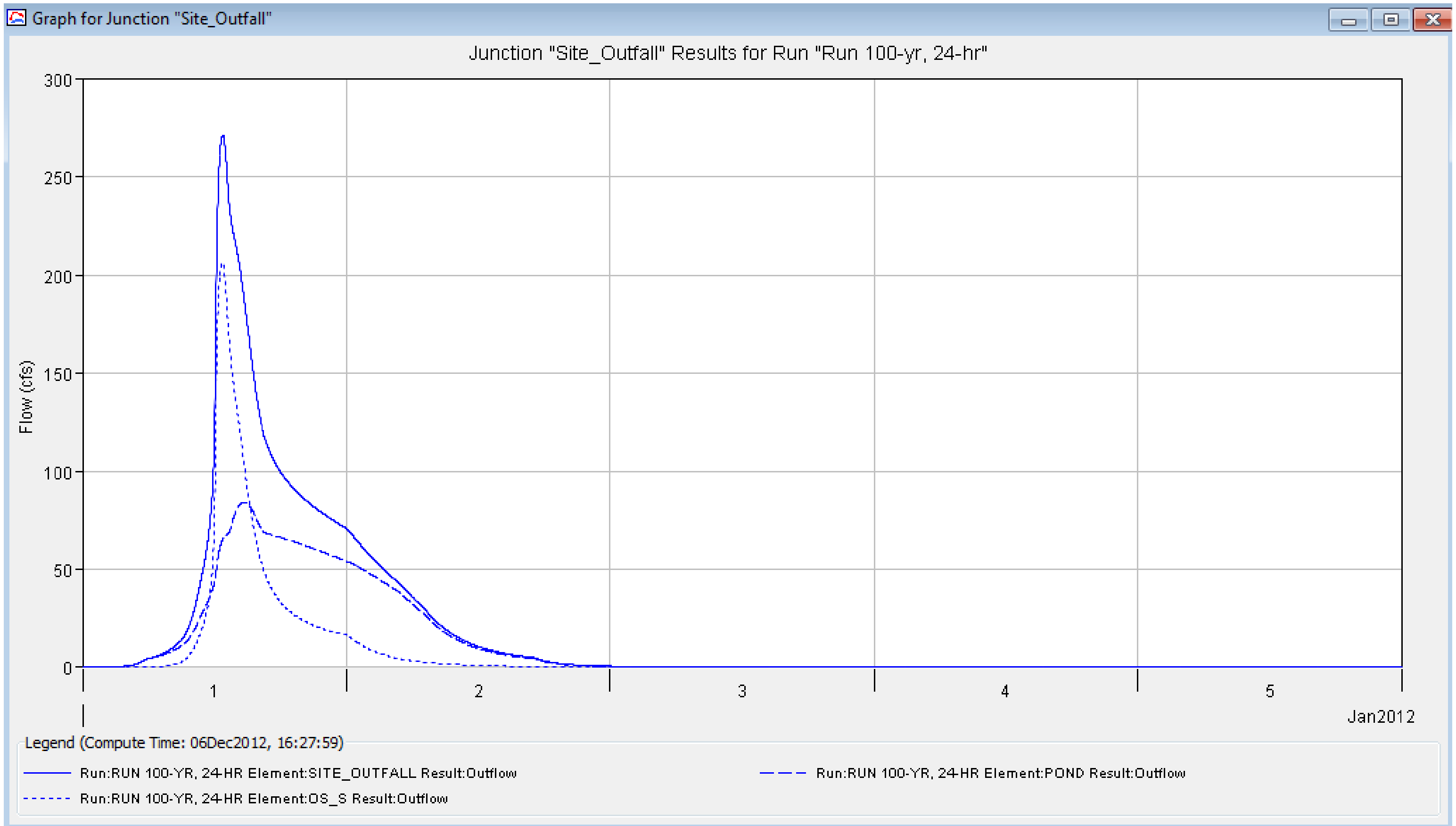
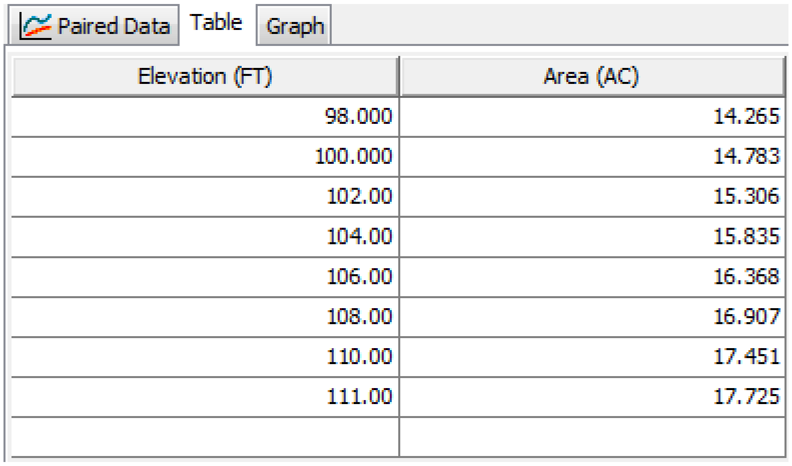


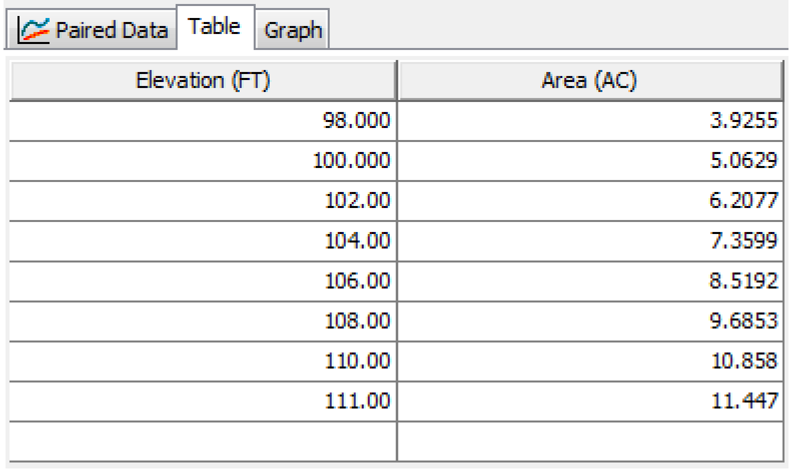
Figure 2B-1-4. Pre-Development 100-Year, 24-Hour Runoff Hydrograph at Site Outfall

Table 2B-1-6. Post-Development Northeast Surface Water Pond Elevation-Area Relationship



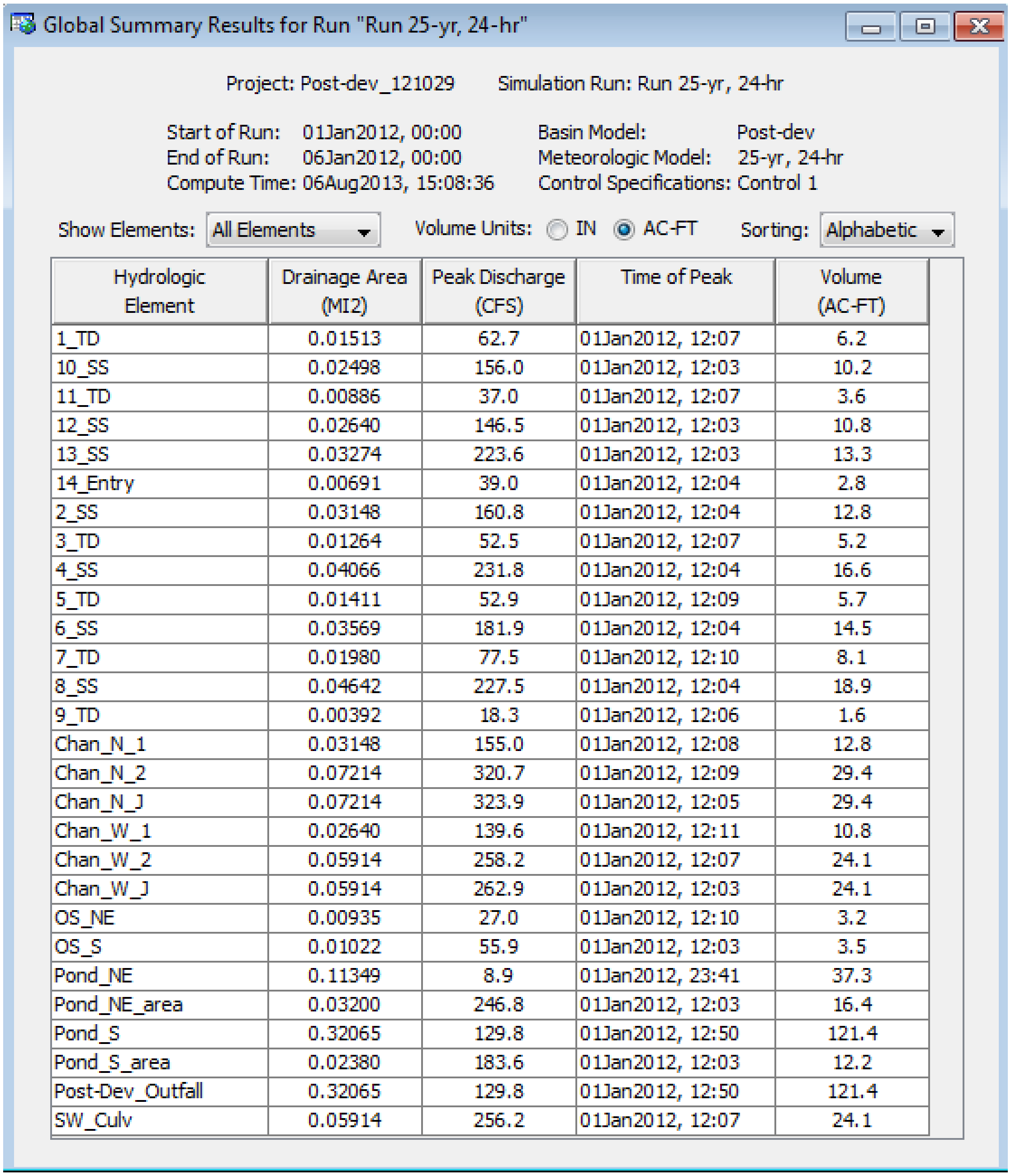
Elevation (FT)	Area (AC)
98.000	14.265
100.000	14.783
102.00	15.306
104.00	15.835
106.00	16.368
108.00	16.907
110.00	17.451
111.00	17.725

Table 2B-1-6. Post-Development South Surface Water Pond Elevation-Area Relationship



Elevation (FT)	Area (AC)
98.000	3.9255
100.000	5.0629
102.00	6.2077
104.00	7.3599
106.00	8.5192
108.00	9.6853
110.00	10.858
111.00	11.447

Table 2B-1-7. Post-Development 25-Year, 24-Hour Storm Nodal Areas, Peak Flow Rates, and Runoff Volumes



Global Summary Results for Run "Run 25-yr, 24-hr"

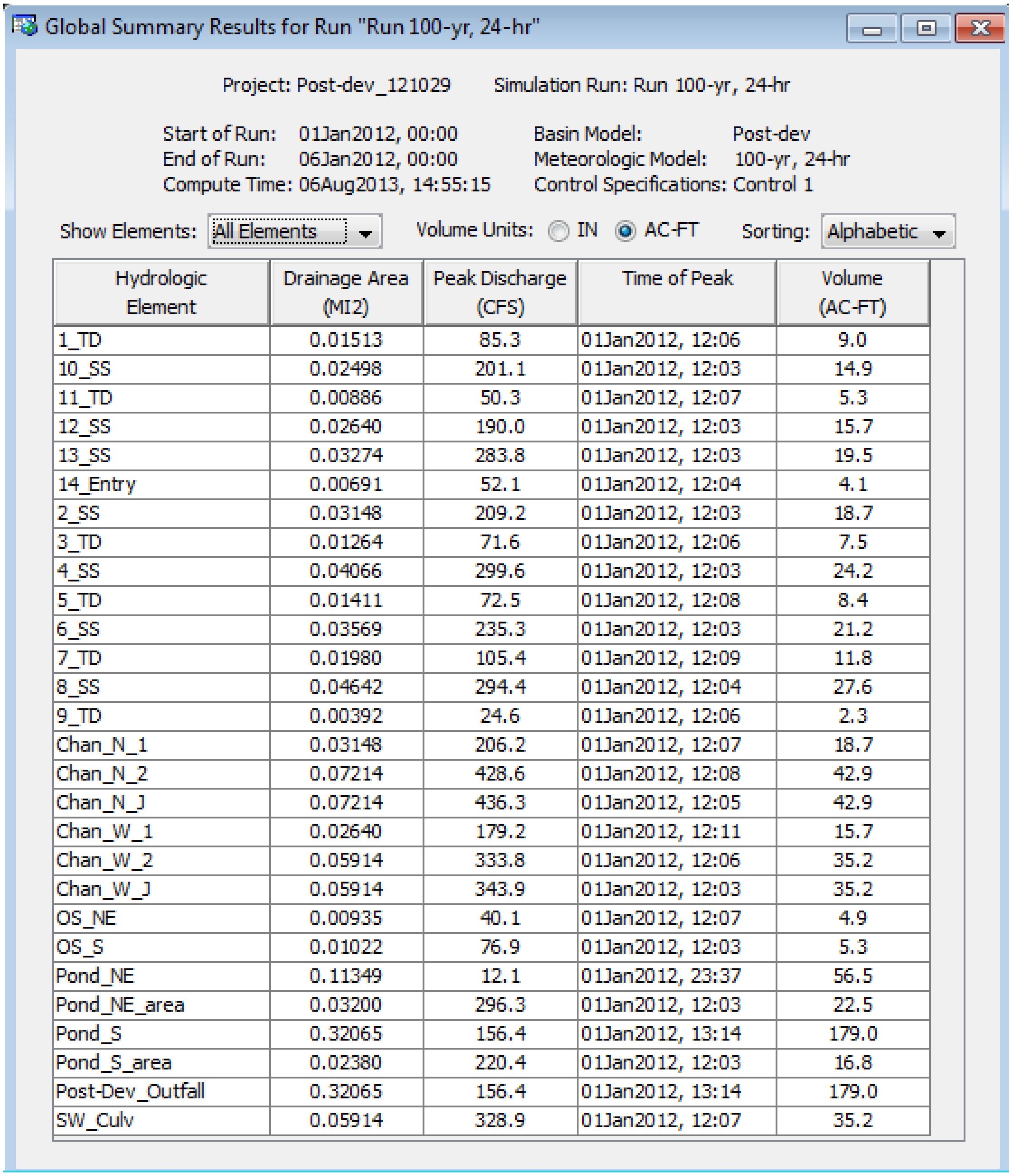
Project: Post-dev_121029   Simulation Run: Run 25-yr, 24-hr

Start of Run: 01Jan2012, 00:00   Basin Model: Post-dev
End of Run: 06Jan2012, 00:00   Meteorologic Model: 25-yr, 24-hr
Compute Time: 06Aug2013, 15:08:36   Control Specifications: Control 1

Show Elements: All Elements   Volume Units: ○ IN ● AC-FT   Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
1_TD	0.01513	62.7	01Jan2012, 12:07	6.2
10_SS	0.02498	156.0	01Jan2012, 12:03	10.2
11_TD	0.00886	37.0	01Jan2012, 12:07	3.6
12_SS	0.02640	146.5	01Jan2012, 12:03	10.8
13_SS	0.03274	223.6	01Jan2012, 12:03	13.3
14_Entry	0.00691	39.0	01Jan2012, 12:04	2.8
2_SS	0.03148	160.8	01Jan2012, 12:04	12.8
3_TD	0.01264	52.5	01Jan2012, 12:07	5.2
4_SS	0.04066	231.8	01Jan2012, 12:04	16.6
5_TD	0.01411	52.9	01Jan2012, 12:09	5.7
6_SS	0.03569	181.9	01Jan2012, 12:04	14.5
7_TD	0.01980	77.5	01Jan2012, 12:10	8.1
8_SS	0.04642	227.5	01Jan2012, 12:04	18.9
9_TD	0.00392	18.3	01Jan2012, 12:06	1.6
Chan_N_1	0.03148	155.0	01Jan2012, 12:08	12.8
Chan_N_2	0.07214	320.7	01Jan2012, 12:09	29.4
Chan_N_J	0.07214	323.9	01Jan2012, 12:05	29.4
Chan_W_1	0.02640	139.6	01Jan2012, 12:11	10.8
Chan_W_2	0.05914	258.2	01Jan2012, 12:07	24.1
Chan_W_J	0.05914	262.9	01Jan2012, 12:03	24.1
OS_NE	0.00935	27.0	01Jan2012, 12:10	3.2
OS_S	0.01022	55.9	01Jan2012, 12:03	3.5
Pond_NE	0.11349	8.9	01Jan2012, 23:41	37.3
Pond_NE_area	0.03200	246.8	01Jan2012, 12:03	16.4
Pond_S	0.32065	129.8	01Jan2012, 12:50	121.4
Pond_S_area	0.02380	183.6	01Jan2012, 12:03	12.2
Post-Dev_Outfall	0.32065	129.8	01Jan2012, 12:50	121.4
SW_Culv	0.05914	256.2	01Jan2012, 12:07	24.1

Table 2B-1-8. Post-Development 100-Year, 24-Hour Storm Nodal Areas, Peak Flow Rates, and Runoff Volumes



Global Summary Results for Run "Run 100-yr, 24-hr"

Project: Post-dev_121029 Simulation Run: Run 100-yr, 24-hr

Start of Run: 01Jan2012, 00:00
End of Run: 06Jan2012, 00:00
Compute Time: 06Aug2013, 14:55:15

Basin Model: Post-dev
Meteorologic Model: 100-yr, 24-hr
Control Specifications: Control 1

Show Elements: All Elements
Volume Units: ○ IN ● AC-FT
Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
1_TD	0.01513	85.3	01Jan2012, 12:06	9.0
10_SS	0.02498	201.1	01Jan2012, 12:03	14.9
11_TD	0.00886	50.3	01Jan2012, 12:07	5.3
12_SS	0.02640	190.0	01Jan2012, 12:03	15.7
13_SS	0.03274	283.8	01Jan2012, 12:03	19.5
14_Entry	0.00691	52.1	01Jan2012, 12:04	4.1
2_SS	0.03148	209.2	01Jan2012, 12:03	18.7
3_TD	0.01264	71.6	01Jan2012, 12:06	7.5
4_SS	0.04066	299.6	01Jan2012, 12:03	24.2
5_TD	0.01411	72.5	01Jan2012, 12:08	8.4
6_SS	0.03569	235.3	01Jan2012, 12:03	21.2
7_TD	0.01980	105.4	01Jan2012, 12:09	11.8
8_SS	0.04642	294.4	01Jan2012, 12:04	27.6
9_TD	0.00392	24.6	01Jan2012, 12:06	2.3
Chan_N_1	0.03148	206.2	01Jan2012, 12:07	18.7
Chan_N_2	0.07214	428.6	01Jan2012, 12:08	42.9
Chan_N_J	0.07214	436.3	01Jan2012, 12:05	42.9
Chan_W_1	0.02640	179.2	01Jan2012, 12:11	15.7
Chan_W_2	0.05914	333.8	01Jan2012, 12:06	35.2
Chan_W_J	0.05914	343.9	01Jan2012, 12:03	35.2
OS_NE	0.00935	40.1	01Jan2012, 12:07	4.9
OS_S	0.01022	76.9	01Jan2012, 12:03	5.3
Pond_NE	0.11349	12.1	01Jan2012, 23:37	56.5
Pond_NE_area	0.03200	296.3	01Jan2012, 12:03	22.5
Pond_S	0.32065	156.4	01Jan2012, 13:14	179.0
Pond_S_area	0.02380	220.4	01Jan2012, 12:03	16.8
Post-Dev_Outfall	0.32065	156.4	01Jan2012, 13:14	179.0
SW_Culv	0.05914	328.9	01Jan2012, 12:07	35.2

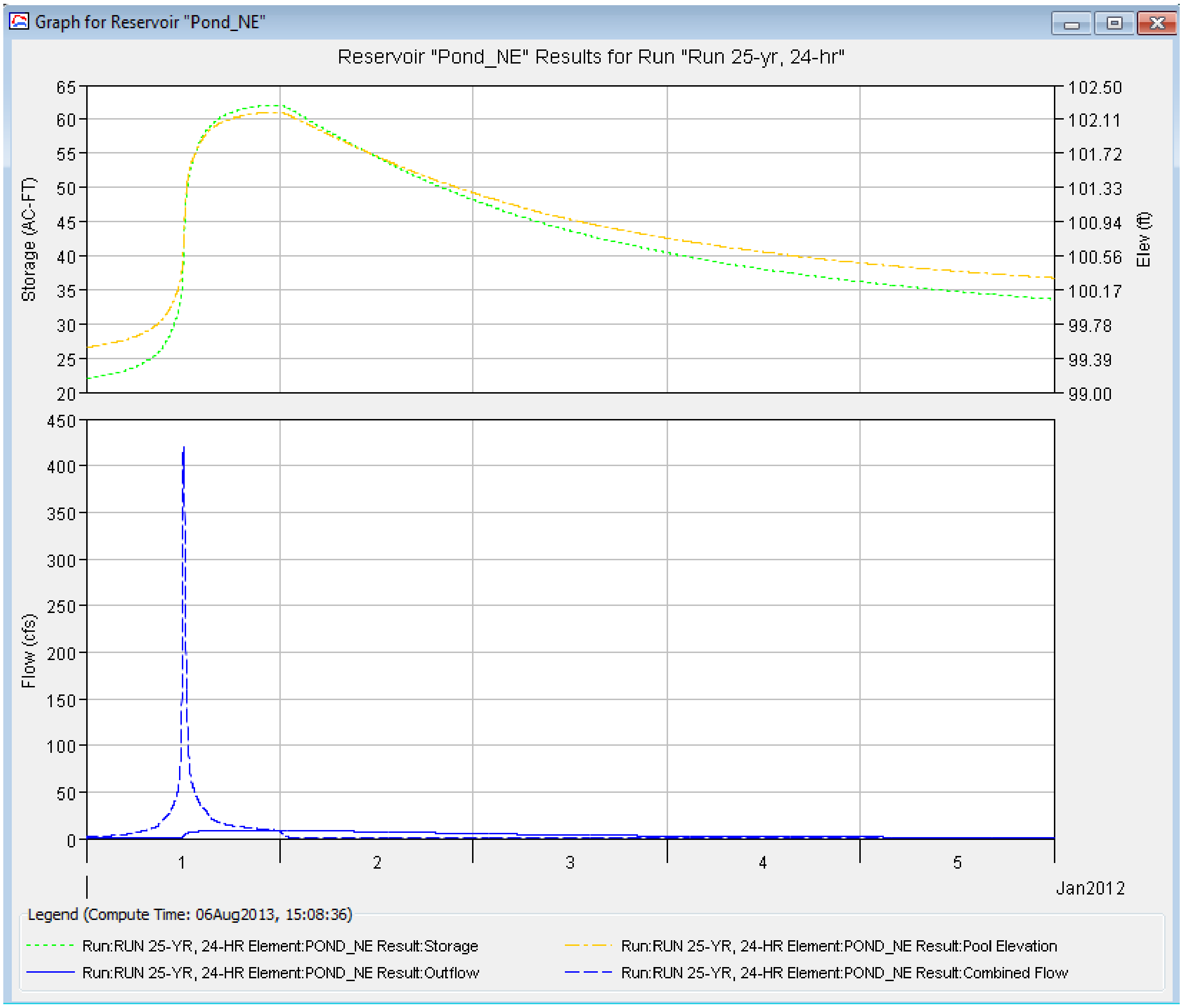


Figure 2B-1-5. Post-Development 25-Year, 24-Hour Northeast Surface Water Pond Hydrograph and Elevation/Storage Relationships

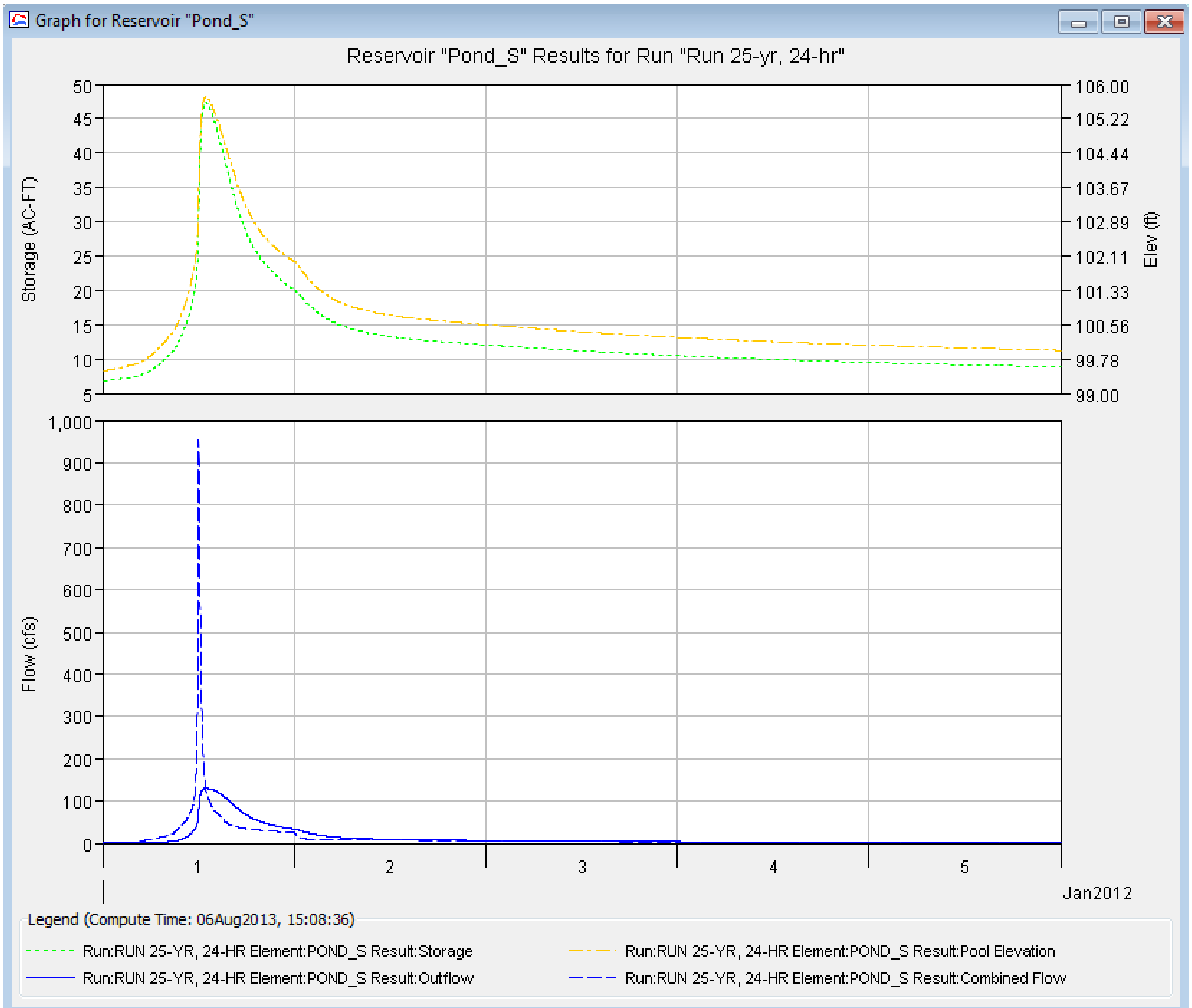


Figure 2B-1-6. Post-Development 25-Year, 24-Hour South Surface Water Pond Hydrograph and Elevation/Storage Relationships

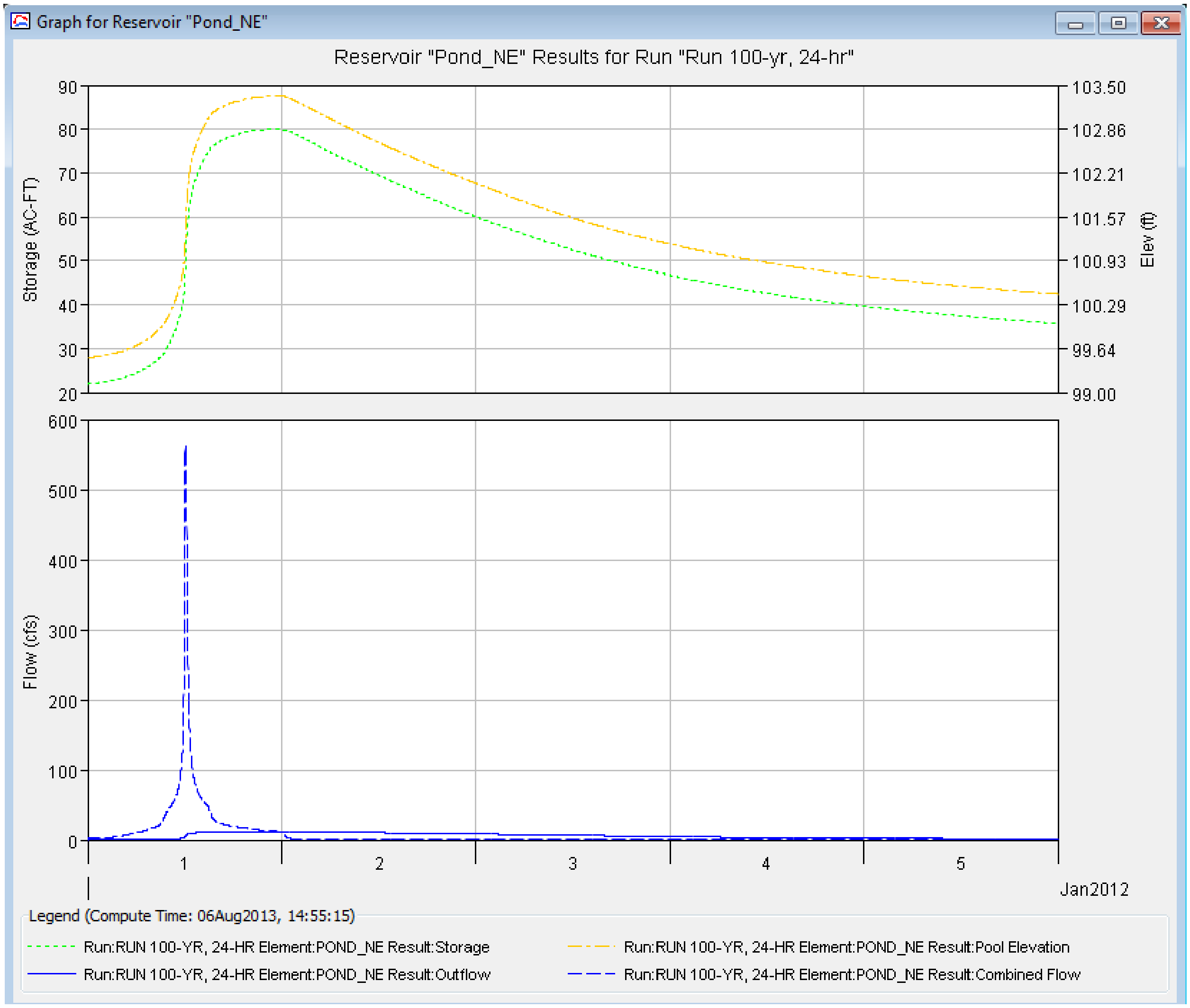


Figure 2B-1-7. Post-Development 100-Year, 24-Hour Northeast Surface Water Pond Hydrograph and Elevation/Storage Relationships

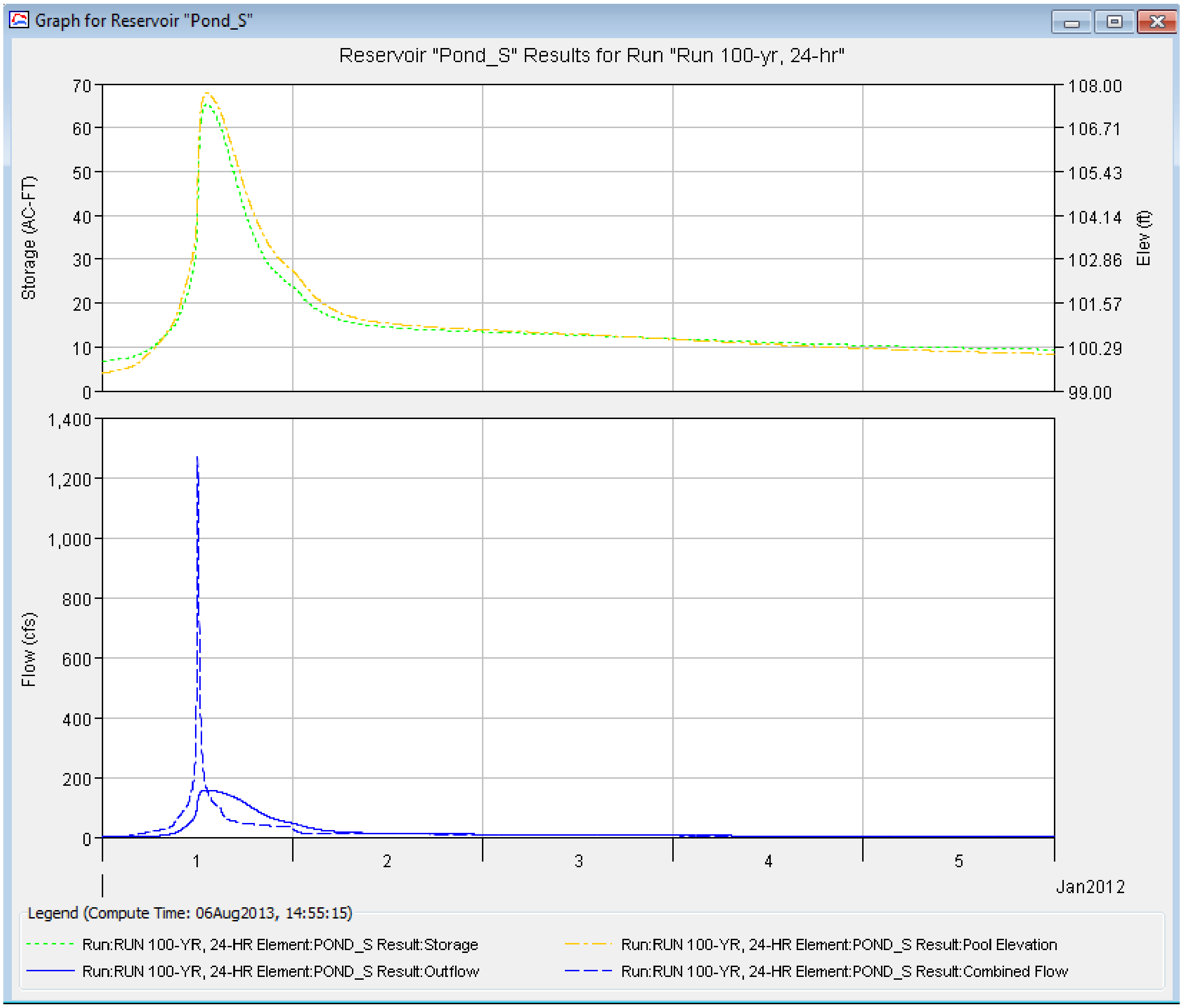


Figure 2B-1-8. Post-Development 100-Year, 24-Hour South Surface Water Pond Hydrograph and Elevation/Storage Relationships

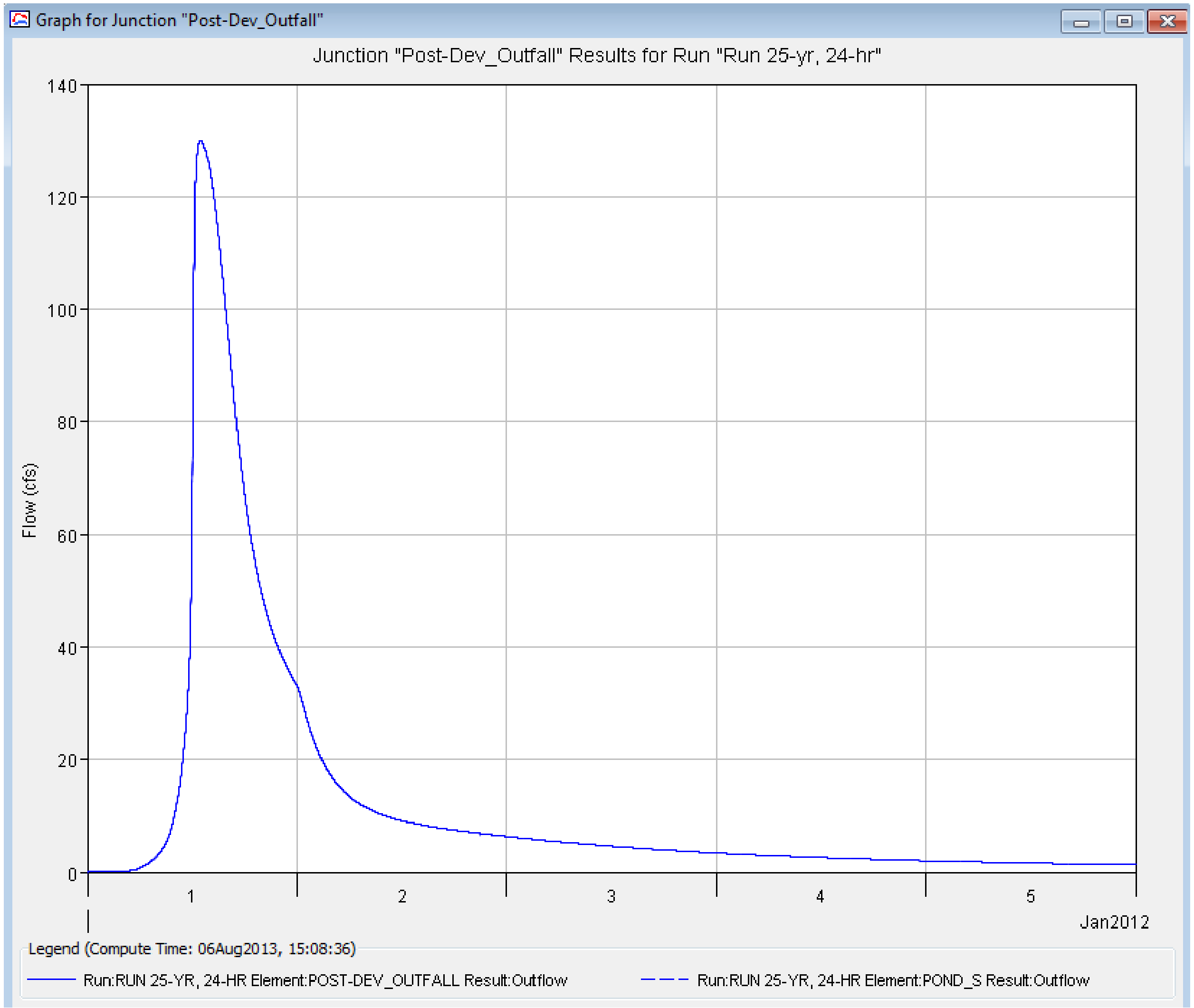


Figure 2B-1-9. Post-Development 25-Year, 24-Hour Runoff Hydrograph at Site Outfall

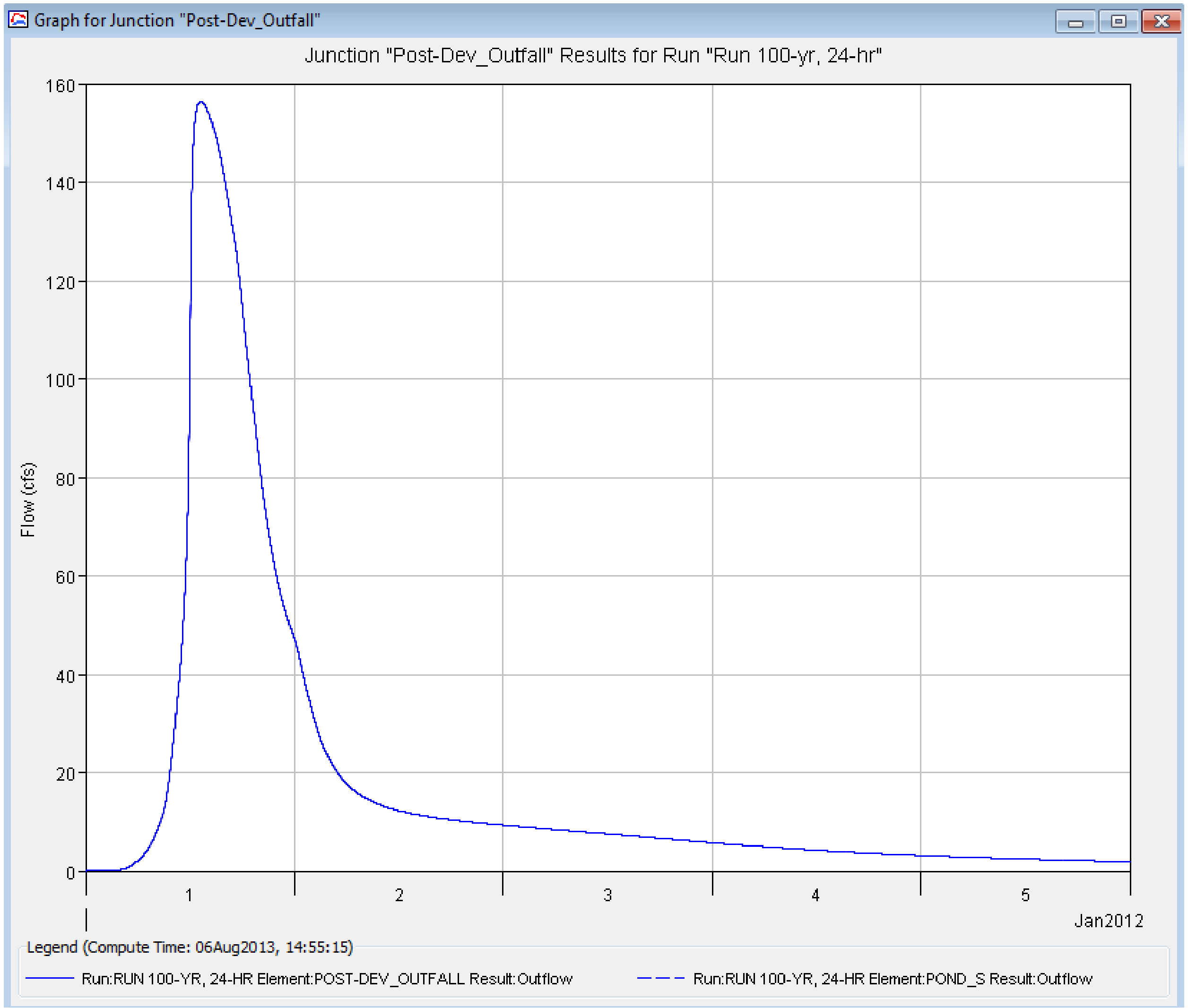


Figure 2B-1-10. Post-Development 100-Year, 24-Hour Runoff Hydrograph at Site Outfall

HEC-HMS PRE-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Pre-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

Pre-development			Plane 1				Plane 2				Loss 1	Loss 2	Collector (Top Deck Drainage Terraces)							Channel (Perimeter Channels or Downchute Channels)					
Subcatchment Designation	Area A (mi^2)	Area A (acres)	Length L (ft)	Slope S (ft/ft)	Roughness N	Area Percent	Length L (ft)	Slope S (ft/ft)	Roughness N	Area Percent	CN	CN	Collector Length (ft)	Slope (ft/ft)	Manning n	Area A (mi^2)	Shape	Bottom Width (ft)	Side Slope (H:V)	Collector Length (ft)	Slope (ft/ft)	Shape	Manning n	Bottom Width (ft)	Side Slope (H:V)
A_SS_1	0.00280	1.79	60	0.2500	0.15	60	40	0.1000	0.15	40	84	84								710	0.0015	trapezoid	0.04	2	3
A_SS_2	0.00704	4.51	80	0.2500	0.15	44	100	0.0200	0.15	56	84	84								1032	0.0015	trapezoid	0.04	2	3
A_SS_3	0.00225	1.44	70	0.2500	0.15	58	50	0.0400	0.15	42	84	84								422	0.0015	trapezoid	0.04	2	3
A_TD_NE	0.00321	2.05	215	0.0500	0.15	100					84		570	0.0015	0.04	0.00321	triangle	0	3	65	0.2500	trapezoid	0.03	2	3
A_TD_SW	0.00224	1.44	180	0.0500	0.15	100					84		390	0.0015	0.04	0.00224	triangle	0	3	60	0.2500	trapezoid	0.03	2	3
E_SS_1	0.00442	2.83	85	0.2500	0.15	63	50	0.0800	0.15	37	84	84								863	0.0015	triangle	0.04	0	3
E_SS_2	0.00354	2.27	100	0.2500	0.15	63	60	0.0667	0.15	38	84	84								684	0.0015	triangle	0.04	0	3
E_TD_1	0.02419	15.48	526	0.0494	0.15	100					84		770	0.0015	0.04	0.02419	triangle	0	3	70	0.2500	trapezoid	0.03	2	3
E_TD_2	0.00126	0.80	366	0.0300	0.15	100					84		90	0.0015	0.04	0.00126	triangle	0	3	85	0.2500	trapezoid	0.03	2	3
E_TD_3	0.00507	3.24	375	0.0347	0.15	100					84		515	0.0015	0.04	0.00507	triangle	0	3	85	0.2500	trapezoid	0.03	2	3
OS_NE	0.05842	37.39	1750	0.0050	0.15	100					74									830	0.0072	triangle	0.04	0	3
OS_S	0.08142	52.11	4000	0.0025	0.15	100					74									875	0.0023	trapezoid	0.04	8	3
Pond_area	0.01581	10.12									99														
S_SS_1	0.00126	0.81	45	0.2500	0.15	38	75	0.0533	0.15	63	84	84								300	0.0015	trapezoid	0.04	2	3
S_SS_2	0.00261	1.67	65	0.2500	0.15	36	115	0.0522	0.15	64	84	84								400	0.0015	trapezoid	0.04	2	2.5
S_SS_3	0.00483	3.09	90	0.2500	0.15	62	55	0.0727	0.15	38	84	84								940	0.0015	trapezoid	0.04	2	3
S_SS_4	0.00264	1.69	85	0.2500	0.15	57	65	0.0308	0.15	43	84	84								481	0.0015	trapezoid	0.04	2	3
S_SS_5	0.00838	5.36	115	0.2500	0.15	62	70	0.0286	0.15	38	84	84								1394	0.0015	trapezoid	0.04	2	3
S_TD_1	0.00599	3.83	681	0.0323	0.15	100					84		400	0.0015	0.04	0.00599	triangle	0	3	25	0.2500	trapezoid	0.03	2	3
S_TD_2	0.01907	12.21	575	0.0400	0.15	100					84		940	0.0015	0.04	0.01907	triangle	0	3	40	0.2500	trapezoid	0.03	2	3
S_TD_3	0.00290	1.86	485	0.0371	0.15	100					84		170	0.0015	0.04	0.00290	triangle	0	3	60	0.2500	trapezoid	0.03	2	3
S_TD_4	0.01193	7.64	407	0.0442	0.15	100					84		690	0.0015	0.04	0.01193	triangle	0	3	85	0.2500	trapezoid	0.03	2	3
W_SS_1	0.00446	2.86	95	0.2500	0.15	66	50	0.1200	0.15	34	84	84								853	0.0015	triangle	0.04	0	3
W_SS_2	0.00346	2.22	75	0.2500	0.15	60	50	0.1200	0.15	40	84	84								710	0.0015	trapezoid	0.04	2	3
W_SS_3	0.00556	3.56	85	0.2500	0.15	43	115	0.0522	0.15	58	84	84								787	0.0015	trapezoid	0.04	2	3
W_SS_4	0.00688	4.40	95	0.2500	0.15	34	185	0.0216	0.15	66	84	84								670	0.0015	trapezoid	0.04	2	3
W_TD_1	0.00842	5.39	644	0.0373	0.15	100					84		325	0.0015	0.04	0.00842	triangle	0	3	75	0.2500	trapezoid	0.03	2	3
W_TD_2	0.00941	6.02	785	0.0306	0.15	100					84		550	0.0015	0.04	0.00941	triangle	0	3	45	0.2500	trapezoid	0.03	2	3
W_TD_3	0.00457	2.93	575	0.0417	0.15	100					84		230	0.0015	0.04	0.00457	triangle	0	3	45	0.2500	trapezoid	0.03	2	3
W_TD_4	0.00658	4.21	715	0.0294	0.15	100					84		590	0.0015	0.04	0.00658	triangle	0	3	60	0.2500	trapezoid	0.03	2	3
Total	0.32063	205.20																							

```
Basin: Pre-Dev
     Last Modified Date: 6 December 2012
     Last Modified Time: 21:16:21
     Version: 3.5
     Filepath Separator: \
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No

     Enable Sediment Routing: No

     Enable Quality Routing: No
End:

Subbasin: E_TD_1
     Description: East ditch, top deck
     Canvas X: 3067081.1200204236
     Canvas Y: 1.3892341127883058E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.02419
     Downstream: E_SS_1

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 526
     Slope: 0.0494
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 700
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.02419
     Number of Increments: 5

     Channel: Main
     Length: 70
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: E_SS_1
     Description: East ditch, side slope
     Canvas X: 3067459.4225884504
     Canvas Y: 1.3892649098142663E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00442
     Downstream: E_SS_2

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 85
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 63
     Number of Increments: 5

     Plane: 2
     Length: 50
     Slope: 0.08
     Mannings N: 0.15
     Percent of Area: 37
     Number of Increments: 5

     Channel: Main
     Length: 863
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: E_TD_2
     Description: East ditch, top deck
     Canvas X: 3067933.6328497804
     Canvas Y: 1.3892415722755626E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
```

```
    Area: 0.00126
    Downstream: E_SS_2

    Canopy 1: None

    Surface 1: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 366
    Slope: 0.03
    Mannings N: 0.15
    Percent of Area: 100
    Number of Increments: 5

    Channel: 2
    Length: 90
    Slope: 0.0015
    Mannings N: 0.04
    Shape: Triangle
    Side Slope: 3
    Contributing Area: 0.00126
    Number of Increments: 5

    Channel: Main
    Length: 85
    Slope: 0.25
    Mannings N: 0.03
    Shape: Trapezoid
    Width: 2
    Side Slope: 3
    Number of Increments: 5

    Baseflow: None
End:

Subbasin: E_SS_2
    Description: East ditch, side slope
    Canvas X: 3068333.248238541
    Canvas Y: 1.3892692789425168E7
    From Canvas X: 3071222.469895692
    From Canvas Y: 1.3894552670662308E7
    Area: 0.00354
    Downstream: S_SS_5

    Canopy 1: None

    Canopy 2: None

    Surface 1: None

    Surface 2: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    LossRate 2: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 100
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 63
    Number of Increments: 5

    Plane: 2
    Length: 60
    Slope: 0.0667
    Mannings N: 0.15
    Percent of Area: 37
    Number of Increments: 5

    Channel: Main
    Length: 684
    Slope: 0.0015
    Mannings N: 0.04
    Shape: Triangle
    Side Slope: 3
    Number of Increments: 5
    Route Upstream: Yes

    Baseflow: None
End:

Subbasin: E_TD_3
    Description: East ditch, top deck
    Canvas X: 3068173.402083037
    Canvas Y: 1.3892303830446774E7
    From Canvas X: 3071222.469895692
    From Canvas Y: 1.3894552670662308E7
    Area: 0.00507
    Downstream: S_SS_5

    Canopy 1: None

    Surface 1: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 375
    Slope: 0.0347
    Mannings N: 0.15
    Percent of Area: 100
    Number of Increments: 5

    Channel: 2
    Length: 515
```

```
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00507
     Number of Increments: 5

     Channel: Main
     Length: 85
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: S_SS_5
     Description: South ditch, side slope
     Canvas X: 3068422.060028711
     Canvas Y: 1.3892015996094918E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00838
     Downstream: S_SS_4

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 115
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 62
     Number of Increments: 5

     Plane: 2
     Length: 70
     Slope: 0.0286
     Mannings N: 0.15
     Percent of Area: 38
     Number of Increments: 5

     Channel: Main
     Length: 1394
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: S_TD_4
     Description: South ditch, top deck
     Canvas X: 3067645.909769872
     Canvas Y: 1.3892021435572049E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.01193
     Downstream: S_SS_4

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 407
     Slope: 0.0442
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 690
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.01193
     Number of Increments: 5

     Channel: Main
     Length: 85
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: S_SS_4
     Description: South ditch, side slope
```

Canvas X: 3067482.28741518
Canvas Y: 1.389163095161464E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00264
Downstream: S_SS_3

Canopy 1: None

Canopy 2: None

Surface 1: None

Surface 2: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

LossRate 2: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 85
Slope: 0.25
Mannings N: 0.15
Percent of Area: 57
Number of Increments: 5

Plane: 2
Length: 65
Slope: 0.0308
Mannings N: 0.15
Percent of Area: 43
Number of Increments: 5

Channel: Main
Length: 481
Slope: 0.0015
Mannings N: 0.04
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: S_TD_3
Description: South ditch, top deck
Canvas X: 3067181.8721532794
Canvas Y: 1.3891915891243987E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00290
Downstream: S_SS_3

Canopy 1: None

Surface 1: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 485
Slope: 0.0371
Mannings N: 0.15
Percent of Area: 100
Number of Increments: 5

Channel: 2
Length: 170
Slope: 0.0015
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Contributing Area: 0.0029
Number of Increments: 5

Channel: Main
Length: 60
Slope: 0.25
Mannings N: 0.03
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5

Baseflow: None
End:

Subbasin: S_SS_3
Description: South ditch, side slope
Canvas X: 3066852.0071975337
Canvas Y: 1.3891445989412233E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00483
Downstream: S_D

Canopy 1: None

Canopy 2: None

Surface 1: None

Surface 2: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

LossRate 2: SCS
Percent Impervious Area: 0.0

```
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 90
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 62
     Number of Increments: 5

     Plane: 2
     Length: 55
     Slope: 0.0727
     Mannings N: 0.15
     Percent of Area: 38
     Number of Increments: 5

     Channel: Main
     Length: 940
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: W_TD_1
     Description: West ditch, top deck
     Canvas X: 3066335.171294736
     Canvas Y: 1.3892271861215672E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00842
     Downstream: W_SS_2

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 644
     Slope: 0.0373
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 325
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00842
     Number of Increments: 5

     Channel: Main
     Length: 75
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: W_SS_1
     Description: West ditch, side slope
     Canvas X: 3066473.704629507
     Canvas Y: 1.3892618194552599E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00446
     Downstream: W_SS_2

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 95
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 66
     Number of Increments: 5

     Plane: 2
     Length: 50
     Slope: 0.12
     Mannings N: 0.15
     Percent of Area: 34
     Number of Increments: 5

     Channel: Main
     Length: 853
     Slope: 0.0015
```

```
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: W_SS_2
     Description: West ditch, side slope
     Canvas X: 3066047.4482148285
     Canvas Y: 1.3892644835578516E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00346
     Downstream: W_SS_3

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 75
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 60
     Number of Increments: 5

     Plane: 2
     Length: 50
     Slope: 0.12
     Mannings N: 0.15
     Percent of Area: 40
     Number of Increments: 5

     Channel: Main
     Length: 710
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: W_TD_2
     Description: West ditch, top deck
     Canvas X: 3065924.199944777
     Canvas Y: 1.3892303576890895E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00941
     Downstream: W_SS_3

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 785
     Slope: 0.0306
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 550
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00941
     Number of Increments: 5

     Channel: Main
     Length: 45
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: W_SS_3
     Description: West ditch, side slope
     Canvas X: 3065605.889991068
     Canvas Y: 1.3892417688006377E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00556
     Downstream: W_SS_4

     Canopy 1: None

     Canopy 2: None
```

```
     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 85
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 43
     Number of Increments: 5

     Plane: 2
     Length: 115
     Slope: 0.0522
     Mannings N: 0.15
     Percent of Area: 57
     Number of Increments: 5

     Channel: Main
     Length: 787
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: W_TD_3
     Description: West ditch, top deck
     Canvas X: 3065972.85334226
     Canvas Y: 1.3891925527878746E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00457
     Downstream: W_SS_4

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 575
     Slope: 0.0417
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 230
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00457
     Number of Increments: 5

     Channel: Main
     Length: 45
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: W_SS_4
     Description: West ditch, side slope
     Canvas X: 3065529.370009763
     Canvas Y: 1.3891576870824952E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00688
     Downstream: S_SS_1

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 95
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 34
     Number of Increments: 5
```

```
     Plane: 2
     Length: 185
     Slope: 0.0216
     Mannings N: 0.15
     Percent of Area: 66
     Number of Increments: 5

     Channel: Main
     Length: 670
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: W_TD_4
     Description: West ditch, top deck
     Canvas X: 3065866.2892385903
     Canvas Y: 1.389164313300402E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00658
     Downstream: S_SS_1

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 715
     Slope: 0.0294
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 590
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00658
     Number of Increments: 5

     Channel: Main
     Length: 60
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: S_SS_1
     Description: South ditch, side slope
     Canvas X: 3065718.394377545
     Canvas Y: 1.389114830817959E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00126
     Downstream: S_SS_2

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 45
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 38
     Number of Increments: 5

     Plane: 2
     Length: 75
     Slope: 0.0533
     Mannings N: 0.15
     Percent of Area: 62
     Number of Increments: 5

     Channel: Main
     Length: 300
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:
```

Subbasin: S_TD_1
Description: South ditch, top deck
Canvas X: 3066160.3125561285
Canvas Y: 1.389148072719884E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00599
Downstream: S_SS_2

Canopy 1: None

Surface 1: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 681
Slope: 0.0323
Mannings N: 0.15
Percent of Area: 100
Number of Increments: 5

Channel: 2
Length: 400
Slope: 0.0015
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Contributing Area: 0.00599
Number of Increments: 5

Channel: Main
Length: 25
Slope: 0.25
Mannings N: 0.03
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5

Baseflow: None
End:

Subbasin: S_SS_2
Description: South ditch, side slope
Canvas X: 3066138.0277029476
Canvas Y: 1.3891163594537508E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00261
Downstream: S_D

Canopy 1: None

Canopy 2: None

Surface 1: None

Surface 2: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

LossRate 2: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 65
Slope: 0.25
Mannings N: 0.15
Percent of Area: 36
Number of Increments: 5

Plane: 2
Length: 115
Slope: 0.0522
Mannings N: 0.15
Percent of Area: 64
Number of Increments: 5

Channel: Main
Length: 400
Slope: 0.0015
Mannings N: 0.04
Shape: Trapezoid
Width: 2
Side Slope: 2.5
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: S_TD_2
Description: South ditch, top deck
Canvas X: 3066650.9075749437
Canvas Y: 1.3891811097339874E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.01907
Downstream: S_D

Canopy 1: None

Surface 1: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 575

```
     Slope: 0.04
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 940
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.01907
     Number of Increments: 5

     Channel: Main
     Length: 40
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Junction: S_D
     Description: South ditch junction
     Canvas X: 3066659.1023761914
     Canvas Y: 1.3891365314563861E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Downstream: Pond
End:

Subbasin: A_TD_NE
     Description: Additional area, top deck
     Canvas X: 3068127.3068565233
     Canvas Y: 1.3891571085646333E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00321
     Downstream: A_SS_2

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 215
     Slope: 0.05
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: 2
     Length: 570
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00321
     Number of Increments: 5

     Channel: Main
     Length: 65
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 2
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: A_SS_1
     Description: Additional area, side slope
     Canvas X: 3068372.0076032453
     Canvas Y: 1.3891776856728803E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.00280
     Downstream: A_SS_2

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 60
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 60
     Number of Increments: 5

     Plane: 2
     Length: 40
     Slope: 0.1
     Mannings N: 0.15
     Percent of Area: 40
     Number of Increments: 5
```

Channel: Main
Length: 710
Slope: 0.0015
Mannings N: 0.04
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: A_SS_2
Description: Additional area, side slope
Canvas X: 3068422.060028711
Canvas Y: 1.3891315262138397E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00704
Downstream: A_SS_3

Canopy 1: None

Canopy 2: None

Surface 1: None

Surface 2: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

LossRate 2: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 80
Slope: 0.25
Mannings N: 0.15
Percent of Area: 44
Number of Increments: 5

Plane: 2
Length: 100
Slope: 0.02
Mannings N: 0.15
Percent of Area: 56
Number of Increments: 5

Channel: Main
Length: 1032
Slope: 0.0015
Mannings N: 0.04
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: A_TD_SW
Description: Additional area, top deck
Canvas X: 3067992.2431067987
Canvas Y: 1.3891414020181132E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00224
Downstream: A_SS_3

Canopy 1: None

Surface 1: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 180
Slope: 0.05
Mannings N: 0.15
Percent of Area: 100
Number of Increments: 5

Channel: 2
Length: 390
Slope: 0.0015
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Contributing Area: 0.00224
Number of Increments: 5

Channel: Main
Length: 60
Slope: 0.25
Mannings N: 0.03
Shape: Trapezoid
Width: 2
Side Slope: 3
Number of Increments: 5

Baseflow: None
End:

Subbasin: A_SS_3
Description: Additional area, side slope
Canvas X: 3067837.7251564777
Canvas Y: 1.3891254174025627E7
From Canvas X: 3071222.469895692
From Canvas Y: 1.3894552670662308E7
Area: 0.00225

```
    Downstream: A_D

    Canopy 1: None

    Canopy 2: None

    Surface 1: None

    Surface 2: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    LossRate 2: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 70
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 58
    Number of Increments: 5

    Plane: 2
    Length: 50
    Slope: 0.04
    Mannings N: 0.15
    Percent of Area: 42
    Number of Increments: 5

    Channel: Main
    Length: 422
    Slope: 0.0015
    Mannings N: 0.04
    Shape: Trapezoid
    Width: 2
    Side Slope: 3
    Number of Increments: 5
    Route Upstream: Yes

    Baseflow: None
End:

Junction: A_D
    Canvas X: 3067699.191821707
    Canvas Y: 1.3891350081718931E7
    From Canvas X: 3071222.469895692
    From Canvas Y: 1.3894552670662308E7
    Downstream: Pond
End:

Subbasin: Pond_area
    Canvas X: 3067440.2245787554
    Canvas Y: 1.3891186287343869E7
    Area: 0.01581
    Downstream: Pond

    Canopy: None

    Surface: None

    LossRate: SCS
    Percent Impervious Area: 100
    Curve Number: 99

    Transform: SCS
    Lag: 1
    Unitgraph Type: STANDARD

    Baseflow: None
End:

Reservoir: Pond
    Description: Existing Permitted Pond
    Canvas X: 3067278.263612212
    Canvas Y: 1.3891312784282645E7
    From Canvas X: 3071222.469895692
    From Canvas Y: 1.3894552670662308E7
    Downstream: Site_Outfall

    Route: Controlled Outflow
    Routing Curve: Elevation-Area
    Initial Elevation: 104.81
    Elevation-Area Table: Exist_Pond
    Adaptive Control: On
    Main Tailwater Condition: None
    Auxiliary Tailwater Condition: None

    Conduit: Culvert
    Conduit Outlet: Main
    Culvert Shape: Circular
    Chart Number: 1
    Scale Number: 1
    Solution Control: Automatic
    Diameter: 4
    Number Barrels: 1
    Culvert Length: 850
    Entrance Loss Coefficient: 0.5
    Exit Loss Coefficient: 1
    Top Manning's n: 0.024
    Bottom Manning's n:
    Bottom Depth:
    Fill Depth:
    Inlet Invert Elevation: 104.81
    Outlet Invert Elevation: 103.95
    End Conduit:

    Spillway: Broad-Crested Spillway
    Spillway Outlet: Main
    Spillway Crest Length: 20
    Spillway Crest Elevation: 114.35
    Spillway Coefficient: 3
    End Spillway:

    Evaporation Method: Zero Evaporation
    End Evaporation:
End:
```

```
Subbasin: OS_NE
     Description: Outside pre-dev permit boundary near northeastern corner
     Canvas X: 3068999.273886476
     Canvas Y: 1.3891952168904664E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.05842
     Downstream: OS_S

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 74

     Transform: Kinematic Wave

     Plane: 1
     Length: 1750
     Slope: 0.005
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 830
     Slope: 0.0072
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: OS_S
     Description: Outside pre-dev permit boundary along southern perimeter
     Canvas X: 3068445.1405473943
     Canvas Y: 1.3890630774019161E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
     Area: 0.08142
     Downstream: Site_Outfall

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 74

     Transform: Kinematic Wave

     Plane: 1
     Length: 4000
     Slope: 0.0025
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 875
     Slope: 0.0023
     Mannings N: 0.04
     Shape: Trapezoid
     Width: 8
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Junction: Site_Outfall
     Canvas X: 3065335.49379165
     Canvas Y: 1.3890798053741915E7
     From Canvas X: 3071222.469895692
     From Canvas Y: 1.3894552670662308E7
End:

Basin Schematic Properties:
     Last View N: 1.38930670970297E7
     Last View S: 1.3890080635643572E7
     Last View W: 3065141.4653930664
     Last View E: 3069372.43618989
     Maximum View N: 1.38930670970297E7
     Maximum View S: 1.3890080635643572E7
     Maximum View W: 3065141.4653930664
     Maximum View E: 3069372.43618989
     Extent Method: Maps
     Buffer: 10
     Draw Icons: No
     Draw Icon Labels: Yes
     Draw Map Objects: No
     Draw Gridlines: No
     Draw Flow Direction: No
     Fix Element Locations: No
     Fix Hydrologic Order: No
     Map: hec.map.aishape.AiShapeMap
     Map File Name: P:\GIS\Fairbanks\Shapefiles\Pre-dev_drainage_area.shp
     Minimum Scale: -2147483648
     Maximum Scale: 2147483647
     Map Shown: Yes
End:
```

HEC-HMS POST-DEVELOPMENT HYDROLOGIC MODEL INPUT PARAMETERS

Post-Development HEC-HMS Basin Input Parameters for Kinematic Wave Model

Post-development			**Plane 1**				**Plane 2**				**Loss 1**	**Loss 2**	**Collector (Side Slope Drainage Terraces)**							**Channel (Top Deck Drainage Terraces or Downchute Channels)**					
Subcatchment Designation	Area A (mi^2)	Area A (acres)	Length L (ft)	Slope S (ft/ft)	Roughness N	Area Percent	Length L (ft)	Slope S (ft/ft)	Roughness N	Area Percent	CN	CN	Collector Length (ft)	Slope (ft/ft)	Manning n	Area A (mi^2)	Shape	Bottom Width (ft)	Side Slope (H:V)	Collector Length (ft)	Slope (ft/ft)	Shape	Manning n	Bottom Width (ft)	Side Slope (H:V)
1_TD	0.01513	9.68	490	0.0300	0.15	100					84									475	0.0015	triangle	0.04	0	3
10_SS	0.02106	13.48	200	0.2500	0.15	49	200	0.2500	0.15	51	84	84	570	0.0300	0.04	0.00702	triangle	0	3	525	0.2500	trapezoid	0.03	6	3
11_TD	0.00886	5.67	470	0.0300	0.15	100					84									475	0.0015	triangle	0.04	0	3
12_SS	0.01754	11.22	200	0.2500	0.15	59	200	0.2500	0.15	41	84	84	395	0.0300	0.04	0.00585	triangle	0	3	505	0.2500	trapezoid	0.03	6	3
13_SS	0.03274	20.96	200	0.2500	0.15	49	200	0.2500	0.15	51	84	84	575	0.0300	0.04	0.01091	triangle	0	3	505	0.2500	trapezoid	0.03	8	3
14_Entry	0.00691	4.42	165	0.0200	0.15	100					84									100	0.0300	triangle	0.04	0	3
2_SS	0.01635	10.47	200	0.2500	0.15	48	200	0.2500	0.15	52	84	84	430	0.0300	0.04	0.00545	triangle	0	3	495	0.2500	trapezoid	0.03	6	3
3_TD	0.01264	8.09	490	0.0300	0.15	100					84									375	0.0015	triangle	0.04	0	3
4_SS	0.02802	17.94	200	0.2500	0.15	26	200	0.2500	0.15	74	84	84	660	0.0300	0.04	0.00934	triangle	0	3	480	0.2500	trapezoid	0.03	10	3
5_TD	0.01411	9.03	620	0.0300	0.15	100					84									700	0.0015	triangle	0.04	0	3
6_SS	0.02158	13.81	200	0.2500	0.15	21	200	0.2500	0.15	79	84	84	630	0.0300	0.04	0.00719	triangle	0	3	490	0.2500	trapezoid	0.03	8	3
7_TD	0.01980	12.67	495	0.0300	0.15	100					84									1130	0.0015	triangle	0.04	0	3
8_SS	0.02662	17.04	200	0.2500	0.15	37	200	0.2500	0.15	63	84	84	730	0.0300	0.04	0.00887	triangle	0	3	486	0.2500	trapezoid	0.03	10	3
9_TD	0.00392	2.51	345	0.0300	0.15	100					84									350	0.0015	triangle	0.04	0	3
OS_NE	0.00935	5.98	312	0.0050	0.15	100					74									100	0.0050	triangle	0.04	0	3
OS_S	0.01022	6.54	200	0.0050	0.15	100					74									50	0.0050	triangle	0.04	0	3
Pond_NE_area	0.03200	20.48									99														
Pond_S_area	0.02376	15.21									99														
Total	0.32062	205.20																							

```
Basin: Post-dev
     Last Modified Date: 5 August 2013
     Last Modified Time: 22:09:54
     Version: 3.5
     Filepath Separator: \
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No

     Enable Sediment Routing: No

     Enable Quality Routing: No
End:

Subbasin: 3_TD
     Canvas X: 3067876.4368578726
     Canvas Y: 1.389192616170832E7
     Computation Point: Yes
     Area: 0.01264
     Downstream: 4_SS

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 490
     Slope: 0.03
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 375
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: 4_SS
     Canvas X: 3068152.423961481
     Canvas Y: 1.3892450668113485E7
     Computation Point: Yes
     Area: 0.02802
     Downstream: Chan_N_J

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 26
     Number of Increments: 5

     Plane: 2
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 74
     Number of Increments: 5

     Channel: 2
     Length: 660
     Slope: 0.03
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00934
     Number of Increments: 5

     Channel: Main
     Length: 480
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 10
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: 1_TD
     Canvas X: 3067072.6278594946
     Canvas Y: 1.3891990427151982E7
     Area: 0.01513
     Downstream: 2_SS

     Canopy 1: None

     Surface 1: None
```

```
     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 490
     Slope: 0.03
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 475
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 2
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: 2_SS
     Canvas X: 3067134.5833735433
     Canvas Y: 1.3892450668113485E7
     Area: 0.01635
     Downstream: Chan_N_1

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 48
     Number of Increments: 5

     Plane: 2
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 52
     Number of Increments: 5

     Channel: 2
     Length: 430
     Slope: 0.03
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00545
     Number of Increments: 5

     Channel: Main
     Length: 495
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 6
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Reach: Chan_N_1
     Canvas X: 3068196.6779000866
     Canvas Y: 1.3892649810837211E7
     From Canvas X: 3067223.0912507554
     From Canvas Y: 1.3892676363200376E7
     Downstream: Chan_N_J

     Route: Kinematic Wave
     Channel: Kinematic Wave
     Length: 775
     Energy Slope: 0.0015
     Shape: Trapezoid
     Mannings n: 0.04
     Number of Increments: 2
     Width: 6
     Side Slope: 3
     Channel Loss: None
End:

Junction: Chan_N_J
     Canvas X: 3068196.6779000866
     Canvas Y: 1.3892649810837211E7
     Downstream: Chan_N_2
End:

Reach: Chan_N_2
     Canvas X: 3069081.8101852234
     Canvas Y: 1.3892362118877906E7
     From Canvas X: 3068196.6779000866
     From Canvas Y: 1.3892649810837211E7
     Downstream: Pond_NE

     Route: Kinematic Wave
     Channel: Kinematic Wave
     Length: 850
     Energy Slope: 0.0015
     Shape: Trapezoid
     Mannings n: 0.04
```

```
     Number of Increments: 2
     Width: 10
     Side Slope: 3
     Channel Loss: None
End:

Subbasin: Pond_NE_area
     Canvas X: 3069192.3737102957
     Canvas Y: 1.3892516479151761E7
     Area: 0.0320
     Downstream: Pond_NE

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 100
     Curve Number: 99

     Transform: SCS
     Lag: 1
     Unitgraph Type: STANDARD

     Baseflow: None
End:

Subbasin: OS_NE
     Canvas X: 3068816.350668236
     Canvas Y: 1.3892882171589777E7
     Area: 0.00935
     Downstream: Pond_NE

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 74

     Transform: Kinematic Wave

     Plane: 1
     Length: 312
     Slope: 0.005
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 100
     Slope: 0.005
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Reservoir: Pond_NE
     Canvas X: 3069081.8101852234
     Canvas Y: 1.3892362118877906E7
     Downstream: Pond_S

     Route: Controlled Outflow
     Routing Curve: Elevation-Area
     Initial Elevation: 99.51
     Elevation-Area Table: Pond_NE_elev-area
     Adaptive Control: On
     Main Tailwater Condition: None
     Auxiliary Tailwater Condition: None

     Conduit: Culvert
     Conduit Outlet: Main
     Culvert Shape: Circular
     Chart Number: 2
     Scale Number: 1
     Solution Control: Automatic
     Diameter: 2
     Number Barrels: 1
     Culvert Length: 200
     Entrance Loss Coefficient: 0.5
     Exit Loss Coefficient: 1
     Top Manning's n: 0.024
     Bottom Manning's n:
     Bottom Depth:
     Fill Depth:
     Inlet Invert Elevation: 99.5
     Outlet Invert Elevation: 99.5
     End Conduit:

     Spillway: Broad-Crested Spillway
     Spillway Outlet: Main
     Spillway Crest Length: 50
     Spillway Crest Elevation: 110.5
     Spillway Coefficient: 3
     End Spillway:

     Evaporation Method: Zero Evaporation
     End Evaporation:
End:

Subbasin: 13_SS
     Canvas X: 3065895.4730925756
     Canvas Y: 1.3891662948006298E7
     Area: 0.03274
     Downstream: Chan_W_J

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84
```

```
     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 49
     Number of Increments: 5

     Plane: 2
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 51
     Number of Increments: 5

     Channel: 2
     Length: 575
     Slope: 0.03
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.01091
     Number of Increments: 5

     Channel: Main
     Length: 505
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 8
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Subbasin: 11_TD
     Canvas X: 3066448.6473251507
     Canvas Y: 1.3891946173213376E7
     Area: 0.00886
     Downstream: 12_SS

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 470
     Slope: 0.03
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 475
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: 12_SS
     Canvas X: 3066116.7427856056
     Canvas Y: 1.3892468369688926E7
     Area: 0.01754
     Downstream: Chan_W_1

     Canopy 1: None

     Canopy 2: None

     Surface 1: None

     Surface 2: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     LossRate 2: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 59
     Number of Increments: 5

     Plane: 2
     Length: 200
     Slope: 0.25
     Mannings N: 0.15
     Percent of Area: 41
     Number of Increments: 5

     Channel: 2
     Length: 395
     Slope: 0.03
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Contributing Area: 0.00585
     Number of Increments: 5
```

```
     Channel: Main
     Length: 505
     Slope: 0.25
     Mannings N: 0.03
     Shape: Trapezoid
     Width: 6
     Side Slope: 3
     Number of Increments: 5
     Route Upstream: Yes

     Baseflow: None
End:

Reach: Chan_W_1
     Canvas X: 3065585.695522334
     Canvas Y: 1.389122925940796E7
     From Canvas X: 3065731.7335197334
     From Canvas Y: 1.389257015374772E7
     Downstream: Chan_W_J

     Route: Kinematic Wave
     Channel: Kinematic Wave
     Length: 1500
     Energy Slope: 0.0015
     Shape: Trapezoid
     Mannings n: 0.04
     Number of Increments: 2
     Width: 4
     Side Slope: 3
     Channel Loss: None
End:

Junction: Chan_W_J
     Canvas X: 3065585.695522334
     Canvas Y: 1.389122925940796E7
     Downstream: Chan_W_2
End:

Reach: Chan_W_2
     Canvas X: 3065876.6405800977
     Canvas Y: 1.3890861680355666E7
     From Canvas X: 3065585.695522334
     From Canvas Y: 1.389122925940796E7
     Downstream: SW_Culv

     Route: Kinematic Wave
     Channel: Kinematic Wave
     Length: 780
     Energy Slope: 0.0015
     Shape: Trapezoid
     Mannings n: 0.04
     Number of Increments: 2
     Width: 11
     Side Slope: 3
     Channel Loss: None
End:

Reach: SW_Culv
     Canvas X: 3068608.5149941123
     Canvas Y: 1.3890505345435854E7
     From Canvas X: 3065876.6405800977
     From Canvas Y: 1.3890861680355666E7
     Downstream: Pond_S

     Route: Kinematic Wave
     Channel: Kinematic Wave
     Length: 440
     Energy Slope: 0.01
     Shape: Rectangular
     Mannings n: 0.013
     Number of Increments: 2
     Width: 10
     Invert Elevation: 106.4
     Channel Loss: None
End:

Subbasin: 7_TD
     Canvas X: 3067222.53051797
     Canvas Y: 1.3891420349657165E7
     Area: 0.0198
     Downstream: 8_SS

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 495
     Slope: 0.03
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 1130
     Slope: 0.0015
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: 8_SS
     Canvas X: 3067515.1672455547
     Canvas Y: 1.3890990288139487E7
     Area: 0.02662
     Downstream: Pond_S

     Canopy 1: None

     Canopy 2: None

     Surface 1: None
```

```
    Surface 2: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    LossRate 2: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 200
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 37
    Number of Increments: 5

    Plane: 2
    Length: 200
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 63
    Number of Increments: 5

    Channel: 2
    Length: 730
    Slope: 0.03
    Mannings N: 0.04
    Shape: Triangle
    Side Slope: 3
    Contributing Area: 0.00887
    Number of Increments: 5

    Channel: Main
    Length: 486
    Slope: 0.25
    Mannings N: 0.03
    Shape: Trapezoid
    Width: 10
    Side Slope: 3
    Number of Increments: 5
    Route Upstream: Yes

    Baseflow: None
End:

Subbasin: 5_TD
    Canvas X: 3067948.8558438933
    Canvas Y: 1.3891375297405358E7
    Area: 0.01411
    Downstream: 6_SS

    Canopy 1: None

    Surface 1: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 620
    Slope: 0.03
    Mannings N: 0.15
    Percent of Area: 100
    Number of Increments: 5

    Channel: Main
    Length: 700
    Slope: 0.0015
    Mannings N: 0.04
    Shape: Triangle
    Side Slope: 3
    Number of Increments: 5

    Baseflow: None
End:

Subbasin: 6_SS
    Canvas X: 3068541.8586212136
    Canvas Y: 1.3891092072198281E7
    Area: 0.02158
    Downstream: Pond_S

    Canopy 1: None

    Canopy 2: None

    Surface 1: None

    Surface 2: None

    LossRate 1: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    LossRate 2: SCS
    Percent Impervious Area: 0.0
    Curve Number: 84

    Transform: Kinematic Wave

    Plane: 1
    Length: 200
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 21
    Number of Increments: 5

    Plane: 2
    Length: 200
    Slope: 0.25
    Mannings N: 0.15
    Percent of Area: 79
    Number of Increments: 5

    Channel: 2
```

Length: 630
Slope: 0.03
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Contributing Area: 0.00719
Number of Increments: 5

Channel: Main
Length: 490
Slope: 0.25
Mannings N: 0.03
Shape: Trapezoid
Width: 8
Side Slope: 3
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: 9_TD
Canvas X: 3066340.0604476254
Canvas Y: 1.3891453387353363E7
Area: 0.00392
Downstream: 10_SS

Canopy 1: None

Surface 1: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 345
Slope: 0.03
Mannings N: 0.15
Percent of Area: 100
Number of Increments: 5

Channel: Main
Length: 350
Slope: 0.0015
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Number of Increments: 5

Baseflow: None
End:

Subbasin: 10_SS
Canvas X: 3066610.5793427536
Canvas Y: 1.3891116425220834E7
Area: 0.02106
Downstream: Pond_S

Canopy 1: None

Canopy 2: None

Surface 1: None

Surface 2: None

LossRate 1: SCS
Percent Impervious Area: 0.0
Curve Number: 84

LossRate 2: SCS
Percent Impervious Area: 0.0
Curve Number: 84

Transform: Kinematic Wave

Plane: 1
Length: 200
Slope: 0.25
Mannings N: 0.15
Percent of Area: 49
Number of Increments: 5

Plane: 2
Length: 200
Slope: 0.25
Mannings N: 0.15
Percent of Area: 51
Number of Increments: 5

Channel: 2
Length: 570
Slope: 0.03
Mannings N: 0.04
Shape: Triangle
Side Slope: 3
Contributing Area: 0.00702
Number of Increments: 5

Channel: Main
Length: 525
Slope: 0.25
Mannings N: 0.03
Shape: Trapezoid
Width: 6
Side Slope: 3
Number of Increments: 5
Route Upstream: Yes

Baseflow: None
End:

Subbasin: Pond_S_area
Canvas X: 3069159.1520915953
Canvas Y: 1.3890537419866348E7
Area: 0.0238
Downstream: Pond_S

Canopy: None

```
     Surface: None

     LossRate: SCS
     Percent Impervious Area: 100
     Curve Number: 99

     Transform: SCS
     Lag: 1
     Unitgraph Type: STANDARD

     Baseflow: None
End:

Subbasin: OS_S
     Canvas X: 3069137.1733472776
     Canvas Y: 1.3890385587832874E7
     Area: 0.01022
     Downstream: Pond_S

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 74

     Transform: Kinematic Wave

     Plane: 1
     Length: 50
     Slope: 0.005
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 50
     Slope: 0.005
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Subbasin: 14_Entry
     Canvas X: 3069148.1375801153
     Canvas Y: 1.3891100922986003E7
     Area: 0.00691
     Downstream: Pond_S

     Canopy 1: None

     Surface 1: None

     LossRate 1: SCS
     Percent Impervious Area: 0.0
     Curve Number: 84

     Transform: Kinematic Wave

     Plane: 1
     Length: 165
     Slope: 0.02
     Mannings N: 0.15
     Percent of Area: 100
     Number of Increments: 5

     Channel: Main
     Length: 100
     Slope: 0.03
     Mannings N: 0.04
     Shape: Triangle
     Side Slope: 3
     Number of Increments: 5

     Baseflow: None
End:

Reservoir: Pond_S
     Canvas X: 3068608.5149941123
     Canvas Y: 1.3890505345435854E7
     Downstream: Post-Dev_Outfall

     Route: Controlled Outflow
     Routing Curve: Elevation-Area
     Initial Elevation: 99.5
     Elevation-Area Table: Pond_S_elev-area
     Adaptive Control: On
     Main Tailwater Condition: None
     Auxiliary Tailwater Condition: None

     Conduit: Culvert
     Conduit Outlet: Main
     Culvert Shape: Circular
     Chart Number: 2
     Scale Number: 1
     Solution Control: Automatic
     Diameter: 5
     Number Barrels: 1
     Culvert Length: 330
     Entrance Loss Coefficient: 0.5
     Exit Loss Coefficient: 1
     Top Manning's n: 0.024
     Bottom Manning's n:
     Bottom Depth:
     Fill Depth:
     Inlet Invert Elevation: 99.5
     Outlet Invert Elevation: 98
     End Conduit:

     Spillway: Broad-Crested Spillway
     Spillway Outlet: Main
     Spillway Crest Length: 50
     Spillway Crest Elevation: 110.5
     Spillway Coefficient: 3
     End Spillway:

     Evaporation Method: Zero Evaporation
```

```
    End Evaporation:
End:

Junction: Post-Dev_Outfall
    Canvas X: 3065660.927217964
    Canvas Y: 1.3890609704267476E7
End:

Basin Schematic Properties:
    Last View N: 1.3893206388095506E7
    Last View S: 1.3890115248325806E7
    Last View W: 3064905.1775252004
    Last View E: 3069422.997188606
    Maximum View N: 1.38930670970297E7
    Maximum View S: 1.3890319999067307E7
    Maximum View W: 3065352.798095733
    Maximum View E: 3069368.675430268
    Extent Method: Maps
    Buffer: 0
    Draw Icons: No
    Draw Icon Labels: Yes
    Draw Map Objects: No
    Draw Gridlines: No
    Draw Flow Direction: No
    Fix Element Locations: No
    Fix Hydrologic Order: No
    Map: hec.map.aishape.AiShapeMap
    Map File Name:
P:\GIS\Fairbanks\Shapefiles\Post_drainage_area.shp
    Minimum Scale: -2147483648
    Maximum Scale: 2147483647
    Map Shown: Yes
End:
```

ATTACHMENT 2C

ON-SITE DESIGN –
SURFACE WATER POND APPURTENANCES
DESIGN CALCULATIONS

ON-SITE DESIGN – SURFACE WATER POND APPURTENANCES DESIGN CALCULATIONS
FAIRBANKS LANDFILL EXPANSION

8/26/2013

SCOTT M. GRAVES
86557

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 10

GEOSYNTEC CONSULTANTS
TX ENG FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this package is to present the methodology, parameters, and calculations for the design of the appurtenances for the surface water pond outlet structures of the Fairbanks Landfill facility surface water management system. Surface water diversion structures on the final cover system convey runoff through a system of drainage terraces, downchute channels, and perimeter channels to the Northeast and South Surface Water Ponds. The Northeast Surface Water Pond is connected to the South Surface Water Pond through a 24-inch diameter corrugated metal pipe (CMP) (designated as culvert C2) at a constant elevation of 99.5 ft MSL. The South Surface Water Pond outlet will be the overall site outfall location where surface water is ultimately discharged and leaves the site. This outfall will be in the same location as the current (existing) site outfall, but under final design conditions of the proposed expansion when all ponds are in-place, the existing 48-inch diameter CMP, will be removed and replaced with a 60-inch diameter CMP. As with the existing outfall, this proposed outfall will be located at the southwest corner of the South Surface Water Pond (designated as culvert C3 in this design package). The modeling and design supporting the surface water management system is described in Attachment 2B: *On-Site Drainage Analysis – Hydrology*. The appurtenance designs supporting the outlet control structure include anti-seep collars and a riprap outlet apron as discussed herein.

2 METHODOLOGY

2.1 Anti-Seep Collar Design

Anti-seep collars are required for penetrations through a basin berm to control seepage. The methodology utilized to design the anti-seep collars follows the guidance provided in the *Kentucky Division of Water Engineering Memorandum No.* 5, (KDNREP, 1999) and the Tennessee Department of Transportation Drainage Manual (TDOT, 2007). Although these guidance documents are from different states, the methods provided are appropriate and have a sound technical basis for design at this site. The memorandum recommends placing anti-seep collars along the portion of the outlet structure culverts within the saturated zone spaced at distances of no more than 25-feet, which provide an increase in flow length along the pipe of 15%. This relationship may be described as (KDNREP, 1999):

$$\frac{L_S+2nV}{L_S} \geq 1.15 \tag{1}$$

where: L_s = length of pipe within the saturated zone (ft),

V = vertical and horizontal projection of the collar (ft), and

n = number of anti-seep collars.

The length of pipe in the saturated zone, L_s, is computed based on the following assumptions: (i) the groundwater table is located below the elevation of the outlet pipe; (ii) the phreatic surface slopes at a 4H:1V slope from the elevation of ponded surface water runoff due to the 25-year, 24-hour rainfall event; and (iii) the side slopes of the surface water ponds are sloped at 3H:1V.

Based on these assumptions, L_s can be computed as follows (TDOT, 2007):

$$L_S = y \times (z+4) \times \left(1+\frac{S}{0.25-S}\right) \tag{2}$$

where: L_s = length of pipe within saturated zone (ft);

y = depth of surface water in the pond after a 25-year, 24-hour rainfall event;

z = embankment side slope (i.e., 3H:1V, z = 3); and

S = slope of the outlet pipe (ft/ft).

Figure 2C-1 further depicts the geometry behind the calculation of L_s.

2.2 Riprap Outlet Apron Design

The riprap apron at the outlet culvert is designed to protect against erosion and scour from the South Surface Water Pond outflows. The riprap apron was sized from the outflow based on the 25-year, 24-hour rainfall event. The design guidance from the Federal Highway Administration (FHWA) provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3}\frac{D}{TW} \qquad (3)$$

where: d_{50} = riprap size (ft),

Q = design discharge (cfs),

D = culvert diameter (ft),

TW = tailwater depth (ft), and

g = gravitational constant.

The tailwater depth should be limited to between 0.4D and D. FHWA (2006) recommends the use of a tailwater depth equal to 0.4D if the tailwater is unknown.

The required length and depth of the riprap apron can be estimated based on the culvert rise and riprap size as provided in Table 2C-1.

3 DESIGN PARAMETERS

3.1 Anti-Seep Collar Design Parameters

Anti-seep collars were designed for the culverts between the Northeast Surface Water Pond and the South Surface Water Pond (C2) and for the outflow of the South Surface Water

Pond (C3) located at the southwest corner of the facility. The side slopes of the surface water ponds are 3H:1V. These ponds will have a permanent pool elevation of 99.5 ft MSL.

The Northeast and South Surface Water Ponds are connected by a 24-inch diameter corrugated metal pipe. The inlet and outlet invert elevations of culvert C2 are 99.5 ft MSL (i.e., a 0% pipe slope).

The outfall culvert C3 from the South Surface Water Pond has an inlet invert elevation, outlet invert elevation, and length of pipe of 99.5 ft MSL, 98.0 ft MSL, and 330 ft, respectively. Therefore, the slope (S) of the outflow pipe is calculated as 0.0045 ft/ft.

The elevation of surface water due to the 25-year, 24-hour rainfall event was calculated as 105.7 ft MSL for the South Surface Water Pond, as shown in Attachment 2B. The depth, y, of surface water within the pond was then calculated as 6.2 ft (i.e., y = 105.7 ft – 99.5 ft = 6.2 ft).

3.2 Riprap Outlet Apron Design Parameters

The South Surface Water Pond discharges runoff through Culvert C3 (a 60-inch diameter CMP) that conveys a maximum outflow of 129.8 cfs during a 25-year, 24-hour rainfall event, as calculated in Attachment 2B. The rip-rap apron was designed with this peak flow rate.

4 RESULTS

4.1 Anti-Seep Collars

Based on the design parameters above, the length of the pipe within the saturated zone, L_s, was calculated as:

$$\mathrm{L_s} = 6.2\ \mathrm{ft}\ \times (3+4) \times \left(1 + \frac{0.0045}{0.25 - 0.0045}\right) = 44.2\ \mathrm{ft}$$

Anti-seep collars should be spaced no more than 25 ft apart. Therefore, a minimum of two seep collars (n = 2) is necessary for the outflow culvert. The minimum vertical and horizontal projection (V) of the each seep collar was back calculated by Equation (1).

$$\frac{44.2\ \text{ft} + (2)(2)\text{V}}{44.2\ \text{ft}} = 1.15 \rightarrow \text{V} = 1.65\ \text{ft}$$

The vertical and horizontal projection of each seep collar was calculated as 1.65 ft. Based on recommendations by Tennessee Department of Transportation (TDOT), the anti-seep collar should extend at least two feet in all directions around the outflow pipe (TDOT, 2007). Thus, the vertical and horizontal projection (V) of the anti-seep collar was rounded up to two feet.

The first anti-seep collar should be constructed approximately 12.5 feet from the up gradient end of the outflow pipe (C3), and the second anti-seep collar should be spaced 25 feet from the first collar or 37.5 feet from the up gradient end of the outflow pipe for the South Surface Water Pond. The anti-seep collars should extend two feet in every direction from the pipe. Using the same methodology above, anti-seep collars should be constructed 12.5 feet and 37.5 feet from the down gradient end of culvert C2.

4.2 Rip-Rap Outlet Apron

Equation (3) provides the calculations to size the riprap apron for the South Surface Water Pond outlet. The calculations were performed based on a 60-inch diameter pipe (i.e., D = 5 feet), a design flow rate of Q = 129.8 cfs, and a recommended tailwater depth of TW = 0.4D = 2.0 feet. Based on Equation (3) a minimum d_{50} size for the riprap of 0.76 feet is selected. The minimum apron length was selected based on Table 2C-1. The riprap size corresponds to a riprap class 3, resulting in an apron length of 5D = 25 feet and an apron depth of $2.4d_{50}$ = 1.8 feet. FHWA (2006) recommends an apron width of 3D = 15 feet at the up gradient end of the apron near the pipe outlet and a 3:1 expansion resulting in an apron width of 50 feet at the down gradient end of the apron. If the receiving channel from the culvert is less than the previously calculated widths, the entire width channel should be lined with riprap.

5 REFERENCES

FHWA (2006). *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Federal Highway Administration, US Department of Transportation, Hydraulic Engineering Circular No. 14, Third Edition.

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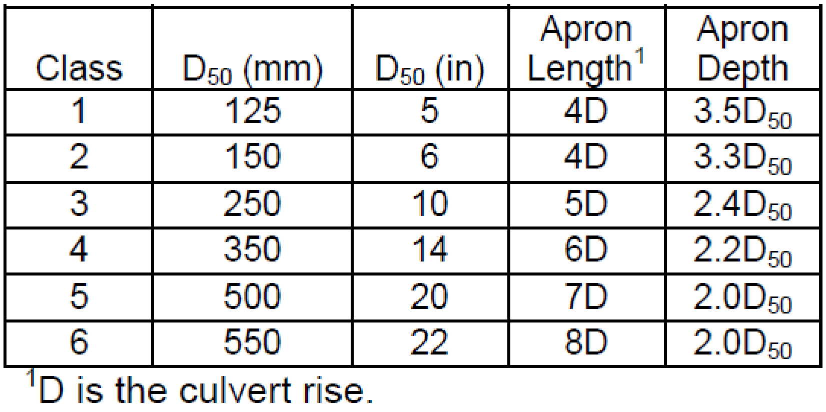
TDOT (2007). *TDOT Design Division Drainage Manual: Chapter VII Stormwater Storage Facilities,* Tennessee Department of Transportation, March 2007.

TABLES

- Table 2C-1. Riprap Classes and Apron Dimensions (from FHWA, 2006)

Table 2C-1. Riprap Classes and Apron Dimensions (from FHWA, 2006)

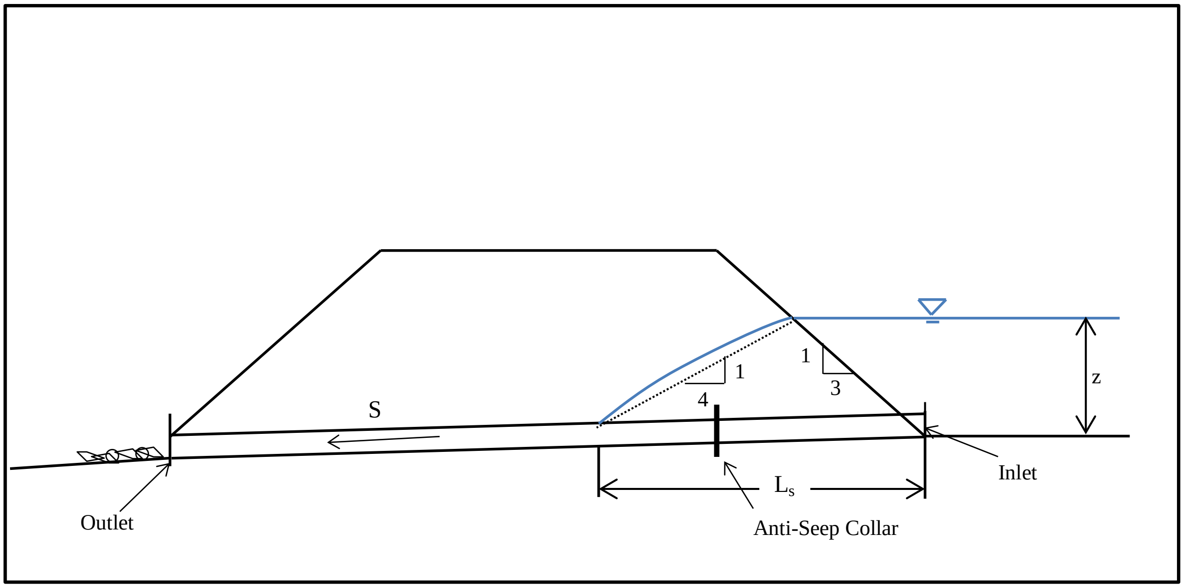


Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1] D is the culvert rise.

FIGURES

Figure 2C-1. Anti-Seep Collar Design Schematic (not to scale)



ATTACHMENT 2D

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS

Written by: **J. McNash** Date: **10/31/2012** Reviewed by: **S. Graves** Date: **12/5/2012**

Client: **USAWLTX** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

ON-SITE DESIGN – DRAINAGE TERRACES AND DOWNCHUTE CHANNELS FAIRBANKS LANDFILL EXPANSION

SCOTT M. GRAVES
86557

8/26/2013

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 32

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the top deck drainage terraces, side slope drainage terraces, and downchute channels for the facility surface water management system for the Fairbanks Landfill. As part of the facility surface water management system design, sheet flow runoff from the final cover system is intercepted by drainage terraces located at the base of the top deck surface and on the 4 horizontal: 1 vertical (4H:1V) final cover side slopes. Top deck and side slope drainage terraces convey runoff to downchute channels. These downchute channels subsequently convey the runoff to perimeter drainage channels located at the toe of the 4H:1V side slopes, and ultimately into two surface water ponds. The Facility Surface Water Management Plan shows the layout of each of these features and can be found in Drawing 2-1 of that Plan.

2 METHODOLOGY

The top deck drainage terraces and side slope drainage terraces are designed as grass-lined v-shaped channels (i.e., trapezoidal channels with bottom width equal to zero), and are sized to convey runoff from the 25-year, 24-hour design rainfall event with one foot of freeboard and to convey the 100-year, 24-hour design rainfall event without overtopping. Additionally, the average velocity and the average tractive stress are calculated based on the predicted peak flow for each rainfall event. The top deck drainage terraces are located at the base of the 3% top deck surfaces; while, the side slope drainage terraces are spaced approximately 200-feet apart horizontally on the 4H:1V final cover side slopes. Typical terrace and downchute cross-sections for the final cover system are shown on the drawings presented in Attachment 2 (the Facility Surface Water Drainage Report) of the Site

Development Plan (SDP). The hydraulic design of the terrace and downchute drainage features meets or exceeds the design criteria described herein.

Downchute channels are evaluated as articulated concrete block lined trapezoidal channels in this calculation package. The downchute channels are designed to convey the 25-year, 24-hour design rainfall event with one foot of freeboard (and to convey the 100-year, 24-hour rainfall event without overtopping) down the 4H:1V final cover side slopes and into the perimeter drainage channels or surface water ponds. The peak 25-year, 24-hour design storm discharge and resulting calculated average tractive stresses are used to design the lining system of the downchute channels.

The capacity of each downchute channel and drainage terrace is calculated by solving Manning's equation for the depth of flow within each channel or terrace. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \tag{1}$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The average tractive stresses in the downchute or drainage terrace for various flows are estimated by Equation (2) (HCFCD, 2001).

$$\tau_o = \gamma_w RS \tag{2}$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

The top deck drainage terraces and downchute channels were designed based on computed peak discharges from the HEC-HMS model, as discussed in Attachment 2B. The side slope drainage terrace capacity was estimated based on the Rational Method (TxDOT, 2009) from to the computed side slope drainage area modeled in the HEC-HMS model. The Rational Method calculates the peak flow as follows (TxDOT, 2009):

$$Q = C \times I \times A \tag{3}$$

where:

Q = peak runoff rate (cfs),

C = runoff coefficient,

I = rainfall intensity (in/hr), and

A = drainage area (acres).

Rainfall intensity is calculated by the following equation (TxDOT, 2009):

$$I = \frac{b}{(t_c + d)^e} \tag{4}$$

where:

I = design rainfall intensity (in/hr),

t_c = time of concentration (min), and

b, d, e = coefficients for specific frequencies listed by Texas county.

The values for b, d, and e are obtained from TxDOT (2009). For a 25-year rainfall event in

Harris County, b = 81, d = 7.7, and e = 0.724. For a 100-year rainfall event in Harris County, b = 91, d = 7.9, and e = 0.706.

The time of concentration is the time for runoff to flow from the most hydraulically remote point of the drainage area to the point under investigation. The time of concentration is estimated by dividing the longest drainage path by the velocity of runoff. For a conservative design approach, a minimum time of concentration of 10 minutes was used to calculate the rainfall intensity. TxDOT (2009) recommends 10 minutes for the minimum time of concentration because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high.

Based on these values, the rainfall intensity for the Fairbanks Landfill is calculated as 10.1 in/hr and 11.9 in/hr for the 25-year and 100-year rainfall events, respectively, for a time of concentration equal to 10 minutes.

3 DESIGN PARAMETERS

The design parameters, including channel geometry, Manning's roughness coefficient, and calculated peak discharges for the 25-year and 100-year events (Attachment 2B), are summarized for each downchute channel and top deck drainage terrace in Table 2D-1 and Table 2D-2, respectively.

The side slope drainage terraces are spaced at a 200-ft interval in the final cover system design. Each side slope drainage terrace was analyzed using representative contributing area based on the typical terrace spacing. A runoff coefficient (C) was selected based on information provided by TxDOT (2009) for rural watersheds, as shown in Table 2D-3. The runoff coefficients provided apply to storms of up to a 10-year frequency. The total runoff coefficient is based on the sum of the four runoff components in Table 2D-3. A runoff coefficient adjustment factor is required for higher frequency storm events. The adjustment factor, C_f, for a 25-year event is 1.1, whereas the adjustment factor for a 100-year event is 1.25. The runoff coefficient is calculated using the following equation:

$$C = C_f \times (C_r + C_i + C_v + C_s) \qquad (5)$$

The following runoff coefficients are estimated for the relatively steeper 4H:1V side slope drainage areas for a 25-year and 100-year event, respectively:

$$C_{25} = 1.1 \times (0.26 + 0.16 + 0.04 + 0.12) = 0.638$$

$$C_{100} = 1.25 \times (0.26 + 0.16 + 0.04 + 0.12) = 0.725$$

The side slope drainage terraces are designed as a v-shaped tack-on berms constructed on the 4H:1V side slopes of the final cover system. Thus, the side slopes of the terrace are 4H:1V on the final cover side and 3H:1V on the berm side and each terrace has a depth of 2.50 ft. The nominal longitudinal slope of each side slope drainage terrace is approximately 3% and most terraces are laid out to this longitudinal slope. However, due to final cover geometry and to maintain the 200-ft spacing between terraces, the longitudinal slopes range from 1.99% to 6.25% depending on location on the final cover – and each of these site-specific conditions was analyzed to confirm that the terrace design is adequate for the contributing drainage area and terrace slope.

Each drainage structure is designed to maintain one foot of freeboard during the 25-year, 24-hour design rainfall event. Additionally, each terrace and downchute channel is designed to convey the peak flow during the 100-year, 24-hour design rainfall event without overtopping.

The downchute channel design evaluation is for an articulated concrete block (ACB) channel-lining to resist erosive forces, consistent with the *Design Manual for Articulating Concrete Block Systems* (HCFCD, 2001). The method relates the tested critical shear stress of an ACB system on a horizontal plane to the design conditions, and then accounts for slope by checking that the frictional resistance is adequate to prevent sliding. The critical shear stress for a horizontal bottom width surface for the example ACB type selected for this design computation package is calculated as 16.5 psf as shown in Table 2D-5 (Ayres Associates, 2001). The maximum tractive stress for a 25-year, 24-hour design event is calculated as 11.85 psf, which is less than the critical shear stress. Geosyntec also computed and verified that the frictional resistance against sliding was greater than the driving force of the water and the slope conditions. The peak flows applied to the design of each downchute channel are based on the flows from the entire top deck and side slope areas for the 25-year, 24-hour design rainfall event as provided in Attachment 2B. This is considered conservative as the sum of these flows will only influence the performance of the lining materials at the down gradient end of each downchute channel as opposed to the entire length of the downchute channel.

Permissible tractive stresses for grass lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) is selected for the design of grass lined channels (as shown in Table 2D-5) and has a maximum permissible tractive stress of 1.0 psf (as shown in Table 2D-6 from TxDOT, 2009). The Manning's roughness coefficients are selected from TxDOT (2009) for the grass lined channels and these values are provided in Table 2D-7.

4 RESULTS

The depth of flow, velocity, and average tractive stress for the peak discharges into each downchute channel, top deck drainage terrace, and each side slope drainage terrace were calculated using Equations (1) and (2). These calculations for the downchutes and top deck terraces were performed using the spreadsheets presented in Appendix 2D-1 and Appendix 2D-2, and results are summarized in Table 2D-8 and Table 2D-9 for downchute channels and top-deck terraces, respectively. The calculations for the side slope terraces were performed using the spreadsheet-based table presented as Table 2D-10.

- Each downchute channel and drainage terrace was calculated to contain the capacity to convey the flows from the 25-year, 24-hour and the 100-year, 24-hour design rainfall events.
- Each downchute channel and drainage terrace was designed to maintain one foot of freeboard for the 25-year, 24-hour design rainfall event.
- For each downchute channel, the average tractive stresses were calculated to remain below 11.85 psf during the 25-year, 24-hour design rainfall event. The average tractive stress for each drainage terrace was calculated to remain below 1.0 psf during the 25-year, 24-hour design rainfall event.

5 REFERENCES

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TABLES

Table 2D-1. Design Parameter Summary for Downchute Channels

Downchute Channel Segment	Channel Shape	Longitudinal Channel Slope (%)	Manning's Roughness Coefficient [1]	Channel Dimensions (minimum)			25-yr, 24-hr Peak Flow, Q (cfs) [2]	100-yr, 24-hr Peak Flow, Q (cfs) [2]
				Base Width (ft)	Depth (ft)	Side Slopes (H:V)		
D1	Trapezoidal	25	0.030	6.00	2.00	3:1	160.8	209.2
D2	Trapezoidal	25	0.030	10.00	2.00	3:1	231.8	299.6
D3	Trapezoidal	25	0.030	8.00	2.00	3:1	181.9	235.3
D4	Trapezoidal	25	0.030	10.00	2.00	3:1	227.5	294.4
D5	Trapezoidal	25	0.030	6.00	2.00	3:1	156.0	201.1
D6	Trapezoidal	25	0.030	8.00	2.00	3:1	223.6	283.8
D7	Trapezoidal	25	0.030	6.00	2.00	3:1	146.5	190.0

Notes:

1. Manning’s roughness coefficients were selected from the *Policy Criteria and Procedure Manual* (HCFCD, 2010).
2. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-2. Design Parameter Summary for Top Deck Drainage Terraces

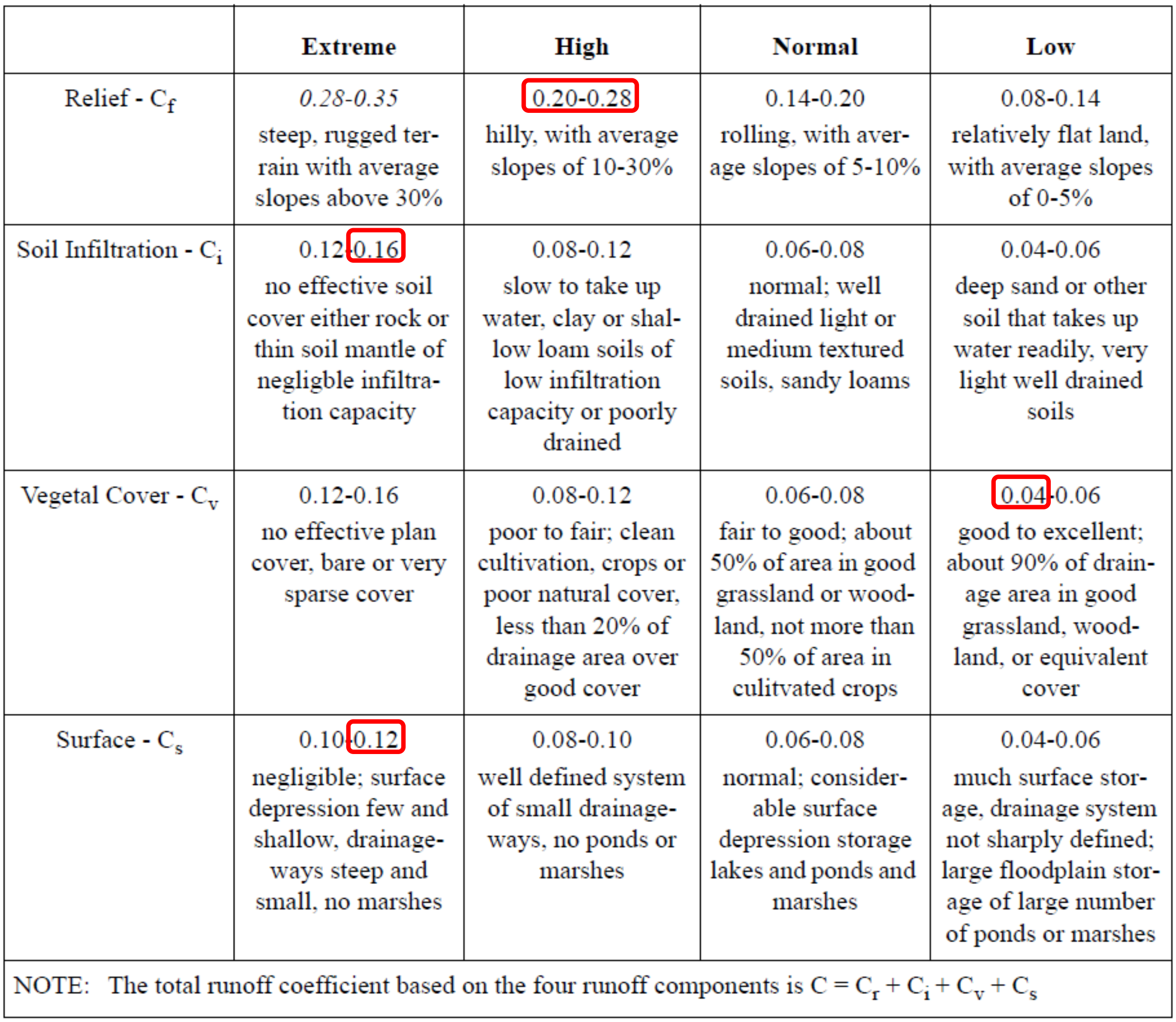
Drainage Terrace	**Channel Shape**	**Longitudinal Channel Slope (%)**	**Manning's Roughness Coefficient [1]**	**Channel Dimensions (minimum)**				**25-yr, 24-hr Peak Flow, Q (cfs) [2]**	**100-yr, 24-hr Peak Flow, Q (cfs) [2]**
				Base Width (ft)	**Depth (ft)**	**Left Side Slope (H:V)**	**Right Side Slope (H:V)**		
TD_1	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	62.7	85.3
TD_3	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	52.5	71.6
TD_5	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	52.9	72.5
TD_7	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	77.5	105.4
TD_9	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	18.3	24.6
TD_11	V-Shaped	0.15	0.040	0.00	3.00	3:1	33:1	37.0	50.3

Notes:

1. Manning’s roughness coefficients are selected from the *Policy Criteria and Procedure Manual* (HCFCD, 2010).
2. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.

Table 2D-3. Runoff Coefficients for Rural Watersheds

(from TxDOT, 2009)

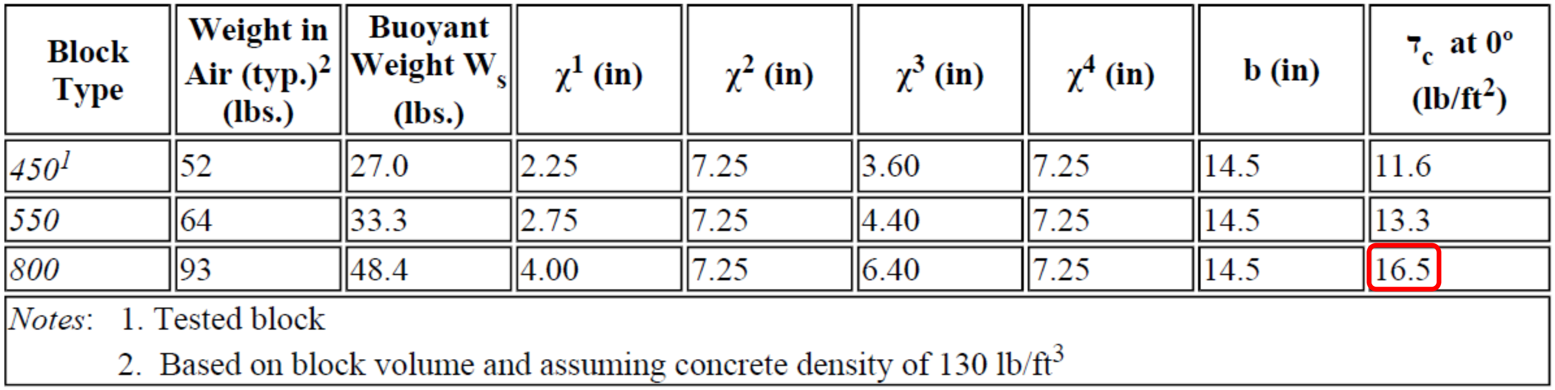


	Extreme	High	Normal	Low
Relief - C_f	*0.28-0.35* steep, rugged terrain with average slopes above 30%	0.20-0.28 hilly, with average slopes of 10-30%	0.14-0.20 rolling, with average slopes of 5-10%	0.08-0.14 relatively flat land, with average slopes of 0-5%
Soil Infiltration - C_i	0.12-0.16 no effective soil cover either rock or thin soil mantle of negligble infiltration capacity	0.08-0.12 slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 normal; well drained light or medium textured soils, sandy loams	0.04-0.06 deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover - C_v	0.12-0.16 no effective plan cover, bare or very sparse cover	0.08-0.12 poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area over good cover	0.06-0.08 fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in culitvated crops	0.04-0.06 good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface - C_s	0.10-0.12 negligible; surface depression few and shallow, drainageways steep and small, no marshes	0.08-0.10 well defined system of small drainageways, no ponds or marshes	0.06-0.08 normal; considerable surface depression storage lakes and ponds and marshes	0.04-0.06 much surface storage, drainage system not sharply defined; large floodplain storage of large number of ponds or marshes

NOTE: The total runoff coefficient based on the four runoff components is $C = C_r + C_i + C_v + C_s$

Table 2D-4. Channel Lock ACB Performance Variables

(from Ayres, 2001)



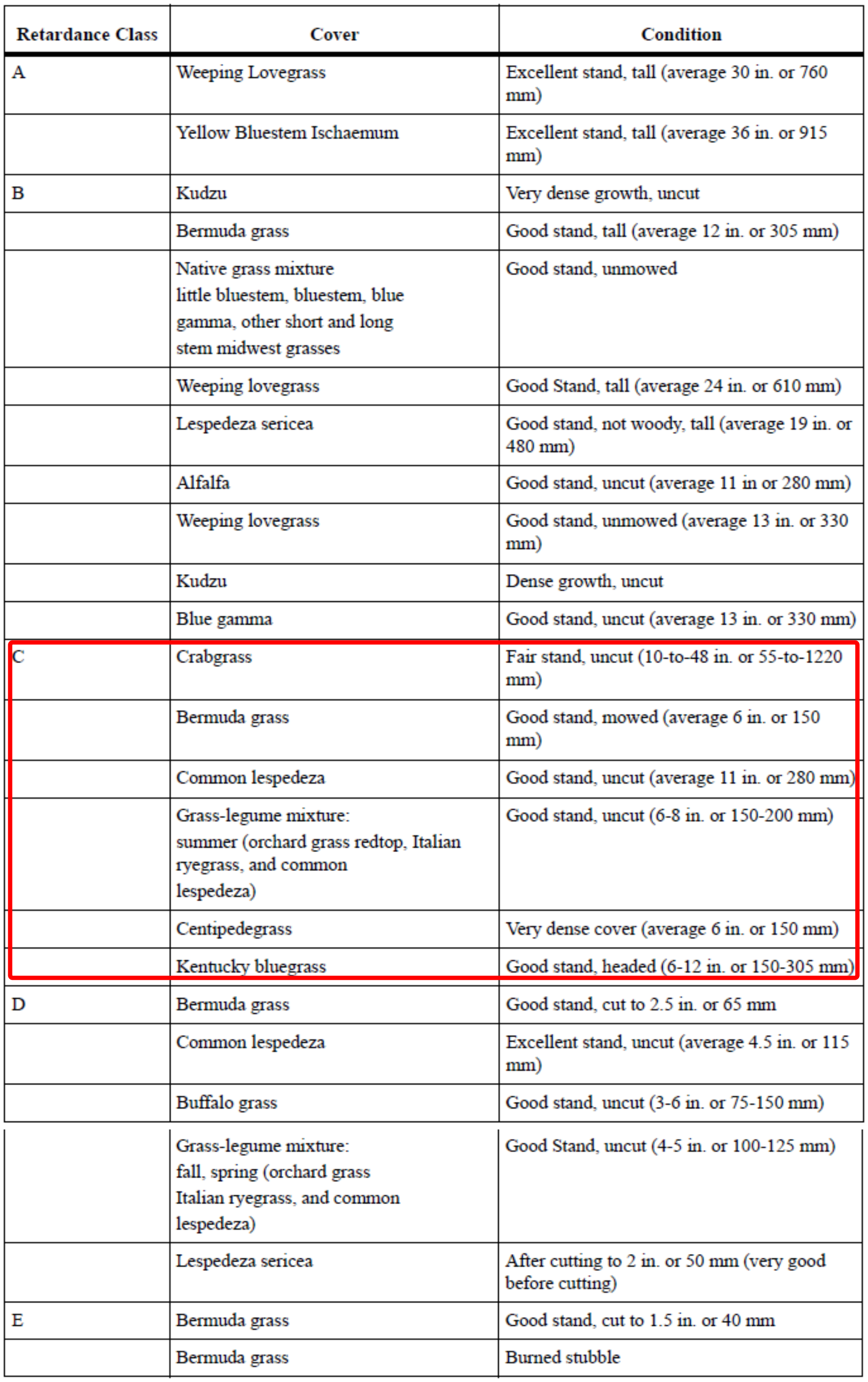
Block Type	Weight in Air (typ.)[2] (lbs.)	Buoyant Weight W_s (lbs.)	χ^1 (in)	χ^2 (in)	χ^3 (in)	χ^4 (in)	b (in)	τ_c at 0° (lb/ft^2)
450[1]	52	27.0	2.25	7.25	3.60	7.25	14.5	11.6
550	64	33.3	2.75	7.25	4.40	7.25	14.5	13.3
800	93	48.4	4.00	7.25	6.40	7.25	14.5	16.5

Notes: 1. Tested block

2. Based on block volume and assuming concrete density of 130 lb/ft^3

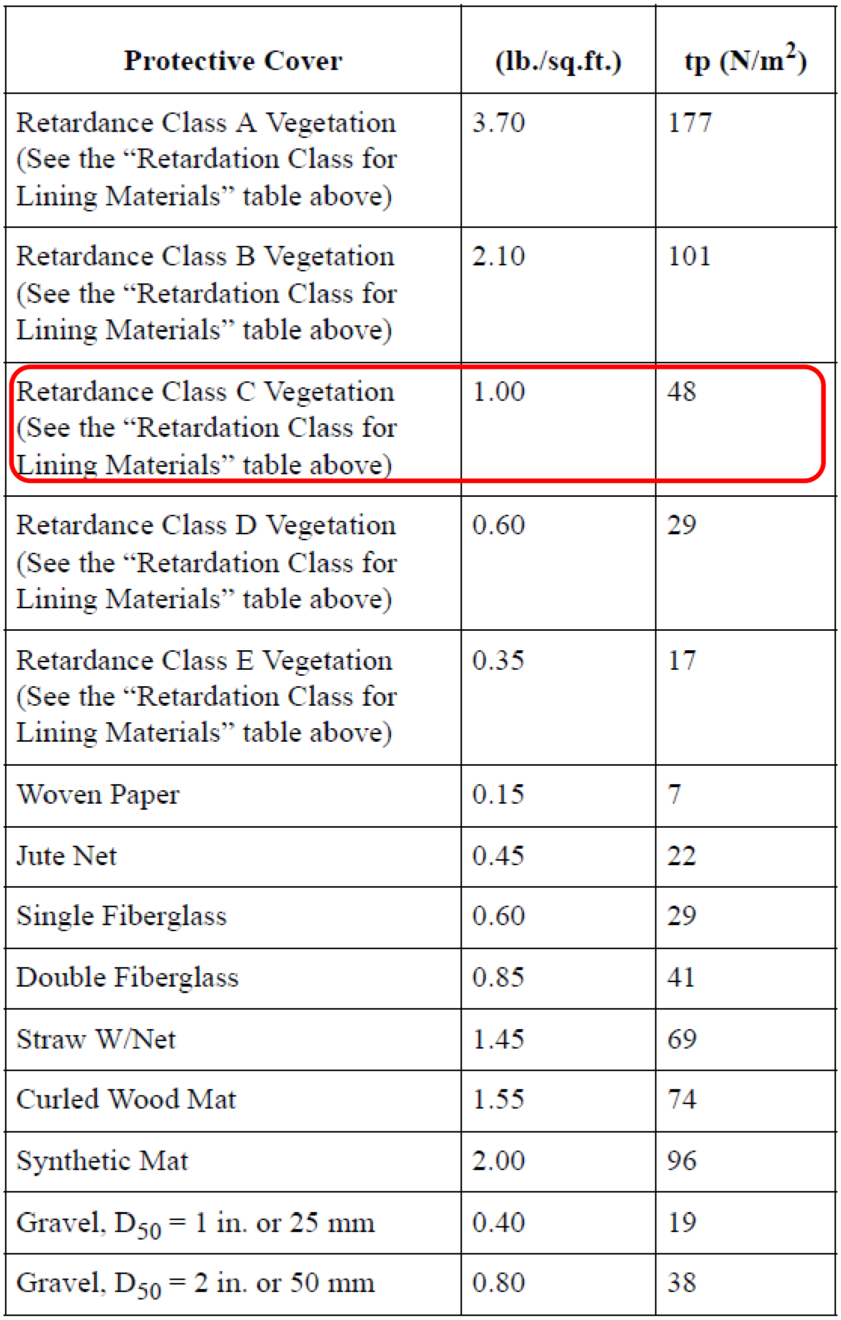
Table 2D-5. Retardation Class for Lining Materials

(from TxDOT, 2009)



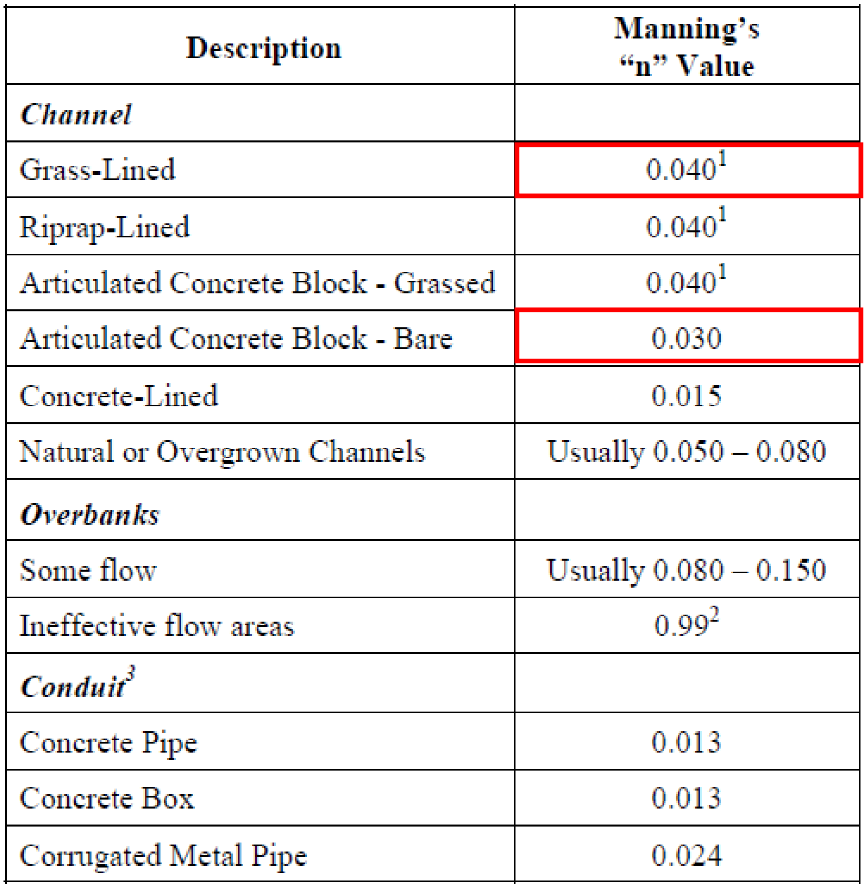
Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

Table 2D-6. Permissible Shear Stresses for Various Linings (from TxDOT, 2009)



Protective Cover	(lb./sq.ft.)	tp (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96
Gravel, D_{50} = 1 in. or 25 mm	0.40	19
Gravel, D_{50} = 2 in. or 50 mm	0.80	38

Table 2D-7. Manning's Roughness Coefficients (from HCFCD, 2010)



Description	**Manning's "n" Value**
Channel	
Grass-Lined	0.040[1]
Riprap-Lined	0.040[1]
Articulated Concrete Block - Grassed	0.040[1]
Articulated Concrete Block - Bare	0.030
Concrete-Lined	0.015
Natural or Overgrown Channels	Usually 0.050 – 0.080
Overbanks	
Some flow	Usually 0.080 – 0.150
Ineffective flow areas	0.99[2]
Conduit[3]	
Concrete Pipe	0.013
Concrete Box	0.013
Corrugated Metal Pipe	0.024

Table 2D-8. Summary of Calculated Results for the Downchute Channels

Downchute Channel Segment	**25-yr, 24-hr Peak Flow, Q (cfs)**	**Depth of Flow (ft)**	**Hydraulic Radius (ft)**	**Average Velocity (ft/s)**	**Avg. Tractive Stress (psf)**	**Freeboard (ft)**	**100-yr, 24-hr Peak Flow, Q (cfs)**	**Depth of Flow (ft)**	**Hydraulic Radius (ft)**	**Average Velocity (ft/s)**	**Avg. Tractive Stress (psf)**
D1	160.8	0.94	0.69	19.44	10.81	1.06	209.2	1.08	0.78	20.99	12.12
D2	231.8	0.90	0.73	20.16	11.41	1.10	299.6	1.04	0.83	21.86	12.88
D3	181.9	0.88	0.69	19.40	10.78	1.12	235.3	1.01	0.78	20.99	12.13
D4	227.5	0.90	0.72	20.04	11.31	1.10	294.4	1.03	0.82	21.74	12.78
D5	156.0	0.92	0.68	19.27	10.67	1.08	201.1	1.06	0.76	20.75	11.92
D6	223.6	0.99	0.76	20.67	11.85	1.01	283.8	1.12	0.85	22.21	13.20
D7	146.5	0.89	0.67	18.92	10.37	1.11	190.0	1.03	0.75	20.41	11.63

Table 2D-9. Summary of Calculated Results for the Top Deck Drainage Terraces

Top Deck Drainage Terrace	25-yr, 24-hr Peak Flow, Q (cfs)	Depth of Flow (ft)	Hydraulic Radius (ft)	Average Velocity (ft/s)	Avg. Tractive Stress (psf)	Freeboard (ft)	100-yr, 24-hr Peak Flow, Q (cfs)	Depth of Flow (ft)	Hydraulic Radius (ft)	Average Velocity (ft/s)	Avg. Tractive Stress (psf)
TD_1	62.7	1.66	0.82	1.27	0.08	1.34	85.3	1.86	0.93	1.37	0.09
TD_3	52.5	1.55	0.77	1.21	0.07	1.45	71.6	1.74	0.87	1.31	0.08
TD_5	52.9	1.55	0.77	1.22	0.07	1.45	72.5	1.75	0.87	1.32	0.08
TD_7	77.5	1.79	0.89	1.34	0.08	1.21	105.4	2.01	1.00	1.44	0.09
TD_9	18.3	1.04	0.52	0.93	0.05	1.96	24.6	1.17	0.58	1.00	0.05
TD_11	37.0	1.36	0.68	1.11	0.06	1.64	50.3	1.53	0.76	1.20	0.07

Table 2D-10. Summary of Calculated Results for the Side Slope Drainage Terraces

		C_{25}	0.638				**Left Side Slope**	3			
		C_{100}	0.725				**Right Side Slope**	4			
		I_{25} (in/hr)	10.1				**Manning's n**	0.04			
		I_{100} (in/hr)	11.9				**SSDT Spacing (ft) =**	200			

Side Slope Drainage Terrace (SSDT)	**Length (ft)**	**Slope (%)**	**Max Contributing Drainage Area (Ac.)**	**Q_{25} (cfs)**	**Q_{100} (cfs)**	**d_{25} (ft)**	**d_{100} (ft)**	**τ_{25} (psf)**	**τ_{100} (psf)**	**V_{25} (fps)**	**V_{100} (fps)**
1	628	2.04%	2.88	18.57	24.86	1.20	1.34	0.73	0.82	3.68	3.96
2	600	2.01%	Calculated as part of SSDT #31 below								
3	474	2.00%	2.18	14.02	18.77	1.08	1.21	0.65	0.73	3.41	3.67
4	849	2.01%	3.90	25.11	33.63	1.35	1.50	0.81	0.91	3.95	4.25
5	588	2.01%	2.70	17.39	23.28	1.17	1.31	0.71	0.79	3.60	3.87
6	686	2.00%	Calculated as part of SSDT #31 below								
7	478	2.00%	2.20	14.15	18.94	1.09	1.21	0.65	0.73	3.42	3.68
8	114	6.25%	0.52	3.37	4.51	0.51	0.57	0.96	1.07	3.66	3.94
9	616	2.01%	2.83	18.21	24.39	1.19	1.33	0.72	0.80	3.64	3.92
10	514	2.01%	Calculated as part of SSDT #30 below								
11	484	3.00%	1.63	10.48	14.03	0.90	1.00	0.81	0.90	3.69	3.97
12	685	2.01%	3.14	20.26	27.13	1.24	1.39	0.75	0.83	3.74	4.03
13	386	1.99%	1.77	11.43	15.31	1.00	1.12	0.60	0.67	3.24	3.48
14	479	3.00%	2.19	14.13	18.92	1.01	1.12	0.91	1.01	3.98	4.28
15	494	2.02%	2.27	14.61	19.56	1.10	1.23	0.67	0.74	3.46	3.72
16	382	1.99%	1.75	11.29	15.12	1.00	1.12	0.60	0.67	3.23	3.47
17	404	3.71%	1.49	9.63	12.89	0.84	0.94	0.93	1.04	3.91	4.21
18	476	2.00%	2.19	14.09	18.87	1.09	1.21	0.65	0.73	3.42	3.68
19	1,062	2.01%	4.87	31.41	42.06	1.47	1.64	0.88	0.98	4.18	4.49
20	391	2.00%	1.80	11.57	15.50	1.01	1.13	0.60	0.67	3.25	3.49
21	569	3.13%	2.21	14.23	19.05	1.00	1.12	0.94	1.05	4.05	4.35
22	434	2.01%	1.99	12.84	17.20	1.05	1.17	0.63	0.70	3.34	3.59
23	945	2.00%	4.34	27.96	37.44	1.40	1.57	0.84	0.94	4.05	4.36
24	374	2.00%	1.72	11.06	14.81	0.99	1.11	0.59	0.66	3.21	3.46
25	569	3.13%	2.59	16.70	22.36	1.06	1.19	1.00	1.11	4.21	4.53
26	562	2.00%	2.58	16.62	22.25	1.16	1.29	0.69	0.77	3.56	3.83
27	904	2.00%	4.15	26.76	35.83	1.38	1.54	0.83	0.93	4.01	4.31
28	224	5.00%	0.56	3.58	4.79	0.55	0.61	0.82	0.92	3.42	3.68
29	278	4.41%	0.97	6.25	8.37	0.69	0.77	0.91	1.02	3.75	4.03
30	938	2.75%	2.87	18.51	24.78	1.13	1.26	0.93	1.04	4.12	4.43
31	1,286	2.01%	4.89	31.51	42.19	1.47	1.64	0.88	0.98	4.18	4.50
32	485	3.69%	1.68	10.85	14.53	0.88	0.98	0.97	1.08	4.02	4.33
33	634	3.14%	2.58	16.64	22.28	1.06	1.18	1.00	1.12	4.21	4.53
34	593	1.90%	2.22	14.30	19.15	1.10	1.23	0.63	0.70	3.36	3.62
35	621	2.00%	2.77	17.86	23.91	1.19	1.32	0.71	0.79	3.62	3.90
36	389	2.00%	1.73	11.12	14.89	0.99	1.11	0.60	0.66	3.22	3.46
37	372	2.00%	1.33	8.54	11.44	0.90	1.00	0.54	0.60	3.01	3.24
38	389	3.49%	1.74	11.24	15.04	0.90	1.00	0.94	1.05	3.98	4.28
39	384	3.40%	1.48	9.53	12.75	0.85	0.95	0.87	0.97	3.78	4.06

Appendix 2D-1

Downchute Channel Calculations

Design/Check: Trapezoidal/Triangular Channel

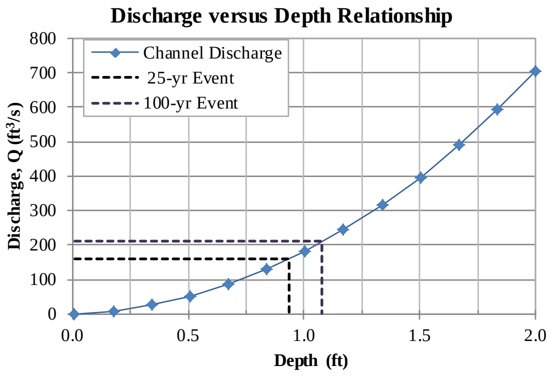
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute, D1**

Peak Discharge, Q_{max}= 160.80 cfs (25-yr Event)
Peak Discharge, Q_{max}= 209.20 cfs (100-yr Event)
Bottom Width, B = 6.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.06	6.06	0.01	1.15	0.1	0.16	
0.18	1.15	7.11	0.16	7.36	8.4	2.52	
0.34	2.40	8.16	0.29	10.98	26.4	4.59	
0.51	3.82	9.21	0.41	13.80	52.7	6.47	
0.67	5.40	10.26	0.53	16.19	87.4	8.21	
0.84	7.15	11.31	0.63	18.29	130.7	9.86	
1.01	9.06	12.36	0.73	20.19	182.9	11.44	
1.17	11.14	13.41	0.83	21.95	244.4	12.96	
1.34	13.38	14.45	0.93	23.59	315.6	14.44	
1.50	15.79	15.50	1.02	25.14	396.8	15.89	
1.67	18.36	16.55	1.11	26.61	488.6	17.30	
1.83	21.10	17.60	1.20	28.02	591.2	18.70	
2.00	24.00	18.65	1.29	29.38	705.2	20.08	
0.94	8.27	11.93	0.69	19.44	160.80	10.81	Q (25-yr Event)
1.08	9.97	12.82	0.78	20.99	209.20	12.12	Q (100-yr Event)



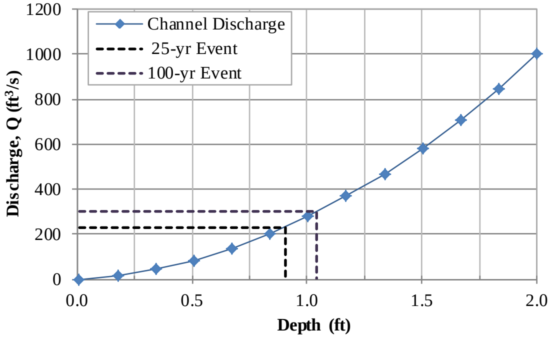
Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation
Project: Fairbanks Landfill Expansion
Ditch ID: **Downchute, D2**

Peak Discharge, Q_{max}= 231.80 cfs (25-yr Event)
Peak Discharge, Q_{max}= 299.60 cfs (100-yr Event)
Bottom Width, B = 10.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.10	10.06	0.01	1.15	0.1	0.16	
0.18	1.85	11.11	0.17	7.51	13.9	2.60	
0.34	3.77	12.16	0.31	11.36	42.8	4.83	
0.51	5.85	13.21	0.44	14.42	84.3	6.91	
0.67	8.09	14.26	0.57	17.02	137.8	8.85	
0.84	10.50	15.31	0.69	19.32	202.9	10.71	
1.01	13.08	16.36	0.80	21.39	279.8	12.48	
1.17	15.82	17.41	0.91	23.30	368.7	14.18	
1.34	18.73	18.45	1.01	25.08	469.6	15.83	
1.50	21.80	19.50	1.12	26.75	583.0	17.44	
1.67	25.03	20.55	1.22	28.33	709.1	19.00	
1.83	28.43	21.60	1.32	29.83	848.2	20.54	
2.00	32.00	22.65	1.41	31.27	1000.7	22.04	
0.90	11.50	15.72	0.73	20.16	231.80	11.41	Q (25-yr Event)
1.04	13.71	16.60	0.83	21.86	299.60	12.88	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

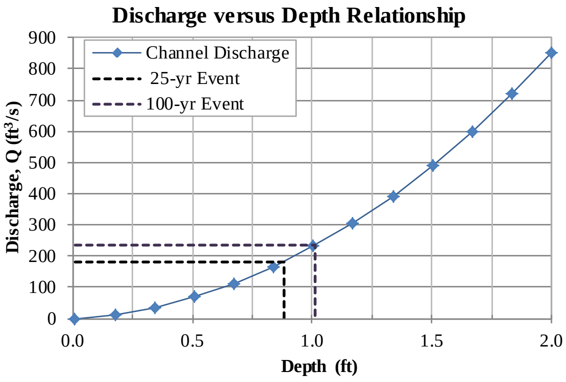
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute, D3**

Peak Discharge, Q_{max}=	181.90	cfs (25-yr Event)
Peak Discharge, Q_{max}=	235.30	cfs (100-yr Event)
Bottom Width, B =	8.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.030	
Longitudinal Channel Slope, S_o =	0.2500	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.08	8.06	0.01	1.15	0.1	0.16	
0.18	1.50	9.11	0.16	7.45	11.2	2.57	
0.34	3.08	10.16	0.30	11.21	34.6	4.73	
0.51	4.83	11.21	0.43	14.17	68.5	6.73	
0.67	6.75	12.26	0.55	16.67	112.5	8.59	
0.84	8.83	13.31	0.66	18.88	166.7	10.35	
1.01	11.07	14.36	0.77	20.88	231.1	12.03	
1.17	13.48	15.41	0.87	22.72	306.2	13.65	
1.34	16.05	16.45	0.98	24.43	392.2	15.22	
1.50	18.79	17.50	1.07	26.04	489.3	16.75	
1.67	21.70	18.55	1.17	27.57	598.1	18.24	
1.83	24.77	19.60	1.26	29.03	718.9	19.71	
2.00	28.00	20.65	1.36	30.43	851.9	21.15	
0.88	9.37	13.57	0.69	19.40	181.90	10.78	Q (25-yr Event)
1.01	11.21	14.42	0.78	20.99	235.30	12.13	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

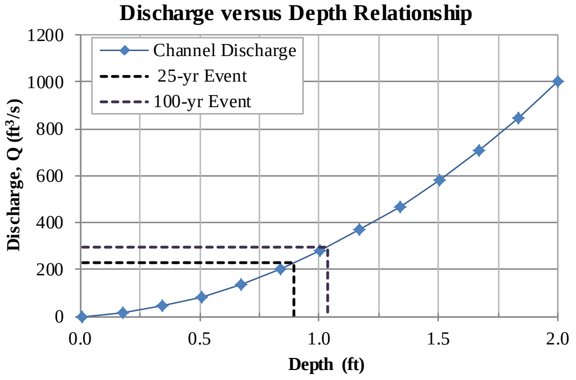
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute, D4**

Peak Discharge, Q_{max}= 227.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 294.40 cfs (100-yr Event)
Bottom Width, B = 10.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.10	10.06	0.01	1.15	0.1	0.16	
0.18	1.85	11.11	0.17	7.51	13.9	2.60	
0.34	3.77	12.16	0.31	11.36	42.8	4.83	
0.51	5.85	13.21	0.44	14.42	84.3	6.91	
0.67	8.09	14.26	0.57	17.02	137.8	8.85	
0.84	10.50	15.31	0.69	19.32	202.9	10.71	
1.01	13.08	16.36	0.80	21.39	279.8	12.48	
1.17	15.82	17.41	0.91	23.30	368.7	14.18	
1.34	18.73	18.45	1.01	25.08	469.6	15.83	
1.50	21.80	19.50	1.12	26.75	583.0	17.44	
1.67	25.03	20.55	1.22	28.33	709.1	19.00	
1.83	28.43	21.60	1.32	29.83	848.2	20.54	
2.00	32.00	22.65	1.41	31.27	1000.7	22.04	
0.90	11.35	15.66	0.72	20.04	227.50	11.31	Q (25-yr Event)
1.03	13.54	16.54	0.82	21.74	294.40	12.78	Q (100-yr Event)

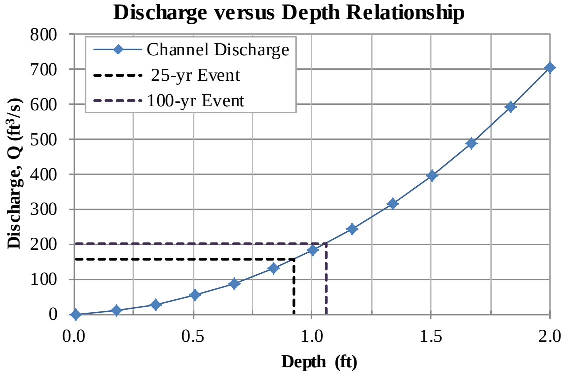


Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation
Project: Fairbanks Landfill Expansion
Ditch ID: **Downchute, D5**

Peak Discharge, Q_{max}= 156.00 cfs (25-yr Event)
Peak Discharge, Q_{max}= 201.10 cfs (100-yr Event)
Bottom Width, B = 6.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.06	6.06	0.01	1.15	0.1	0.16	
0.18	1.15	7.11	0.16	7.36	8.4	2.52	
0.34	2.40	8.16	0.29	10.98	26.4	4.59	
0.51	3.82	9.21	0.41	13.80	52.7	6.47	
0.67	5.40	10.26	0.53	16.19	87.4	8.21	
0.84	7.15	11.31	0.63	18.29	130.7	9.86	
1.01	9.06	12.36	0.73	20.19	182.9	11.44	
1.17	11.14	13.41	0.83	21.95	244.4	12.96	
1.34	13.38	14.45	0.93	23.59	315.6	14.44	
1.50	15.79	15.50	1.02	25.14	396.8	15.89	
1.67	18.36	16.55	1.11	26.61	488.6	17.30	
1.83	21.10	17.60	1.20	28.02	591.2	18.70	
2.00	24.00	18.65	1.29	29.38	705.2	20.08	
0.92	8.09	11.84	0.68	19.27	156.00	10.67	Q (25-yr Event)
1.06	9.69	12.68	0.76	20.75	201.10	11.92	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

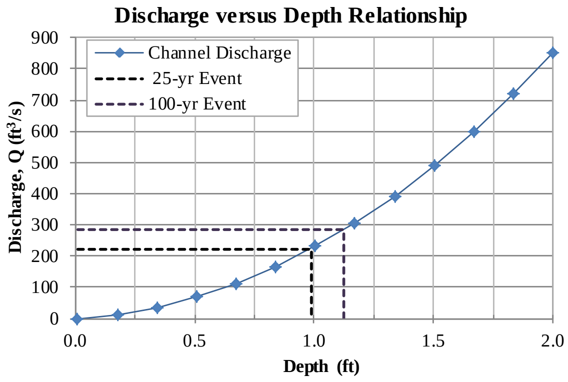
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute, D6**

Peak Discharge, Q_{max}= 223.60 cfs (25-yr Event)
Peak Discharge, Q_{max}= 283.80 cfs (100-yr Event)
Bottom Width, B = 8.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.08	8.06	0.01	1.15	0.1	0.16	
0.18	1.50	9.11	0.16	7.45	11.2	2.57	
0.34	3.08	10.16	0.30	11.21	34.6	4.73	
0.51	4.83	11.21	0.43	14.17	68.5	6.73	
0.67	6.75	12.26	0.55	16.67	112.5	8.59	
0.84	8.83	13.31	0.66	18.88	166.7	10.35	
1.01	11.07	14.36	0.77	20.88	231.1	12.03	
1.17	13.48	15.41	0.87	22.72	306.2	13.65	
1.34	16.05	16.45	0.98	24.43	392.2	15.22	
1.50	18.79	17.50	1.07	26.04	489.3	16.75	
1.67	21.70	18.55	1.17	27.57	598.1	18.24	
1.83	24.77	19.60	1.26	29.03	718.9	19.71	
2.00	28.00	20.65	1.36	30.43	851.9	21.15	
0.99	10.82	14.24	0.76	20.67	223.60	11.85	Q (25-yr Event)
1.12	12.78	15.11	0.85	22.21	283.80	13.20	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

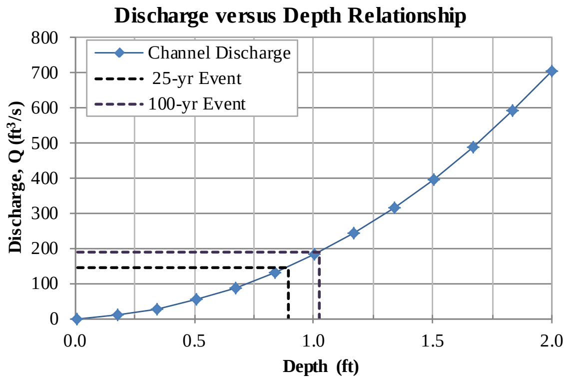
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute, D7**

Peak Discharge, Q_{max}= 146.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 190.00 cfs (100-yr Event)
Bottom Width, B = 6.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.2500 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.06	6.06	0.01	1.15	0.1	0.16	
0.18	1.15	7.11	0.16	7.36	8.4	2.52	
0.34	2.40	8.16	0.29	10.98	26.4	4.59	
0.51	3.82	9.21	0.41	13.80	52.7	6.47	
0.67	5.40	10.26	0.53	16.19	87.4	8.21	
0.84	7.15	11.31	0.63	18.29	130.7	9.86	
1.01	9.06	12.36	0.73	20.19	182.9	11.44	
1.17	11.14	13.41	0.83	21.95	244.4	12.96	
1.34	13.38	14.45	0.93	23.59	315.6	14.44	
1.50	15.79	15.50	1.02	25.14	396.8	15.89	
1.67	18.36	16.55	1.11	26.61	488.6	17.30	
1.83	21.10	17.60	1.20	28.02	591.2	18.70	
2.00	24.00	18.65	1.29	29.38	705.2	20.08	
0.89	7.74	11.64	0.67	18.92	146.50	10.37	Q (25-yr Event)
1.03	9.31	12.49	0.75	20.41	190.00	11.63	Q (100-yr Event)



Appendix 2D-2

Drainage Terrace Calculations

Design/Check: Trapezoidal/Triangular Channel

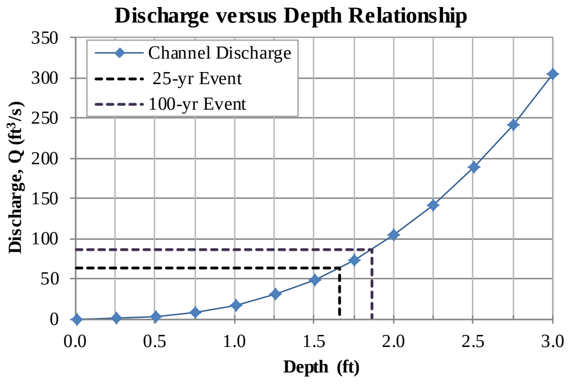
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Top Deck Drainage Terrace, TD_1**

Peak Discharge, Q_{max}= 62.70 cfs (25-yr Event)
Peak Discharge, Q_{max}= 85.30 cfs (100-yr Event)
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.66	49.43	59.95	0.82	1.27	62.70	0.08	Q (25-yr Event)
1.86	62.26	67.29	0.93	1.37	85.30	0.09	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

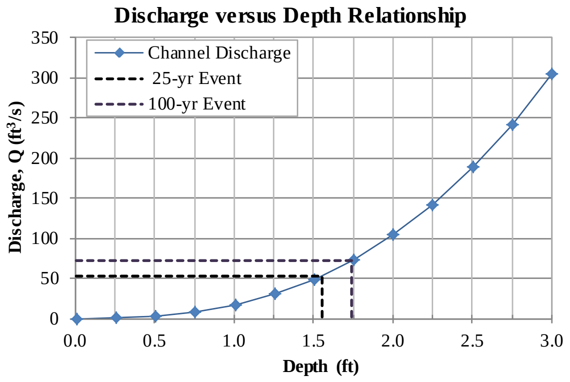
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Top Deck Drainage Terrace, TD_3**

Peak Discharge, Q_{max}= 52.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 71.60 cfs (100-yr Event)
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.55	43.27	56.09	0.77	1.21	52.50	0.07	Q (25-yr Event)
1.74	54.60	63.01	0.87	1.31	71.60	0.08	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

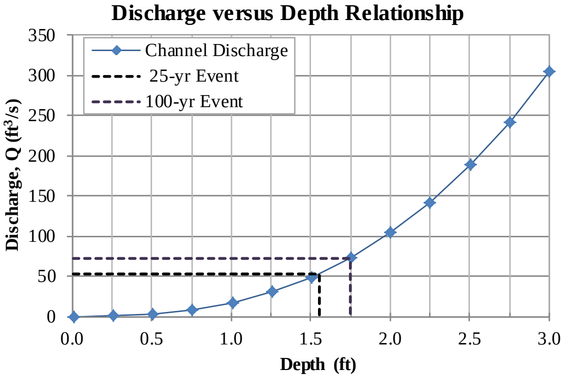
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Top Deck Drainage Terrace, TD_5**

Peak Discharge, Q_{max}= 52.90 cfs (25-yr Event)
Peak Discharge, Q_{max}= 72.50 cfs (100-yr Event)
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

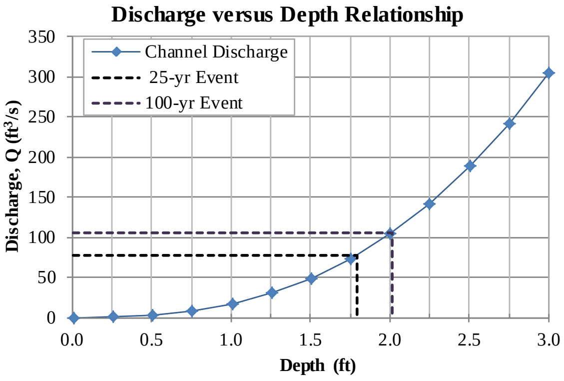
Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.55	43.52	56.25	0.77	1.22	52.90	0.07	Q (25-yr Event)
1.75	55.12	63.31	0.87	1.32	72.50	0.08	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel
Methodology: Manning's Equation
Project: Fairbanks Landfill Expansion
Ditch ID: **Top Deck Drainage Terrace, TD_7**

Peak Discharge, Q_{max}= 77.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 105.40 cfs (100-yr Event)
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.79	57.94	64.91	0.89	1.34	77.50	0.08	Q (25-yr Event)
2.01	72.97	72.84	1.00	1.44	105.40	0.09	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

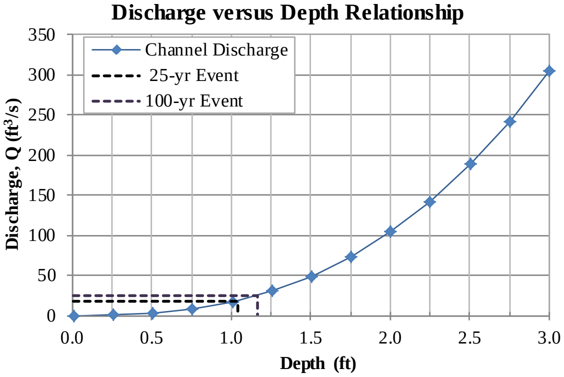
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Top Deck Drainage Terrace, TD_9**

Peak Discharge, Q_{max}= 18.30 cfs (25-yr Event)
Peak Discharge, Q_{max}= 24.60 cfs (100-yr Event)
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.04	19.63	37.78	0.52	0.93	18.30	0.05	Q (25-yr Event)
1.17	24.51	42.21	0.58	1.00	24.60	0.05	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

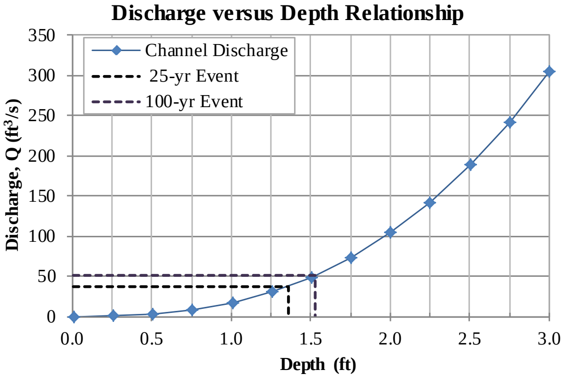
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Top Deck Drainage Terrace, TD_11**

Peak Discharge, Q_{max}=	37.00	cfs (25-yr Event)
Peak Discharge, Q_{max}=	50.30	cfs (100-yr Event)
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	33.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.040	
Longitudinal Channel Slope, S_o =	0.0015	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.26	1.21	9.38	0.13	0.37	0.4	0.01	
0.51	4.65	18.39	0.25	0.58	2.7	0.02	
0.76	10.33	27.40	0.38	0.75	7.8	0.04	
1.01	18.24	36.42	0.50	0.91	16.6	0.05	
1.26	28.39	45.43	0.62	1.05	29.9	0.06	
1.51	40.77	54.45	0.75	1.19	48.5	0.07	
1.75	55.39	63.46	0.87	1.32	73.0	0.08	
2.00	72.24	72.48	1.00	1.44	104.0	0.09	
2.25	91.33	81.49	1.12	1.56	142.2	0.10	
2.50	112.65	90.50	1.24	1.67	188.1	0.12	
2.75	136.21	99.52	1.37	1.78	242.3	0.13	
3.00	162.00	108.53	1.49	1.88	305.3	0.14	
1.36	33.28	49.19	0.68	1.11	37.00	0.06	Q (25-yr Event)
1.53	41.90	55.20	0.76	1.20	50.30	0.07	Q (100-yr Event)



ATTACHMENT 2E

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS

ON-SITE DESIGN – CULVERTS AND PERIMETER DRAINAGE CHANNELS FAIRBANKS LANDFILL EXPANSION

SCOTT M. GRAVES
86557

8/26/2013

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 27

GEOSYNTEC CONSULTANTS
TX ENG FIRM REGISTRATION NO. F-1182

1 PURPOSE

The purpose of this calculation package is to present the design of the perimeter drainage channels and culverts (including riprap aprons) for the proposed facility surface water management system for the Fairbanks Landfill. Note that the design of the surface water pond appurtenances (including riprap aprons at the pond outlet) is presented in Attachment 2C.

Perimeter drainage channels are located at the toe of the 4 horizontal: 1 vertical (4H:1V) side slopes of the final cover system around the north and west sides of the landfill. The perimeter drainage channels convey surface water runoff to the on-site surface water ponds located to the northeast and south of the landfill. The North Perimeter Drainage Channel conveys surface water from the north and east areas of the final cover system through a series of reaches (designated as R1, R2, and R3) to the Northeast Surface Water Pond. The West Perimeter Drainage Channel conveys surface water from the western areas of the final cover to the South Surface Water Pond through a series of reaches (designated as R4, R5, and R6) and a culvert (designated as C1).

A reach is defined as a segment of a perimeter drainage channel with a selected slope, width, and depth. The West and North Perimeter Drainage Channels are separated by a local high point on the northern edge of the final cover system. Surface water from the southern areas of the final cover is conveyed directly into the South Surface Water Pond through downchute channels, which are discussed in Attachment 2D of the Facility Surface

Water Drainage Report (Drainage Report). Also, Drawing 2-1 in Attachment 2A of the Drainage Report shows a plan view of the facility surface water management system.

2 METHODOLOGY

Perimeter Channels

The North Perimeter Drainage Channel and the West Perimeter Drainage Channel are to be grass-lined trapezoidal channels conveying flows to the surface water ponds. Final cover areas contributing to each perimeter channel reach are modeled in the computer program HEC-HMS for the post-development site conditions, and subsequently peak discharges are computed for each reach. The details of this analysis are provided in the *On-Site Drainage Analysis – Hydrology* calculations located in Attachment 2B of the Drainage Report. Each reach is designed to convey the peak surface water discharge of the 25-year, 24-hour design rainfall event flowing to the channel segment, while maintaining a minimum of one foot of freeboard in the channel during this rainfall event. In addition, each reach was designed with the capacity to convey the peak discharge from the 100-year, 24-hour rainfall event without overtopping. Calculations of surface water discharge for these rainfall events are provided in Attachment 2B of the Drainage Report.

Drawing 2-4 in Attachment 2A of the Drainage Report shows the perimeter drainage channel plans with reach designations for each perimeter channel segment. Drawing 2-5 provides perimeter drainage profiles for the North and West Perimeter Drainage Channels. The typical cross-section of a perimeter drainage channel and a channel schedule for the perimeter drainage channels is provided in Drawing 2-10. The channel geometry and peak discharge during the design rainfall events are used to calculate the peak velocity and the peak tractive stress during the design rainfall on the lining of the channel.

It should be noted that channel reaches located along the northern and western portions of the currently permitted landfill have already been constructed. The design associated with this facility expansion considers the existing channel profile (i.e., design slopes and elevations) from the currently permitted surface water plan for the site. However, in several cases, these reaches will need to be enlarged to accommodate increased peak discharge rates flowing from the landfill expansion.

The capacity of each drainage channel segment is calculated and assessed by solving Manning's equation. Manning's equation (Chow, 1959) is expressed as:

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/6/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2} \tag{1}$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak average tractive stresses in the channel for various depths of flow are estimated using the following equation (HCFCD, 2001):

$$\tau_o = \gamma_w RS \tag{2}$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Culverts

Culverts are designed by utilizing the HY-8 Culvert Analysis Program v.7.3 (HY-8). HY-8 was originally developed by the Federal Highway Administration (FHWA) and has since been updated and revised to its current version (Version 7.3). The performance of a culvert is modeled and assessed based on boundary conditions, culvert configuration, and peak flow criteria. HY-8 is applied for the surface water drainage system to model the culvert conveying the peak discharge from West Perimeter Drainage Channel into the South Surface Water Pond. The performance of the box culvert is assessed for two tailwater conditions based on the modeled water surface elevation within the South Surface

Water Pond coinciding with the peak discharge within the culvert for the 25-year, 24-hour rainfall event (Case I) and the 100-year, 24-hour rainfall event (Case II). Results from the HY-8 model are reviewed to verify that the computed headwater elevation does not overtop the berm at the culvert inlet during the peak discharge.

Riprap Apron Design

The riprap aprons at the outlet culvert of C1 and at the outlet of R3 into the surface water pond are designed to protect against erosion and scour peak surface water runoff. The riprap apron is sized from the outflow based on the 25-year, 24-hour rainfall event. The design guidance from the Federal Highway Administration (FHWA) provides a methodology for calculating the required length of apron (L_a) and d_{50} of the riprap based on the culvert diameter and flow rate, and this methodology was adopted for use in the site designs. The d_{50} is the stone size of the riprap for which to 50% of the riprap stones are smaller than d_{50} by mass. The riprap size is calculated using the following equation (FHWA, 2006):

$$d_{50} = 0.2D\left(\frac{Q}{D^{2.5}\sqrt{g}}\right)^{4/3}\frac{D}{TW} \qquad (3)$$

where:

d_{50} = riprap size (ft),

Q = design discharge (cfs),

D = culvert diameter (ft),

TW = tailwater depth (ft), and

g = gravitational constant.

The tailwater depth should be limited to between 0.4D and D. FHWA (2006) recommends the use of a tailwater depth equal to 0.4D if the tailwater is unknown.

The required length and depth of the riprap apron can be estimated based on the culvert rise and riprap size as provided in Table 2E-1.

3 DESIGN PARAMETERS

The design parameters for each reach and culvert, including channel geometry and calculated peak discharges for the 25-year and 100-year events, are summarized in Table 2E-2. Reaches R1 and R4 are directly adjacent to the local high point, and subsequently downchute channels do not flow directly into these reaches (see Drawing 2-1). Therefore, the design parameters (i.e., the 25-year, 24-hour peak discharge and channel geometry) for reaches R1 and R4, were conservatively assumed to be equivalent to the reaches immediately downstream, R2 and R5, respectively.

Permissible peak tractive stresses for grass lined channels range from 0.35 psf to 3.70 psf depending on the retardation class of vegetation. Retardation Class C (which includes Bermuda and Crab grasses among others) was selected for the design of grass lined channels (as shown in Table 2E-3) and has a maximum permissible tractive stress of 1.0 psf (as shown in Table 2E-4 from TxDOT, 2009).

The concrete box culvert C1 is designed under the following parameters to convey both the peak 25-year, 24-hour rainfall discharge and 100-year, 24-hour rainfall discharge. The proposed culvert has a span of 10 feet, a rise of 4.5 feet, and a length of 440 feet. The inlet invert and outlet invert elevations are 104.4 ft MSL and 100.0 ft MSL, respectively, resulting in a culvert slope of 1.0%. A Manning’s roughness coefficient is selected as 0.013 for concrete box culverts, based on guidance in Table 2E-5 from Harris County Flood Control District (HCFCD, 2010). The peak inflow into the culvert and tailwater conditions are computed by HEC-HMS for the design cases, as discussed in Attachment 2B. The peak inflow from reach R6 into the culvert (C1) is calculated as 258.2 cfs and 333.8 cfs for the 25-year, 24-hour rainfall (Case I) and 100-year, 24-hour rainfall (Case II) rainfall events, respectively. The water surface elevations in the South Surface Water Pond (i.e., tailwater conditions) coinciding with the peak discharge within the culvert are 104.1 ft MSL and 105.7 ft MSL for the 25-year, 24-hour and 100-year, 24-hour rainfall events, respectively.

The inflow structure into the culvert influences the conveyance of surface water through the culvert. The box culvert inflow structure was modeled with a beveled 45 degree wingwall. The culvert headwall is to be installed according to the TxDOT standard detail FW-0 for concrete wingwalls with flared wings. The box culvert shall be in accordance with TxDOT standard detail SCP-10 for precast 10-ft span single box culverts. TxDOT standard details for wingwalls and precast culverts are available in Figures 2E-1 and 2E-2, respectively. For the purposes of riprap apron design, the outlet C1 was considered as two representative 4.5 ft diameter culverts each conveying half the peak inflow of C1. Also for the purposes of riprap apron design, the tailwater depth is considered 0.4 times the diameter or 1.8 ft, as the peak tailwater depth during the 25-year, 24-hour rainfall event results in what was judged to be an overly small minimum d_{50}.

A riprap apron was also sized for the outflow of reach R3 into the Northeast Surface Water Pond. The invert elevation of reach R3 into the surface water pond is 104.46 ft MSL, and the peak discharge during the 25-year, 24-hour rainfall event is 323.9 cfs. This 10 ft (base width) by 6 ft (channel depth) trapezoidal channel was considered as two representative 4.95 ft circular culverts (corresponding to the peak depth of flow within the channel). Each representative culvert is assumed to convey half the 25-year, 24-hour peak discharge, solely for the purposes of riprap apron design. Since the invert elevation of R3 is above the peak pond elevation for the 25-year, 24-hour rainfall event, the tailwater depth was taken as 0.4 times the diameter of the representative culvert.

4 RESULTS

The depth of flow, velocity, and average tractive stress for the calculated discharge for each perimeter drainage channel during the design rainfall event were calculated using Equations (1) and (2). Calculations for each perimeter channel reach were performed using spreadsheets that are presented in Appendix 2E-1, and the results are summarized in Table 2E-6. For both design cases, the performance of the culvert (C1) from HY-8 modeling is presented in Table 2E-7, and shown on Figures 2E-3 and 2E-4.

- The available freeboard in all perimeter channel reaches is calculated to be greater than one foot during the 25-year, 24-hour rainfall event.
- Each perimeter channel reach was calculated to be able to convey the 100-year, 24-hour rainfall event without overtopping as presented in Table 2E-6.
- The average tractive stress within each of the perimeter channel reaches is calculated to remain below the maximum one (1) psf during the 25-year, 24-hour rainfall event.
- Culvert C1 contains the capacity to convey the flow from the West Perimeter Drainage Channel to the South Surface Water Pond without overtopping the perimeter berm at the culvert inlet wingwall.

The minimum d_{50} size of the riprap apron was computed by Equation (3) for the outflow of C1 and R3 as 0.96 feet and 1.04 feet, respectively. The calculated minimum d_{50} of the riprap aprons corresponds to a riprap class 4 for the outflow of C1 and R3. Based on Table 2E-1, the riprap apron length at the outlet of C1 and R3 should be at least 6D in length. The width of the box culvert at C1 and R3 are 10 feet and are selected for sizing the length of the apron. Thus, these riprap apron length should be at least 60 feet in length. Furthermore, the apron depth should be $2.2d_{50}$ = 2.2 feet deep for the culvert and 2.3 ft deep for the outlet of R3. FHWA (2006) recommends an apron width of 3D = 30 feet at the up gradient end of the apron near the culvert outlet and a 3:1 apron length to apron width expansion resulting in an apron width of 70 feet at the down gradient end of the apron.

5 REFERENCES

Chow, V.T (1959). *Open Channel-Hydraulics*, McGraw-Hill.

FHWA (2006). *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Federal Highway Administration, US Department of Transportation, Hydraulic Engineering Circular No. 14, Third Edition.

HCFCD (2001). *Design Manual for Articulating Concrete Block Systems*, Houston, Texas, Harris County Flood Control District, September 2001.

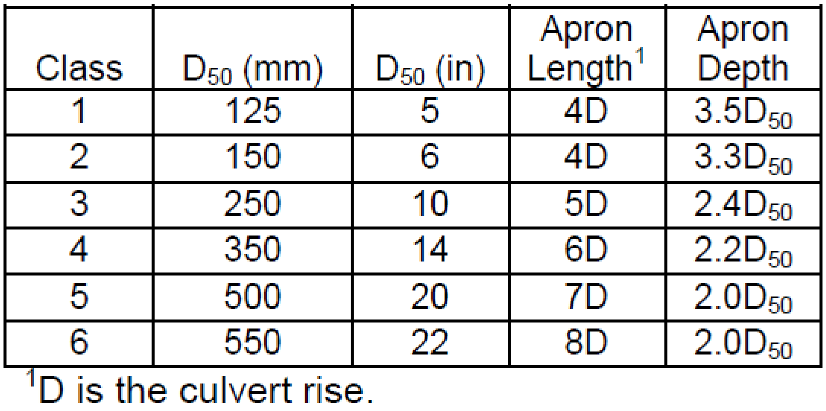
HCFCD (2010). *Policy Criteria and Procedure Manual*, Harris County Flood Control District, December 2010.

TxDOT (2009). *Hydraulic Design Manual*, Texas Department of Transportation, revised March 2009.

TABLES

Table 2E-1. Riprap Classes and Apron Dimensions

(from FHWA, 2006)



Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1] D is the culvert rise.

Table 2E-2. Design Parameter Summary for Perimeter Drainage Channels and Culverts

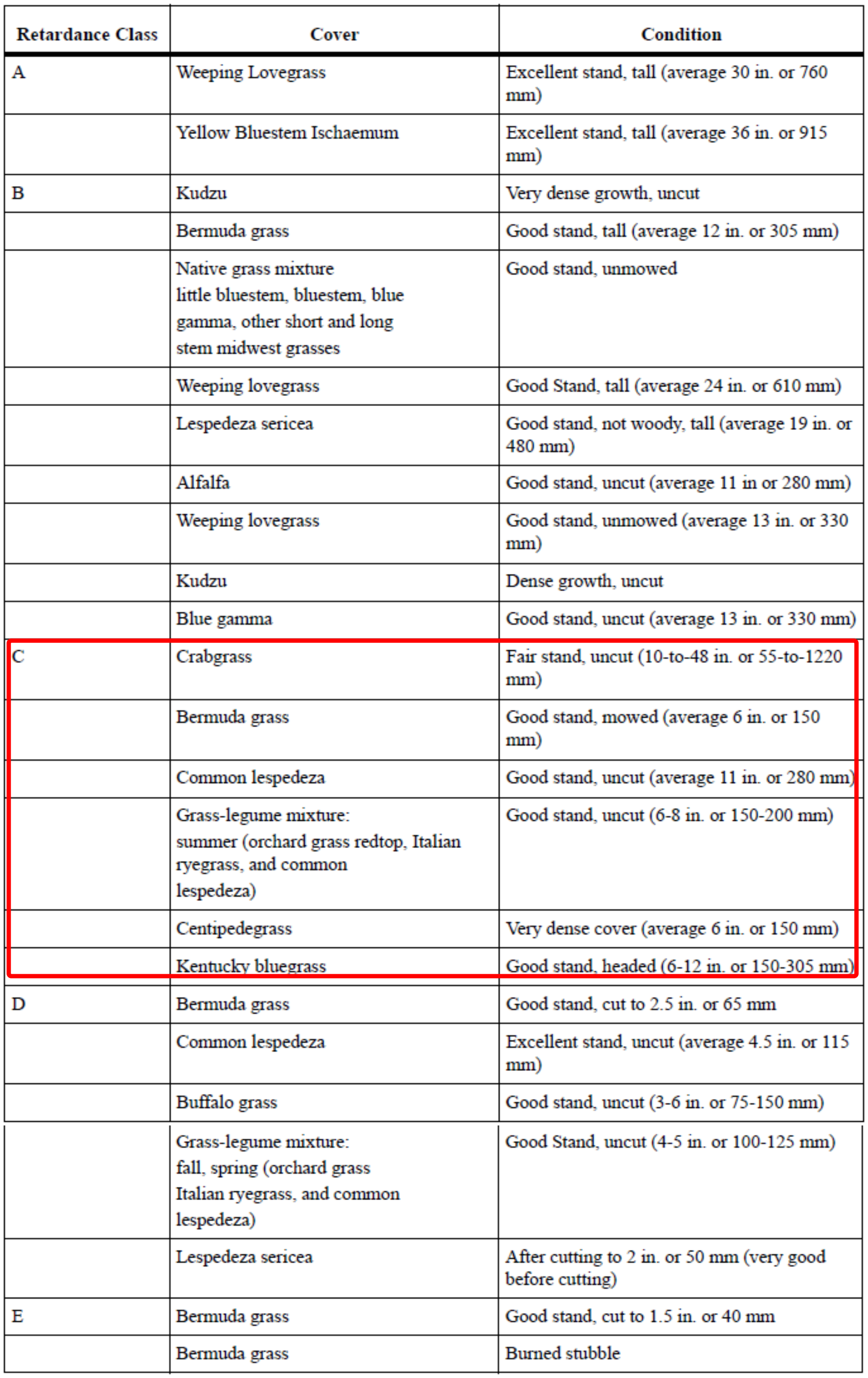
Perimeter Channel/Culvert	**Channel Shape**	**Longitudinal Channel Slope (%)**	**Manning's Roughness Coefficient, n [1]**	**Channel Dimensions (minimum)**			**25-Year, 24-hr Peak Flow, Q (cfs)[2]**	**100-Year, 24-hr Peak Flow, Q (cfs)[2]**
				Bottom Width (ft)	**Depth (ft)**	**Side Slopes (H:V)**		
R1	Trapezoidal	0.15	0.040	6.00	5.00	3:1	160.8	209.2
R2	Trapezoidal	0.15	0.040	6.00	5.00	3:1	160.8	209.2
R3	Trapezoidal	0.15	0.040	10.00	6.00	3:1	323.9	436.3
R4	Trapezoidal	0.15	0.040	4.00	5.00	3:1	146.5	190.0
R5	Trapezoidal	0.15	0.040	4.00	5.00	3:1	146.5	190.0
R6	Trapezoidal	0.15	0.040	12.00	5.25	3:1	262.9	343.9
C1 [3]	Box	1.00	0.013	10.00	4.50	-	258.2	333.8

Notes:

1. Manning’s roughness coefficients were selected from the *Policy Criteria and Procedure Manual* (HCFCD, 2010).
2. The calculation of peak flows for the design rainfall events is presented in Attachment 2B.
3. Inlet control was modeled with a 45 degree beveled wingwall.

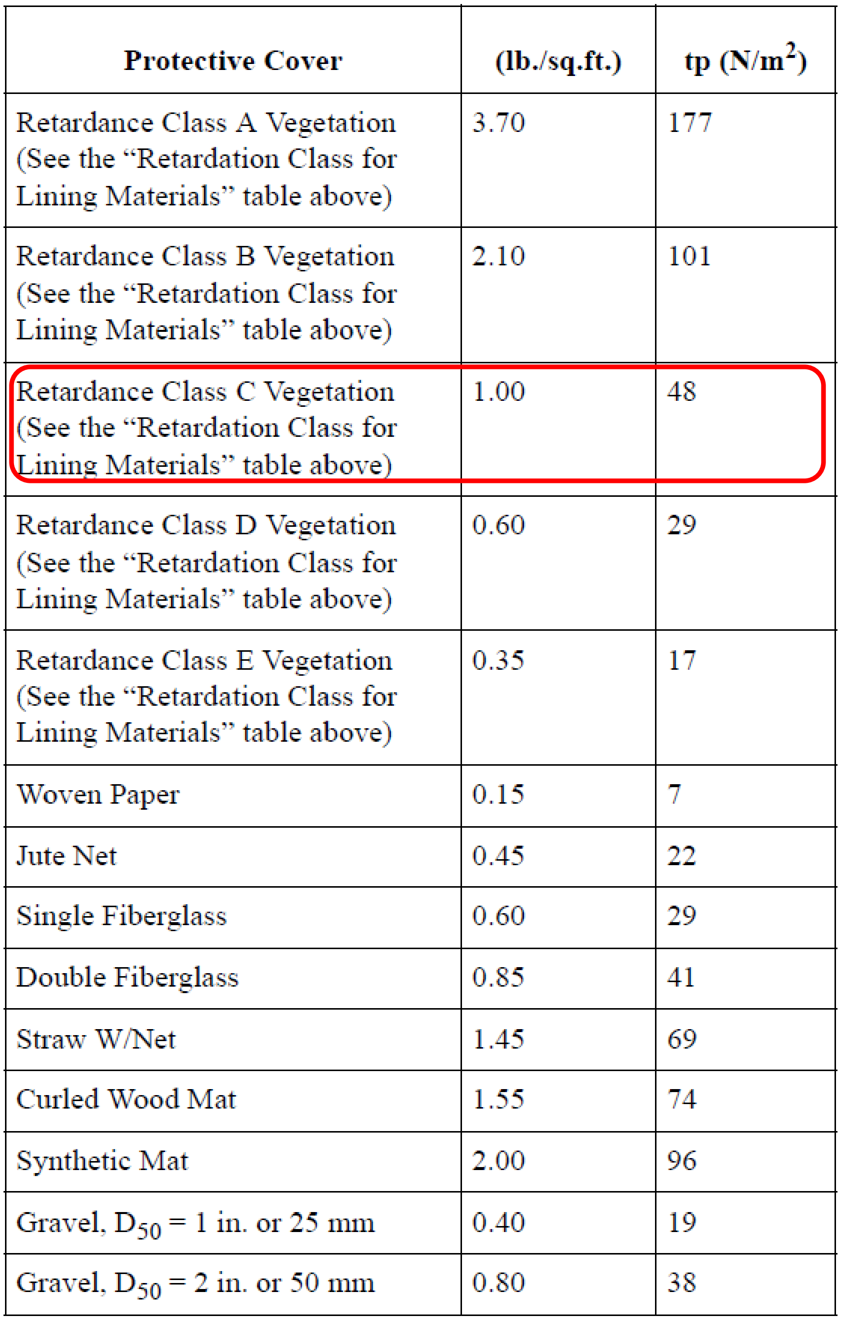
Table 2E-3. Retardation Class for Lining Materials

(from TxDOT, 2009)



Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30 in. or 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36 in. or 915 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12 in. or 305 mm)
	Native grass mixture little bluestem, bluestem, blue gamma, other short and long stem midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good Stand, tall (average 24 in. or 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 19 in. or 480 mm)
	Alfalfa	Good stand, uncut (average 11 in or 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 13 in. or 330 mm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13 in. or 330 mm)
C	Crabgrass	Fair stand, uncut (10-to-48 in. or 55-to-1220 mm)
	Bermuda grass	Good stand, mowed (average 6 in. or 150 mm)
	Common lespedeza	Good stand, uncut (average 11 in. or 280 mm)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6-8 in. or 150-200 mm)
	Centipedegrass	Very dense cover (average 6 in. or 150 mm)
	Kentucky bluegrass	Good stand, headed (6-12 in. or 150-305 mm)
D	Bermuda grass	Good stand, cut to 2.5 in. or 65 mm
	Common lespedeza	Excellent stand, uncut (average 4.5 in. or 115 mm)
	Buffalo grass	Good stand, uncut (3-6 in. or 75-150 mm)
	Grass-legume mixture: fall, spring (orchard grass Italian ryegrass, and common lespedeza)	Good Stand, uncut (4-5 in. or 100-125 mm)
	Lespedeza sericea	After cutting to 2 in. or 50 mm (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5 in. or 40 mm
	Bermuda grass	Burned stubble

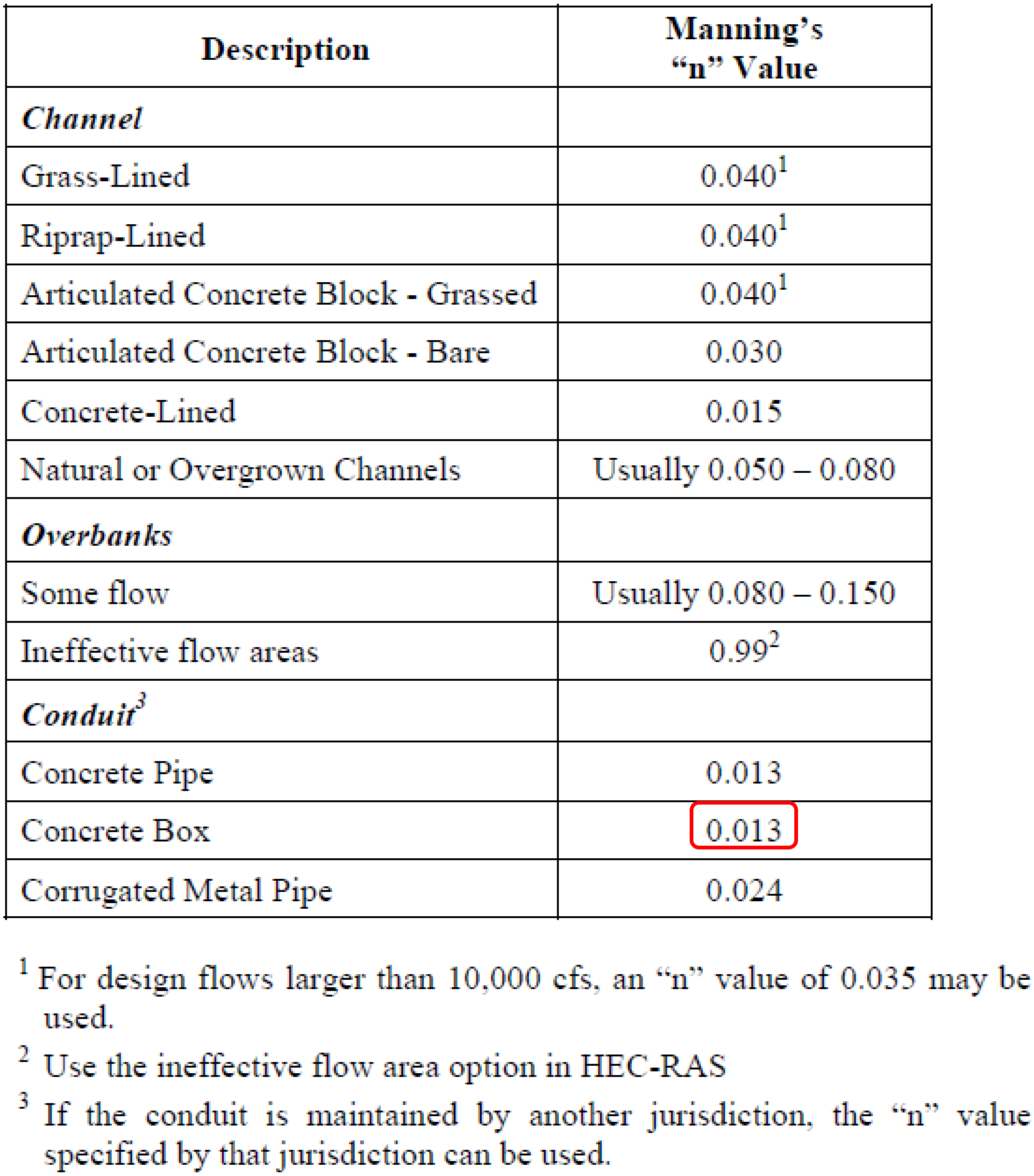
Table 2E-4. Permissible Shear Stress for Various Linings (from TxDOT, 2009)



Protective Cover	(lb./sq.ft.)	tp (N/m^2)
Retardance Class A Vegetation (See the "Retardation Class for Lining Materials" table above)	3.70	177
Retardance Class B Vegetation (See the "Retardation Class for Lining Materials" table above)	2.10	101
Retardance Class C Vegetation (See the "Retardation Class for Lining Materials" table above)	1.00	48
Retardance Class D Vegetation (See the "Retardation Class for Lining Materials" table above)	0.60	29
Retardance Class E Vegetation (See the "Retardation Class for Lining Materials" table above)	0.35	17
Woven Paper	0.15	7
Jute Net	0.45	22
Single Fiberglass	0.60	29
Double Fiberglass	0.85	41
Straw W/Net	1.45	69
Curled Wood Mat	1.55	74
Synthetic Mat	2.00	96
Gravel, D_{50} = 1 in. or 25 mm	0.40	19
Gravel, D_{50} = 2 in. or 50 mm	0.80	38

Table 2E-5. Manning's n Values

(from HCFCD, 2010)



Description	Manning's "n" Value
Channel	
Grass-Lined	0.040[1]
Riprap-Lined	0.040[1]
Articulated Concrete Block - Grassed	0.040[1]
Articulated Concrete Block - Bare	0.030
Concrete-Lined	0.015
Natural or Overgrown Channels	Usually 0.050 – 0.080
Overbanks	
Some flow	Usually 0.080 – 0.150
Ineffective flow areas	0.99[2]
Conduit[3]	
Concrete Pipe	0.013
Concrete Box	0.013
Corrugated Metal Pipe	0.024

[1] For design flows larger than 10,000 cfs, an "n" value of 0.035 may be used.

[2] Use the ineffective flow area option in HEC-RAS

[3] If the conduit is maintained by another jurisdiction, the "n" value specified by that jurisdiction can be used.

Table 2E-6. Channel Capacity Calculation Results

Perimeter Channel/ Culvert	25-yr, 24-hr Peak Flow, Q (cfs)	Peak Depth of Flow (ft)	Hydraulic Radius (ft)	Peak Channel Velocity (ft/s)	Peak Tractive Stress (psf)	Freeboard (ft)	100-yr, 24-hr Peak Flow, Q (cfs)	Peak Depth of Flow (ft)	Hydraulic Radius (ft)	Peak Channel Velocity (ft/s)	Peak Channel Tractive Stress (psf)
R1	160.8	3.79	2.20	2.44	0.21	1.21	209.2	4.27	2.43	2.61	0.23
R2	160.8	3.79	2.20	2.44	0.21	1.21	209.2	4.27	2.43	2.61	0.23
R3	323.9	4.67	2.83	2.89	0.27	1.33	436.3	5.36	3.18	3.12	0.30
R4	146.5	3.90	2.14	2.39	0.20	1.10	190.0	4.36	2.36	2.56	0.22
R5	146.5	3.90	2.14	2.39	0.20	1.10	190.0	4.36	2.36	2.56	0.22
R6	262.9	4.02	2.58	2.72	0.24	1.23	343.9	4.58	2.88	2.92	0.27

Table 2E-7. Culvert Capacity Analysis Results

Design Case	Design Rainfall Event	Peak Flow into Culvert (cfs)	Coincident Tailwater Elevation (ft MSL)	Peak Headwater Elevation (ft MSL)	Peak Outlet Velocity (ft/s)
Case I	25-year, 24-hour	258.2	104.10	108.72	11.40
Case II	100-year, 24-hour	333.8	105.70	109.67	12.28

FIGURES

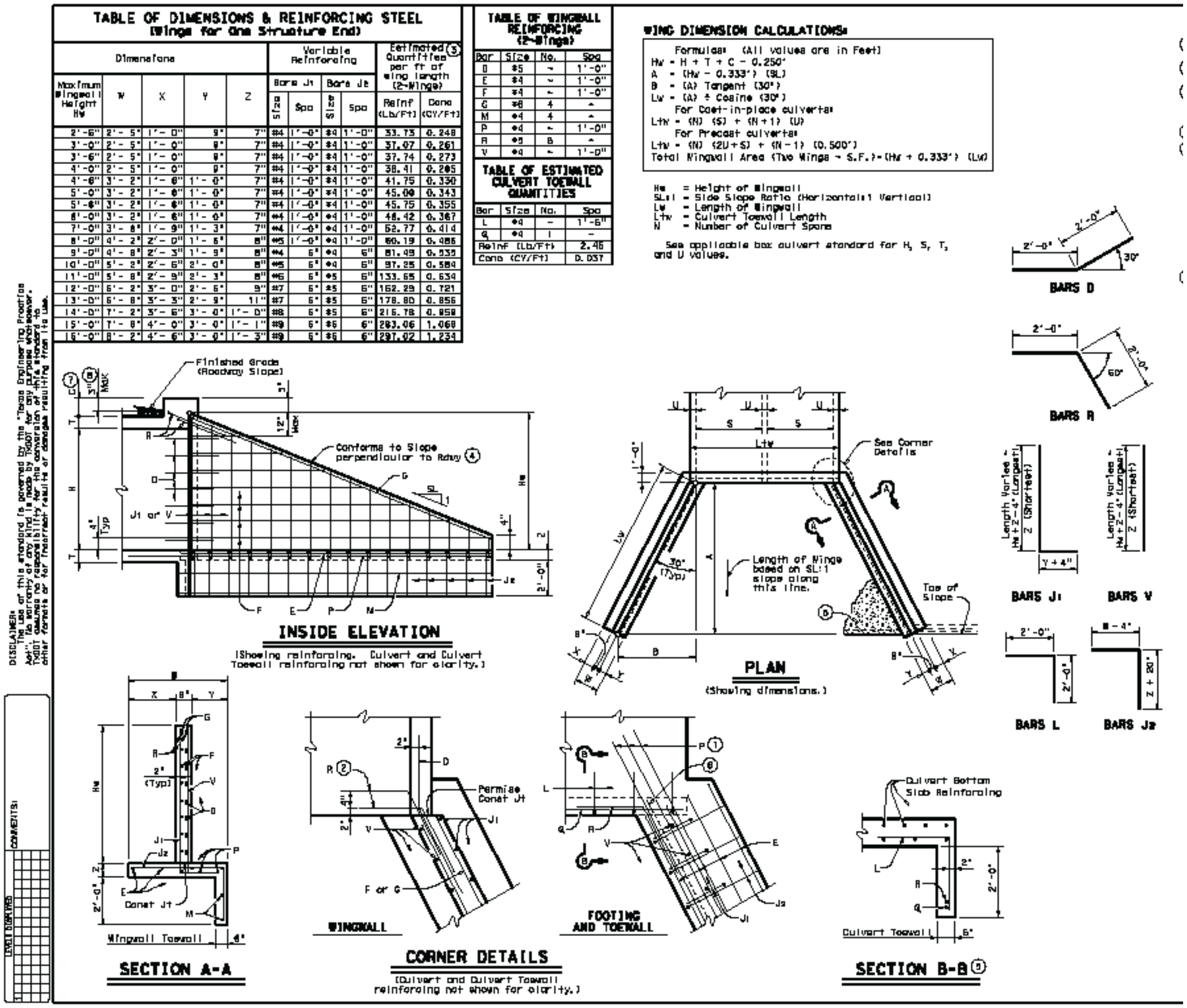


TABLE OF DIMENSIONS & REINFORCING STEEL
(Wings for One Structure End)

Dimensions					Variable Reinforcing				Estimated Quantities ⑤ per ft of wing length (2-Wings)	
					Bars J1		Bars J2			
Maximum Wingwall Height Hw	W	X	Y	Z	Size	Spa	Size	Spa	Reinf (Lb/Ft)	Conc (CY/Ft)
2'-6"	2'- 5"	1'- 0"	9"	7"	#4	1'-0"	#4	1'-0"	33.73	0.248
3'-0"	2'- 5"	1'- 0"	9"	7"	#4	1'-0"	#4	1'-0"	37.07	0.261
3'-6"	2'- 5"	1'- 0"	9"	7"	#4	1'-0"	#4	1'-0"	37.74	0.273
4'-0"	2'- 5"	1'- 0"	9"	7"	#4	1'-0"	#4	1'-0"	38.41	0.285
4'-6"	3'- 2"	1'- 6"	1'- 0"	7"	#4	1'-0"	#4	1'-0"	41.75	0.330
5'-0"	3'- 2"	1'- 6"	1'- 0"	7"	#4	1'-0"	#4	1'-0"	45.09	0.343
5'-6"	3'- 2"	1'- 6"	1'- 0"	7"	#4	1'-0"	#4	1'-0"	45.75	0.355
6'-0"	3'- 2"	1'- 6"	1'- 0"	7"	#4	1'-0"	#4	1'-0"	48.42	0.367
7'-0"	3'- 8"	1'- 9"	1'- 3"	7"	#4	1'-0"	#4	1'-0"	52.77	0.414
8'-0"	4'- 2"	2'- 0"	1'- 6"	8"	#5	1'-0"	#4	1'-0"	60.19	0.486
9'-0"	4'- 8"	2'- 3"	1'- 9"	8"	#4	6"	#4	6"	81.49	0.539
10'-0"	5'- 2"	2'- 6"	2'- 0"	8"	#5	6"	#4	6"	97.25	0.584
11'-0"	5'- 8"	2'- 9"	2'- 3"	8"	#6	6"	#5	6"	133.65	0.634
12'-0"	6'- 2"	3'- 0"	2'- 6"	9"	#7	6"	#5	6"	162.29	0.721
13'-0"	6'- 8"	3'- 3"	2'- 9"	11"	#7	6"	#5	6"	178.80	0.856
14'-0"	7'- 2"	3'- 6"	3'- 0"	1'- 0"	#8	6"	#5	6"	216.78	0.858
15'-0"	7'- 8"	4'- 0"	3'- 0"	1'- 1"	#9	6"	#6	6"	283.06	1.068
16'-0"	8'- 2"	4'- 6"	3'- 0"	1'- 3"	#9	6"	#6	6"	297.02	1.234

TABLE OF WINGWALL REINFORCING
(2-Wings)

Bar	Size	No.	Spa
D	#5	-	1'-0"
E	#4	-	1'-0"
F	#4	-	1'-0"
G	#8	4	-
M	#4	4	-
P	#4	-	1'-0"
R	#5	8	-
V	#4	-	1'-0"

TABLE OF ESTIMATED CULVERT TOEWALL QUANTITIES

Bar	Size	No.	Spa
L	#4	-	1'-6"
Q	#4	1	-
Reinf (Lb/Ft)			2.46
Conc (CY/Ft)			0.037

WING DIMENSION CALCULATIONS:

Formulas: (All values are in Feet)
Hw = H + T + C - 0.250'
A = (Hw - 0.333') (SL)
B = (A) Tangent (30°)
Lw = (A) ÷ Cosine (30°)
For Cast-in-place culverts:
Ltw = (N) (S) + (N + 1) (U)
For Precast culverts:
Ltw = (N) (2U + S) + (N - 1) (0.500')
Total Wingwall Area (Two Wings - S.F.) = (Hw + 0.333') (Lw)

Hw = Height of Wingwall
SL:1 = Side Slope Ratio (Horizontal:1 Vertical)
Lw = Length of Wingwall
Ltw = Culvert Toewall Length
N = Number of Culvert Spans

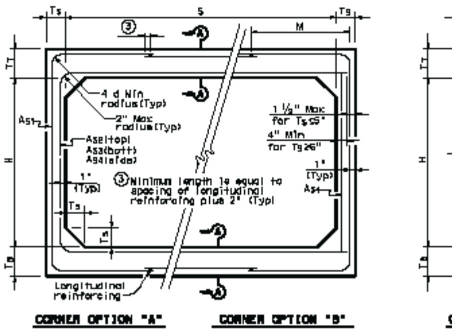
See applicable box culvert standard for H, S, T, and U values.

BOX DATA

SECTION DIMENSIONS					Fill Height	W (Min)	REINFORCING (in²/ft) ②								Lift Weight (Tons) ①
S (ft)	H (ft)	T_T (in)	T_B (in)	T_S (in)	(ft)	(in)	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	
10	5	10	10	10	<2	–	0.30	0.36	0.30	0.24	0.24	0.24	0.24	0.24	17.5
10	5	10	10	10	2<3	58	0.35	0.39	0.34	0.24	–	–	–	–	17.5
10	5	10	10	10	3-5	53	0.28	0.31	0.30	0.24	–	–	–	–	17.5
10	6	10	10	10	10	62	0.33	0.36	0.38	0.24	–	–	–	–	17.6
10	5	10	10	10	15	47	0.42	0.48	0.47	0.24	–	–	–	–	17.5
10	5	10	10	10	20	47	0.55	0.59	0.61	0.24	–	–	–	–	17.5
10	5	10	10	10	25	47	0.68	0.73	0.75	0.24	–	–	–	–	17.5
10	6	10	10	10	<2	–	0.28	0.38	0.33	0.24	0.24	0.24	0.24	0.24	18.6
10	6	10	10	10	2<3	58	0.32	0.42	0.37	0.24	–	–	–	–	18.5
10	6	10	10	10	3-5	52	0.26	0.34	0.33	0.24	–	–	–	–	18.5
10	6	10	10	10	10	52	0.30	0.38	0.39	0.24	–	–	–	–	18.5
10	6	10	10	10	15	47	0.39	0.49	0.51	0.24	–	–	–	–	18.5
10	6	10	10	10	20	47	0.50	0.63	0.65	0.24	–	–	–	–	18.5
10	6	10	10	10	25	47	0.61	0.78	0.80	0.24	–	–	–	–	18.5
10	7	10	10	10	<2	–	0.25	0.40	0.36	0.24	0.24	0.24	0.24	0.24	19.5
10	7	10	10	10	2<3	58	0.30	0.45	0.40	0.24	–	–	–	–	19.5
10	7	10	10	10	3-5	58	0.24	0.36	0.35	0.24	–	–	–	–	19.5
10	7	10	10	10	10	52	0.28	0.40	0.42	0.24	–	–	–	–	19.5
10	7	10	10	10	15	47	0.38	0.52	0.54	0.24	–	–	–	–	19.5
10	7	10	10	10	20	47	0.46	0.67	0.69	0.24	–	–	–	–	19.5
10	7	10	10	10	25	47	0.56	0.82	0.85	0.24	–	–	–	–	19.5
10	8	10	10	10	<2	–	0.24	0.41	0.38	0.24	0.24	0.24	0.24	0.24	20.5
10	8	10	10	10	2<3	64	0.27	0.47	0.43	0.24	–	–	–	–	20.5
10	8	10	10	10	3-5	58	0.24	0.38	0.38	0.24	–	–	–	–	20.5
10	8	10	10	10	10	52	0.26	0.42	0.44	0.24	–	–	–	–	20.5
10	8	10	10	10	15	47	0.34	0.54	0.57	0.24	–	–	–	–	20.5
10	8	10	10	10	20	47	0.43	0.69	0.72	0.24	–	–	–	–	20.5
10	9	10	10	10	<2	–	0.24	0.42	0.41	0.24	0.24	0.24	0.24	0.24	21.5
10	9	10	10	10	2<3	70	0.26	0.50	0.46	0.24	–	–	–	–	21.5
10	9	10	10	10	3-5	64	0.24	0.40	0.40	0.24	–	–	–	–	21.5
10	9	10	10	10	10	58	0.25	0.43	0.46	0.24	–	–	–	–	21.5
10	9	10	10	10	15	52	0.32	0.56	0.59	0.24	–	–	–	–	21.5
10	9	10	10	10	20	47	0.40	0.71	0.75	0.24	–	–	–	–	21.5
10	10	10	10	10	<2	–	0.24	0.44	0.44	0.24	0.24	0.24	0.24	0.24	22.5
10	10	10	10	10	2<3	79	0.25	0.52	0.48	0.24	–	–	–	–	22.5
10	10	10	10	10	3-5	70	0.24	0.42	0.43	0.24	–	–	–	–	22.5
10	10	10	10	10	10	64	0.24	0.44	0.48	0.24	–	–	–	–	22.5
10	10	10	10	10	15	52	0.30	0.57	0.61	0.24	–	–	–	–	22.5
10	10	10	10	10	20	52	0.38	0.73	0.77	0.24	–	–	–	–	22.5

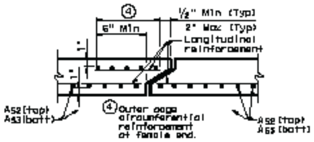
① For Box Length = 8'-0"

② A_{s1} thru A_{s4}, A_{s7} and A_{s8} are minimum required areas of reinforcement per linear foot of box length. A_{s6} and A_{s5} are minimum required areas of reinforcement per linear foot of box width.



③ Minimum length is equal to spacing of longitudinal reinforcing plus 2" (Typ)

FILL HEIGHT 2 FT AND GREATER



④ Outer cage circumferential reinforcement at female end.

SECTION A-A

(TOP AND BOTTOM SLAB JOINT REINFORCEMENT)

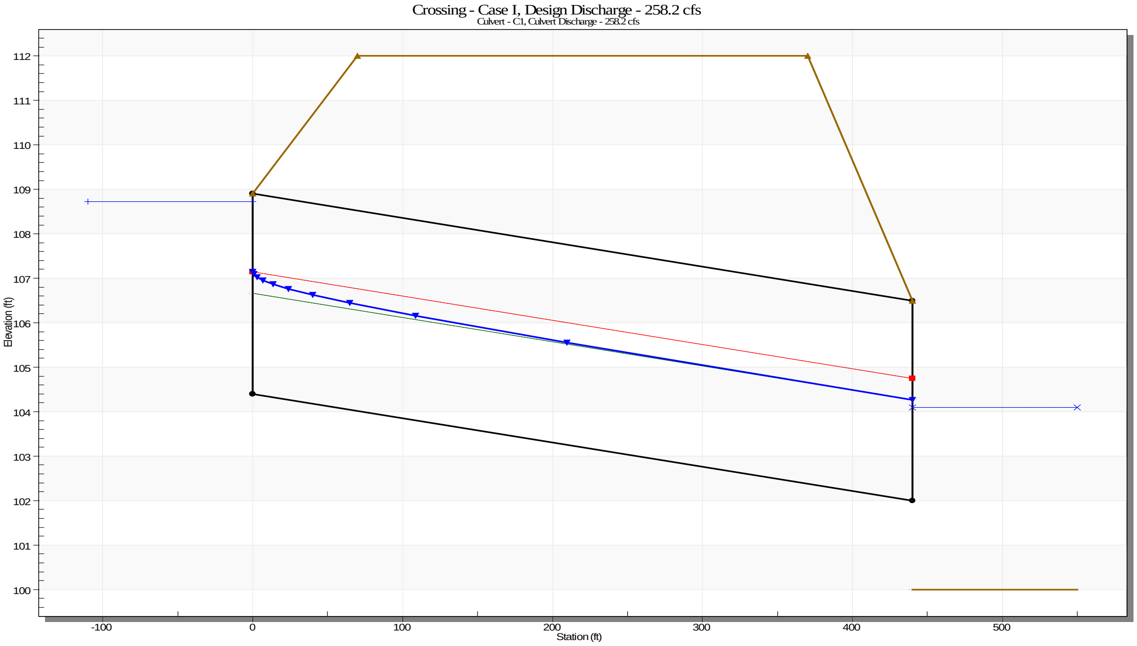


Figure 2E-3. HY-8 Modeling Output for Culvert C1 (Case I)

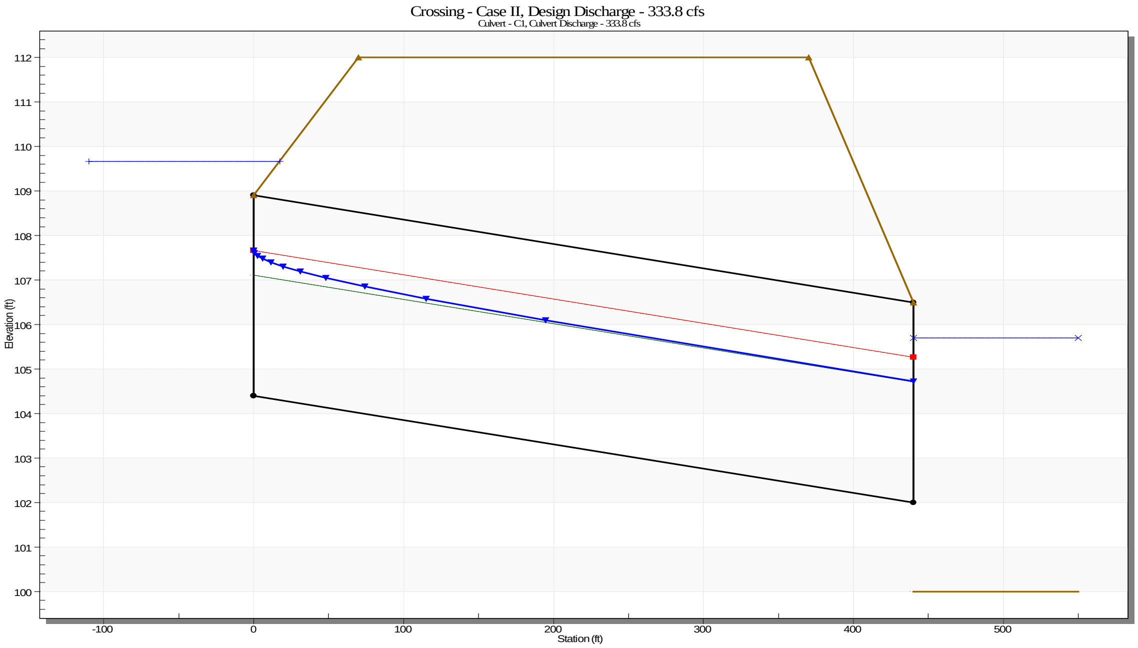


Figure 2E-4. HY-8 Modeling Output for Culvert C1 (Case II)

Appendix 2E-1

Perimeter Channel and Culvert Calculations

Design/Check: Trapezoidal/Triangular Channel

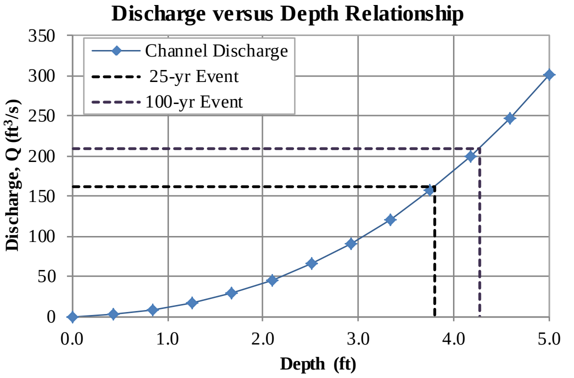
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Reach, R1 (North Perimeter Drainage Channel)**

Peak Discharge, Q_{max}= 160.80 cfs (25-yr Event)
Peak Discharge, Q_{max}= 209.20 cfs (100-yr Event)
Bottom Width, B = 6.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

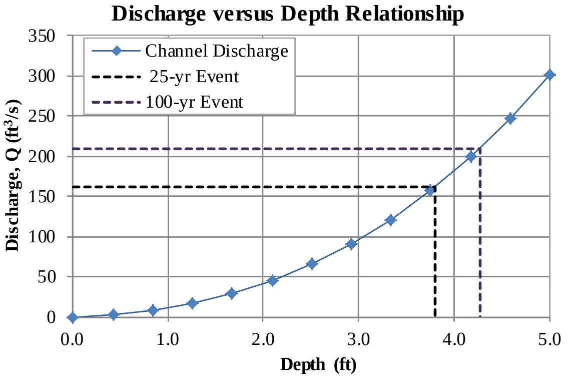
Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.06	6.06	0.01	0.07	0.0	0.00	
0.43	3.10	8.69	0.36	0.73	2.2	0.03	
0.84	7.18	11.32	0.63	1.06	7.6	0.06	
1.26	12.29	13.95	0.88	1.33	16.3	0.08	
1.67	18.44	16.58	1.11	1.55	28.6	0.10	
2.09	25.63	19.21	1.33	1.75	44.8	0.12	
2.51	33.86	21.84	1.55	1.93	65.4	0.15	
2.92	43.12	24.47	1.76	2.10	90.8	0.16	
3.34	53.42	27.10	1.97	2.27	121.2	0.18	
3.75	64.76	29.73	2.18	2.42	157.0	0.20	
4.17	77.14	32.36	2.38	2.57	198.6	0.22	
4.58	90.55	34.99	2.59	2.72	246.3	0.24	
5.00	105.00	37.62	2.79	2.86	300.4	0.26	
3.79	65.91	29.99	2.20	2.44	160.80	0.21	Q (25-yr Event)
4.27	80.18	32.98	2.43	2.61	209.20	0.23	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel
Methodology: Manning's Equation
Project: Fairbanks Landfill Expansion
Ditch ID: **Reach, R2 (North Perimeter Drainage Channel)**

Peak Discharge, Q_{max}= 160.80 cfs (25-yr Event)
Peak Discharge, Q_{max}= 209.20 cfs (100-yr Event)
Bottom Width, B = 6.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

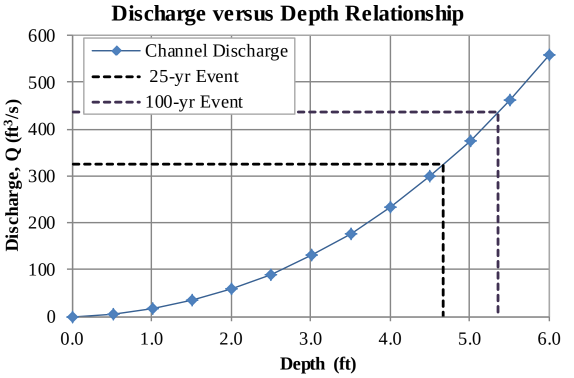
Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.06	6.06	0.01	0.07	0.0	0.00	
0.43	3.10	8.69	0.36	0.73	2.2	0.03	
0.84	7.18	11.32	0.63	1.06	7.6	0.06	
1.26	12.29	13.95	0.88	1.33	16.3	0.08	
1.67	18.44	16.58	1.11	1.55	28.6	0.10	
2.09	25.63	19.21	1.33	1.75	44.8	0.12	
2.51	33.86	21.84	1.55	1.93	65.4	0.15	
2.92	43.12	24.47	1.76	2.10	90.8	0.16	
3.34	53.42	27.10	1.97	2.27	121.2	0.18	
3.75	64.76	29.73	2.18	2.42	157.0	0.20	
4.17	77.14	32.36	2.38	2.57	198.6	0.22	
4.58	90.55	34.99	2.59	2.72	246.3	0.24	
5.00	105.00	37.62	2.79	2.86	300.4	0.26	
3.79	65.91	29.99	2.20	2.44	160.80	0.21	Q (25-yr Event)
4.27	80.18	32.98	2.43	2.61	209.20	0.23	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel
Methodology: Manning's Equation
Project: Fairbanks Landfill Expansion
Ditch ID: **Reach, R3 (North Perimeter Drainage Channel)**

Peak Discharge, Q_{max}=	323.90	cfs (25-yr Event)
Peak Discharge, Q_{max}=	436.30	cfs (100-yr Event)
Bottom Width, B =	10.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	3.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.040	
Longitudinal Channel Slope, S_o =	0.0015	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.10	10.06	0.01	0.07	0.0	0.00	
0.51	5.87	13.22	0.44	0.84	4.9	0.04	
1.01	13.13	16.38	0.80	1.25	16.4	0.08	
1.51	21.89	19.53	1.12	1.56	34.1	0.10	
2.01	32.15	22.69	1.42	1.82	58.5	0.13	
2.51	43.90	25.85	1.70	2.05	90.2	0.16	
3.01	57.14	29.01	1.97	2.27	129.6	0.18	
3.50	71.88	32.16	2.23	2.47	177.3	0.21	
4.00	88.11	35.32	2.49	2.65	233.9	0.23	
4.50	105.84	38.48	2.75	2.83	299.9	0.26	
5.00	125.07	41.63	3.00	3.00	375.8	0.28	
5.50	145.79	44.79	3.25	3.17	462.1	0.30	
6.00	168.00	47.95	3.50	3.33	559.4	0.33	
4.67	112.04	39.52	2.83	2.89	323.90	0.27	Q (25-yr Event)
5.36	139.70	43.89	3.18	3.12	436.30	0.30	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

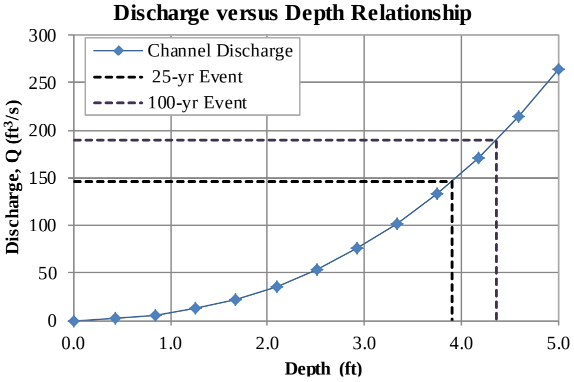
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Reach, R4 (West Perimeter Drainage Channel)**

Peak Discharge, Q_{max}= 146.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 190.00 cfs (100-yr Event)
Bottom Width, B = 4.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.04	4.06	0.01	0.07	0.0	0.00	
0.43	2.25	6.69	0.34	0.70	1.6	0.04	
0.84	5.49	9.32	0.59	1.01	5.6	0.08	
1.26	9.77	11.95	0.82	1.26	12.3	0.12	
1.67	15.09	14.58	1.03	1.48	22.3	0.16	
2.09	21.45	17.21	1.25	1.67	35.8	0.20	
2.51	28.85	19.84	1.45	1.85	53.4	0.23	
2.92	37.28	22.47	1.66	2.02	75.4	0.27	
3.34	46.75	25.10	1.86	2.18	102.1	0.31	
3.75	57.25	27.73	2.06	2.34	134.0	0.35	
4.17	68.80	30.36	2.27	2.49	171.3	0.39	
4.58	81.38	32.99	2.47	2.63	214.4	0.43	
5.00	95.00	35.62	2.67	2.78	263.7	0.47	
3.90	61.22	28.66	2.14	2.39	146.50	0.20	Q (25-yr Event)
4.36	74.35	31.55	2.36	2.56	190.00	0.22	Q (100-yr Event)



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

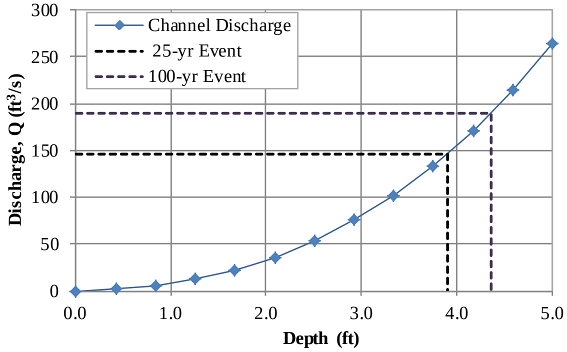
Project: Fairbanks Landfill Expansion

Ditch ID: **Reach, R5 (West Perimeter Drainage Channel)**

Peak Discharge, Q_{max}= 146.50 cfs (25-yr Event)
Peak Discharge, Q_{max}= 190.00 cfs (100-yr Event)
Bottom Width, B = 4.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.04	4.06	0.01	0.07	0.0	0.00	
0.43	2.25	6.69	0.34	0.70	1.6	0.03	
0.84	5.49	9.32	0.59	1.01	5.6	0.06	
1.26	9.77	11.95	0.82	1.26	12.3	0.08	
1.67	15.09	14.58	1.03	1.48	22.3	0.10	
2.09	21.45	17.21	1.25	1.67	35.8	0.12	
2.51	28.85	19.84	1.45	1.85	53.4	0.14	
2.92	37.28	22.47	1.66	2.02	75.4	0.16	
3.34	46.75	25.10	1.86	2.18	102.1	0.17	
3.75	57.25	27.73	2.06	2.34	134.0	0.19	
4.17	68.80	30.36	2.27	2.49	171.3	0.21	
4.58	81.38	32.99	2.47	2.63	214.4	0.23	
5.00	95.00	35.62	2.67	2.78	263.7	0.25	
3.90	61.22	28.66	2.14	2.39	146.50	0.20	Q (25-yr Event)
4.36	74.35	31.55	2.36	2.56	190.00	0.22	Q (100-yr Event)

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

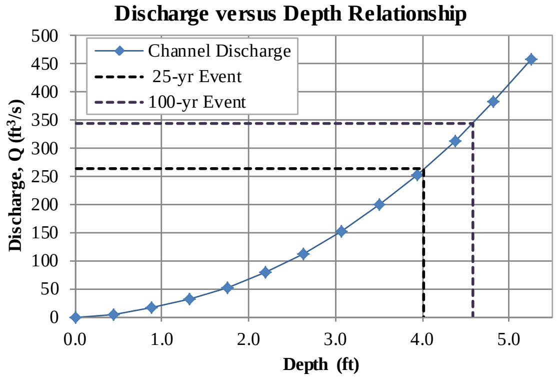
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Reach, R6 (West Perimeter Drainage Channel)**

Peak Discharge, Q_{max}= 262.90 cfs (25-yr Event)
Peak Discharge, Q_{max}= 343.90 cfs (100-yr Event)
Bottom Width, B = 12.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.12	12.06	0.01	0.07	0.0	0.00	
0.45	5.96	14.82	0.40	0.79	4.7	0.04	
0.88	12.94	17.59	0.74	1.18	15.2	0.07	
1.32	21.07	20.35	1.04	1.48	31.1	0.10	
1.76	30.34	23.11	1.31	1.73	52.5	0.12	
2.19	40.75	25.87	1.58	1.95	79.6	0.15	
2.63	52.31	28.63	1.83	2.16	112.8	0.17	
3.07	65.01	31.40	2.07	2.34	152.4	0.19	
3.50	78.86	34.16	2.31	2.52	198.8	0.22	
3.94	93.85	36.92	2.54	2.69	252.3	0.24	
4.38	109.99	39.68	2.77	2.85	313.2	0.26	
4.81	127.26	42.44	3.00	3.00	381.9	0.28	
5.25	145.69	45.20	3.22	3.15	458.8	0.30	
4.02	96.73	37.43	2.58	2.72	262.90	0.24	Q (25-yr Event)
4.58	117.81	40.95	2.88	2.92	343.90	0.27	Q (100-yr Event)



ATTACHMENT 2F

ON-SITE DESIGN-ACTIVE FACE SURFACE WATER CONTROLS

ON-SITE DESIGN – ACTIVE FACE SURFACE WATER CONTROLS FAIRBANKS LANDFILL EXPANSION

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

8/26/2013

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 18

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the analysis for the sizing of the diversion and containment berms to be utilized at the active face (i.e., areas of exposed waste) during development of the Fairbanks Landfill (Figure 2F-1). The diversion and containment berms will be utilized to keep clean surface water separate from potentially contaminated water, to minimize the generation of contaminated water, and to prevent runoff/discharge of contaminated water.

Diversion berms are temporary soil berms constructed up-gradient from the active working face, to intercept flow before it comes in contact with waste. These temporary diversion berms will be used to route the clean runoff around active areas into the surface water management system and away from the active face. Meanwhile, temporary containment berms (down-gradient from, and generally at the base of the active working face), constructed with soil, will be used to contain contaminated water and prevent the migration of contaminated water from the active face. The specific objectives of the analysis include (i) calculating the maximum up-gradient drainage area which can be managed by each diversion berm for the 25-year, 24-hour rainfall event; and (ii) calculating the required height of each containment berm to contain the contaminated runoff resulting from the 25-year, 24-hour rainfall event.

2 ASSUMPTIONS AND PROCEDURES

The following sections discuss the assumptions and procedures for the design of the temporary diversion berms and temporary containment berms.

2.1 Diversion Berm

It is assumed that temporary diversion berms will be installed with flow line (longitudinal) slope ranging from 0.5% to 2%. Temporary diversion berms will be placed up-gradient from the active working face. The temporary diversion berms are assumed to be "tack-on" berms (see Figure 2F-1 of this calculation package) to form a v-shaped channel. A channel depth of 2.5 feet was assumed (i.e., this is a fixed parameter of these calculations). The Rational Method described in the *Hydraulic Design Manual* (TxDOT, 2009) is used to calculate the peak surface water discharge (since the drainage area will be less than 200 acres). A given diversion berm is anticipated to temporarily manage drainage areas of less than 20 acres and designed accordingly as presented herein. The channels were sized assuming they are flowing full, since they are interior and temporary site features. The following steps were utilized to calculate the drainage areas that each diversion berm can accommodate.

1. Compute the discharge capacity of diversion berms with 0.5%, 1%, 1.5%, and 2% slopes using Manning's Equation for open channel flow.

2. Apply the Rational Method to compute the up-gradient drainage area that would produce the discharge capacity calculated in Step 1.

Manning's equation was used to estimate the peak discharge capacity of the v-shaped channel created by a temporary diversion berm. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \tag{1}$$

where:

Q = discharge (cubic feet per second [cfs]),

n = Manning's roughness coefficient,

A = area of cross-section of flow (square feet [ft^2]),

P = wetted perimeter (ft),

R = hydraulic radius = A/P (ft), and

S = longitudinal slope (ft/ft).

The peak discharge from the contributing drainage area by the Rational Method can be computed by:

$$Q = C \times I \times A \tag{2}$$

where:

Q = peak design discharge (cfs),
C = runoff coefficient (dimensionless),
I = design rainfall intensity (inches per hour [in/hr]), and
A = drainage area (acres).

The design rainfall intensity in Equation (2) is calculated by:

$$I = \frac{b}{(t_c + d)^e} \tag{3}$$

where:

I = design rainfall intensity (in/hr),
t_c = time of concentration (minutes [min]), and
b, d, e = coefficients for specific frequencies listed by Texas county.

Equation (2) is rearranged, and the watershed drainage area was back-calculated for each potential flow line slope of a temporary diversion berm. Calculations for each flow line slope are presented in Appendix 2F-1.

2.2 Containment Berm

It is assumed that temporary containment berms will be constructed with 3H:1V side slopes and will be constructed to varying heights, depending on the geometry of the working face, storage area, and resulting calculated volume of contaminated water to be stored. These containment berms are designed to have one foot (1-ft) of freeboard The required height of the containment berms is calculated for drainage areas ranging from 0.5

to 4.0 acres (to encompass a range of potential active area sizes in and around the working face itself) and contaminated water storage areas ranging from 0.1 to 1.0 acres. The following steps were utilized to calculate the height required for each of the containment berm scenarios.

1. Calculate the 25-year, 24-hour rainfall volume to be captured behind the containment berm.

2. Calculate the height of the containment berm required to hold the volume of water calculated in Step 1, and then add 1-ft of freeboard to calculate the resulting total berm height (i.e., the required minimum berm height).

The total required storage volume of surface water is calculated by:

$$V = A_D \times R \qquad (4)$$

where:

V = total storage volume (ft^3),

A_D = drainage area (ft^2), and

R = 25-year, 24-hour rainfall depth (ft).

For these calculations, 100% of the precipitation over the drainage area is considered surface water runoff that requires containment (i.e., no infiltration). This is a conservative assumption for sizing of these berms, because it is likely that some infiltration will in fact occur.

The required height for each of the containment berm scenarios is computed by Equation (5):

$$H = V/A_S + 1.0 \text{ ft freeboard} \qquad (5)$$

where:

V = total storage volume (ft^3),

H = total height of containment berm (ft), and

A_S = storage area (ft^2).

Calculations for each scenario are presented in Appendix 2F-2.

3 DESIGN PARAMETERS

The following sections discuss the justification behind the selected design parameters for the temporary diversion berms and temporary containment berms.

3.1 Diversion Berm

The Manning's Roughness Coefficient (n) for the diversion berm was selected as 0.04 (HCFCD, 2010). The peak discharge flowing to the channel is calculated using the Rational Method. The runoff coefficient (C) was selected as 0.7, as these berms will be placed on relatively steeper slopes (TxDOT, 2009). For a conservative design approach, a minimum time of concentration of 10 minutes was used to calculate the rainfall intensity by Equation (3). TxDOT (2009) recommends 10 minutes for the minimum time of concentration because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The coefficients b, d, and e in Equation (3) were selected as 81, 7.7, 0.724, respectively, for a 25-year rainfall event in Harris County (TxDOT, 2009). The rainfall intensity was then calculated as follows:

$$I = \frac{b}{(t_c + d)^e} = \frac{81}{(10 + 7.7)^{0.724}} = 10.1\ in/hr$$

3.2 Containment Berm

The temporary containment berms were sized by calculating the rainfall depth during the 25-year, 24-hour rainfall event. The Harris County Flood Control District (HCFCD) provides rainfall frequency and duration depths for the Harris County Hydrologic Regions. Table 2B-1 in Attachment 2B, to the Site Development Plan, provides a summary of the rainfall depths for various durations and return periods for Harris County Hydrologic Region 2. Based on this table, the 25-year, 24-hour rainfall depth of 9.6 inches (0.80 ft) was selected to represent the Fairbanks Landfill site in Harris County.

4 RESULTS

The results of the temporary diversion berms calculation are summarized in Table 2F-1 for each assumed flow line slope. The drainage areas calculated represent the maximum drainage area that each temporary diversion berm configuration can accommodate for the 25-year, 24-hour design rainfall event. It should be noted that multiple diversion berms may be constructed if, during operations, a larger area than those calculated in Table 2F-1 will be draining towards the active face, in order to comply with the drainage area requirements presented herein for the given berm height and the selected flow line slope.

The results of the temporary containment berms calculation are summarized in Table 2F-2. It is noted that the results presented in Table 2F-2 cover various combinations of drainage areas and contaminated water storage areas, to allow for flexibility of site operations. The facility will use this information to select the required berm height based on the corresponding dimensions of the drainage area and containment area.

5 REFERENCES

Chow, V.T. (1959), *Open Channel-Hydraulics*, McGraw-Hill.

HCFCD (2009). *Hydrology and Hydraulics Guidance Manual*. Harris County Flood Control District, December 2009.

HCFCD (2010). *Policy, Criteria, and Procedure Manual*. Harris County Flood Control District, December 2010.

TxDOT (2009). *Hydraulic Design Manual*, Texas Department of Transportation, revised March 2009.

TABLES

- Table 2F-1. Diversion Berm Drainage Area Sizing
- Table 2F-2. Containment Berm Heights for Various Drainage and Storage Areas

Table 2F-1. Diversion Berm Drainage Area Sizing

Depth of Channel (ft)	Diversion Berm Flow Line Slope (%)	Maximum Drainage Area (AC)	Maximum Predicted Flow Velocity (ft/s)
2.5	0.5	9.2	3.0
	1.0	13.0	4.2
	1.5	16.0	5.2
	2.0	18.4	6.0

Note:

1. The Drainage Area, as calculated by the Rational Method, assumes that the channel created by the temporary diversion berm is temporarily full when conveying the peak discharge during the 25-year rainfall event.

Table 2F-2. Containment Berm Heights for Various Drainage and Storage Areas

Containment Berm Drainage Area	Contaminated Water Storage Area	Minimum Required Berm Height
(AC)	(AC)	(ft)
0.50	0.10	5.0
	0.25	2.6
	0.50	1.8
1.0	0.10	9.0
	0.25	4.2
	0.50	2.6
1.5	0.25	5.8
	0.50	3.4
	0.75	2.6
2.0	0.25	7.4
	0.50	4.2
	0.75	3.1
3.0	0.40	7.0
	0.75	4.2
	1.00	3.4
4.0	0.50	7.4
	0.75	5.3
	1.00	4.2

Notes:

1. The calculated required berm height includes 1-ft of freeboard for the containment berm.
2. Table 2F-2 is intended as a guide for the landfill operator, as during operation, the active working face location will change as filling progresses, and new containment berms will be constructed accordingly.

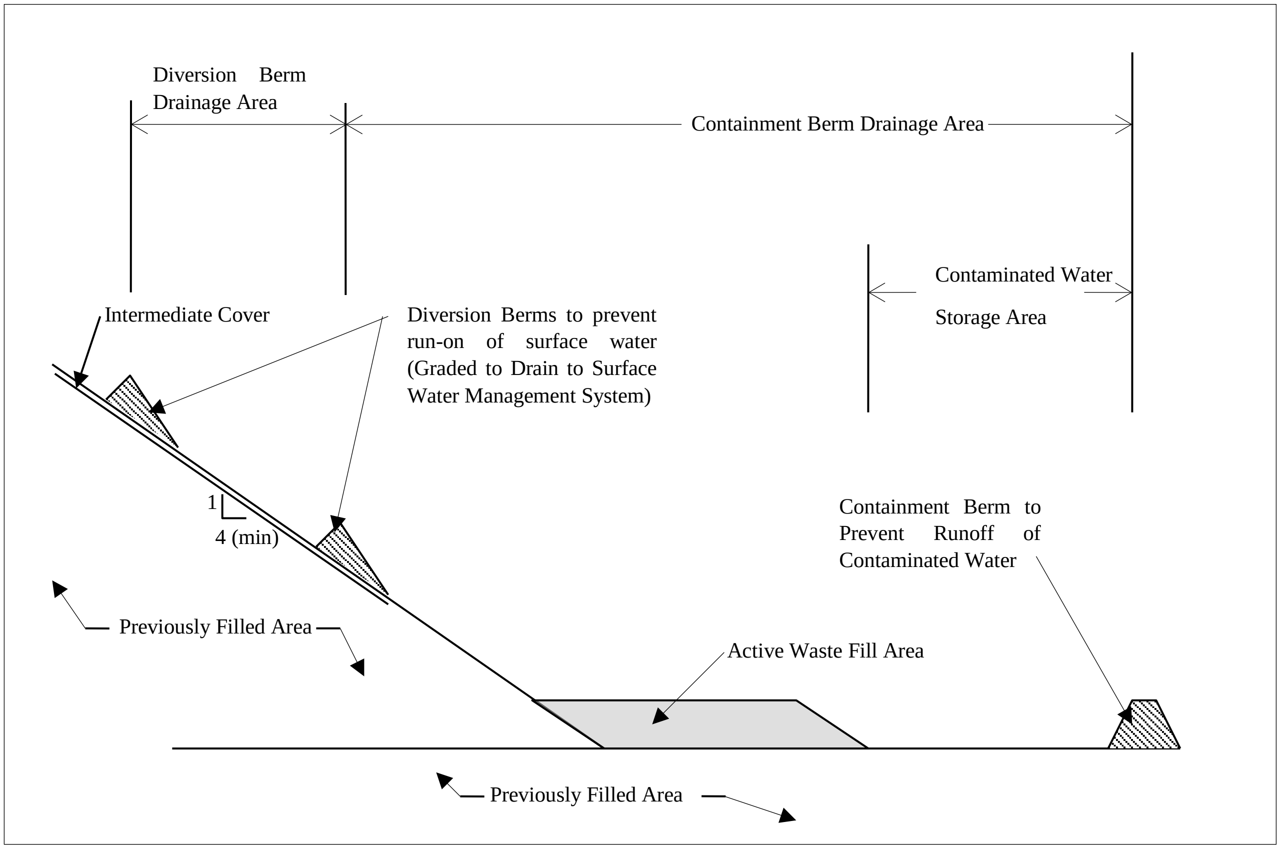
Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

FIGURES

- Figure 2F-1. Typical/Schematic of Active Fill **Area Section**

Figure 2F-1. Typical/Schematic of Active Fill Area Section



Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

APPENDIX 2F-1

DIVERSION BERM CALCULATIONS

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Diversion Berm, 0.5% Flow Line Slope**

Peak Discharge, Q_{max} = - cfs

Bottom Width, B = 0.00 ft

Left Side Slope, Z_1 = 3.00 horizontal :1 vertical

Right Side Slope, Z_2 = 4.00 horizontal :1 vertical

Manning's Roughness Coeff., n = 0.040

Longitudinal Channel Slope, S_o = 0.0050 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.07	0.0	0.00	
0.22	0.17	1.58	0.10	0.58	0.1	0.03	
0.43	0.63	3.10	0.20	0.91	0.6	0.06	
0.63	1.40	4.61	0.30	1.19	1.7	0.09	
0.84	2.47	6.12	0.40	1.44	3.6	0.13	
1.05	3.84	7.63	0.50	1.67	6.4	0.16	
1.26	5.51	9.14	0.60	1.88	10.4	0.19	
1.46	7.49	10.65	0.70	2.08	15.6	0.22	
1.67	9.76	12.17	0.80	2.27	22.2	0.25	
1.88	12.34	13.68	0.90	2.46	30.3	0.28	
2.09	15.22	15.19	1.00	2.64	40.1	0.31	
2.29	18.39	16.70	1.10	2.81	51.7	0.34	
2.50	21.88	18.21	1.20	2.98	65.1	0.37	
2.50	21.88	18.21	1.20	2.98	65.11	0.37	DESIGN Q

Area Sizing

Q = CiA cfs

C = 0.7

I = 10.10 in/hr

Q = 65.11 cfs

Therefore, A = 9.2 Acres

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Diversion Berm, 1% Flow Line Slope**

Peak Discharge, Q_{max}= - cfs

Bottom Width, B = 0.00 ft

Left Side Slope, Z_1 = 3.00 horizontal :1 vertical

Right Side Slope, Z_2 = 4.00 horizontal :1 vertical

Manning's Roughness Coeff., n = 0.040

Longitudinal Channel Slope, S_o = 0.0100 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.11	0.0	0.00	
0.22	0.17	1.58	0.10	0.83	0.1	0.07	
0.43	0.63	3.10	0.20	1.29	0.8	0.13	
0.63	1.40	4.61	0.30	1.68	2.4	0.19	
0.84	2.47	6.12	0.40	2.03	5.0	0.25	
1.05	3.84	7.63	0.50	2.36	9.0	0.31	
1.26	5.51	9.14	0.60	2.66	14.7	0.38	
1.46	7.49	10.65	0.70	2.94	22.0	0.44	
1.67	9.76	12.17	0.80	3.22	31.4	0.50	
1.88	12.34	13.68	0.90	3.48	42.9	0.56	
2.09	15.22	15.19	1.00	3.73	56.7	0.63	
2.29	18.39	16.70	1.10	3.97	73.1	0.69	
2.50	21.88	18.21	1.20	4.21	92.1	0.75	
2.50	21.88	18.21	1.20	4.21	92.07	0.75	DESIGN Q

Area Sizing

Q = CiA cfs

C = 0.7

I = 10.10 in/hr

Q = 92.07 cfs

Therefore, A = 13.0 Acres

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Diversion Berm, 1.5% Flow Line Slope**

Peak Discharge, Q_{max} = - cfs
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 4.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0150 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.13	0.0	0.00	
0.22	0.17	1.58	0.10	1.01	0.2	0.10	
0.43	0.63	3.10	0.20	1.58	1.0	0.19	
0.63	1.40	4.61	0.30	2.06	2.9	0.28	
0.84	2.47	6.12	0.40	2.49	6.2	0.38	
1.05	3.84	7.63	0.50	2.89	11.1	0.47	
1.26	5.51	9.14	0.60	3.26	17.9	0.56	
1.46	7.49	10.65	0.70	3.61	27.0	0.66	
1.67	9.76	12.17	0.80	3.94	38.4	0.75	
1.88	12.34	13.68	0.90	4.26	52.5	0.84	
2.09	15.22	15.19	1.00	4.57	69.5	0.94	
2.29	18.39	16.70	1.10	4.87	89.5	1.03	
2.50	21.88	18.21	1.20	5.16	112.8	1.12	
2.50	21.88	18.21	1.20	5.16	112.77	1.12	DESIGN Q

Area Sizing

Q = CiA cfs
C = 0.7
I = 10.10 in/hr
Q = 112.77 cfs
Therefore, A = 16.0 Acres

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Diversion Berm, 2% Flow Line Slope**

Peak Discharge, Q_{max}= - cfs

Bottom Width, B = 0.00 ft

Left Side Slope, Z_1 = 3.00 horizontal :1 vertical

Right Side Slope, Z_2 = 4.00 horizontal :1 vertical

Manning's Roughness Coeff., n = 0.040

Longitudinal Channel Slope, S_o = 0.0200 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.15	0.0	0.01	
0.22	0.17	1.58	0.10	1.17	0.2	0.13	
0.43	0.63	3.10	0.20	1.83	1.2	0.25	
0.63	1.40	4.61	0.30	2.38	3.3	0.38	
0.84	2.47	6.12	0.40	2.88	7.1	0.50	
1.05	3.84	7.63	0.50	3.33	12.8	0.63	
1.26	5.51	9.14	0.60	3.76	20.7	0.75	
1.46	7.49	10.65	0.70	4.16	31.2	0.88	
1.67	9.76	12.17	0.80	4.55	44.4	1.00	
1.88	12.34	13.68	0.90	4.92	60.7	1.13	
2.09	15.22	15.19	1.00	5.27	80.2	1.25	
2.29	18.39	16.70	1.10	5.62	103.3	1.37	
2.50	21.88	18.21	1.20	5.95	130.2	1.50	
2.50	21.88	18.21	1.20	5.95	130.21	1.50	DESIGN Q

Area Sizing

Q = CiA cfs

C = 0.7

I = 10.10 in/hr

Q = 130.21 cfs

Therefore, A = 18.4 Acres

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

APPENDIX 2F-2

CONTAINMENT BERM CALCULATIONS

Written by: **J. McNash** Date: **11/5/2012** Reviewed by: **S. Graves** Date: **12/4/2012**

Client: **USAWTXL** Project: **Fairbanks Landfill Expansion** Project No.: **TXL0263** Phase No.: **05**

FAIRBANKS LANDFILL EXPANSION
CONTAINMENT BERM SIZING CALCULATIONS

25-yr / 24-hr rainfall depth =	9.6	in
Required Freeboard =	1	ft

Drainage Area, A_D (AC)	Storage Volume, A_s (CF)	Storage Area (AC)	Minimum Required Berm Height (FT)
0.50	17,424	0.10	5.0
		0.25	2.6
		0.50	1.8
1.00	34,848	0.10	9.0
		0.25	4.2
		0.50	2.6
1.50	52,272	0.25	5.8
		0.50	3.4
		0.75	2.6
2.00	69,696	0.25	7.4
		0.50	4.2
		0.75	3.1
3.00	104,544	0.40	7.0
		0.75	4.2
		1.00	3.4
4.00	139,392	0.50	7.4
		0.75	5.3
		1.00	4.2

ATTACHMENT 2G

HCFCD DETERMINATION -

NO ADVERSE IMPACTS TO OFF-SITE WATERSHED

RECEIVED JAN 0 2

HARRIS COUNTY

Public Infrastructure Department
Architecture & Engineering Division

10555 Northwest Frwy., Suite 120
Houston, Texas 77092
(713) 956-3000

December 19, 2012

Mr. Eric Lisenbe, P.E.
Jones & Carter, Inc.
6335 Gulfton Drive, Suite 100
Houston, TX 77081

SUBJECT: Drainage & Detention Analysis for Fairbanks Landfill Expansion; Unit E125-00-00 (Rolling Fork Channel); Key Map 410F; Pct 4; Project No. 2022025

Dear Mr. Lisenbe:

Harris County and the Harris County Flood Control District (HCFCD) have reviewed the above referenced report. Details of our understanding of the design are given on the attached review memo.

The report includes statements that the project will cause no adverse impact to the receiving waterways in storm events up to and including the 100-year event. The documentation within the report generally supports the conclusions stated by the engineer. Based on the stated conclusions, HCFCD interposes no objection to the referenced report. Please note, this acceptance does not necessarily mean that the entire report, including supporting data and calculations, has been completely checked and verified. However, the report is signed, dated, and sealed by a Professional Engineer licensed to practice in the State of Texas, which therefore conveys the licensed engineer's responsibility and accountability.

If you have any questions or need any additional information, please do not hesitate to contact the reviewers.

Sincerely,

Joshua Stuckey, RS,CFM
Manager of Permits

JS/fr
Attachments

cc: Dan Mushen, HCPID
Cheryl Campbell, HCPID

MEMORANDUM

Harris County
Flood Control District

9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

DATE: December 18, 2012

TO: Josh Stuckey,
Manager, HCPID-AE (Permits)

FROM: Terry E. Woodfin, P.E. TEW
Watershed Management Department

RE: Project No. 2022025
Drainage & Detention Analysis for Fairbanks Landfill Expansion,
HCFCD Unit # E125-00-00 (Rolling Fork Channel),
Key Map Page 410 F, Pct 4

Objective

The submitted report has been reviewed pursuant to the HCFCD Policy, Criteria, and Procedure Manual and Section 3.02 of the "Regulations of Harris County, Texas for the Approval and Acceptance of Infrastructure." The goals of the review are to provide technical support to the Harris County Floodplain Administrator and to apply HCFCD policy and criteria where appropriate.

This review addresses issues regarding hydraulic and hydrologic drainage design criteria only. Design criteria regarding the site layout of the proposed development and drainage facilities will be reviewed upon submittal of site plans.

Submitted Report

Drainage & Detention Analysis for
Fairbanks Landfill Expansion
Rolling Fork Channel (HCFCD Unit E125-00-00)
Harris County, Texas
November 2012

Consulting Engineer

The Report was prepared by:

Jones & Carter, Inc.
6335 Gulton Drive, Suite 100
Houston, Texas 77081

Eric Lisenbe, P.E.
TX P.E. No. 107501

A Division of Harris County Public Infrastructure Department

Project Summary

The report describes drainage issues and detention mitigation for the expansion of the Fairbanks Landfill Site which is classified as Type IV Landfill by the TCEQ. The site is located in the White Oak Bayou watershed and detention outflow from the site drains into the Rolling Fork Channel E125-00-00. The existing site occupies an area of 118.1 acres and will add 72.4 acres for the proposed expansion. This analysis includes detention mitigation for the entire proposed 190.5 acre site. The results of the analysis show that the project site expansion with the proposed detention does not adversely impact existing flood hazard conditions for the 10% and 1% exceedance probability storm events in accordance with HCFCD criteria.

Floodplain Information

The report indicates that the project is located within a FEMA regulatory flood plain. The Harris County Public Infrastructure Department – Architecture & Engineering Division (Permits) is the Floodplain Administrator.

HCFCD Jurisdiction

The proposed site development is located in a watershed with a Regional Detention Program authorized by Commissioners Court. Therefore, HCFCD criteria will apply.

Report's Findings

The report states, "No adverse impact to 1%, 4%, and 10% exceedance probability flooding conditions on the Rolling Fork Channel (HCFCD Unit No. E125-00-00 and White Oak Bayou Watershed (HCFCD Unit No. E100-00-00) is expected from the proposed site expansion with the proposed detention. "

Hydrologic and Hydraulic Modeling Review

The Watershed Management Department offers the following:

The report includes statements that the project will cause no adverse impact to the receiving waterways in storm events up to and including the 100-year event. The documentation within the report generally supports the conclusions stated by the engineer. Based on the stated conclusions, HCFCD interposes no objection to the referenced report. Please note: This acceptance does not necessarily mean that the entire report, including all supporting data and calculations, has been completely checked and verified. However, the report is signed, dated, and sealed by a Professional Engineer licensed to practice in the State of Texas, which therefore, conveys the licensed engineer's responsibility and accountability.

Additional HCFCD Criteria

Site plans must be submitted to HCFCD for review and signature.

All work proposed within existing and future HCFCD right-of-way must be designed and constructed in accordance with the HCFCD Policy, Criteria, and Procedure Manual.

Additional HCFCD Criteria Continued

A geotechnical slope stability report must be submitted to HCFCD prior to plan approval for new or modified channels or detention basins intended to be maintained by HCFCD. Specific geotechnical criteria are presented in the HCFCD Policy, Criteria, and Procedure Manual.

Detention Summary

The following table summarizes the detention basin design parameters as indicated by the report:

Detention Basin Drainage Area = 190.5 Acres

Project Name: Fairbanks Landfill Expansion			
Detention Basin Drainage Area	190.5		
Detention Storage Rate (Minimum)	0.55 acre-feet per acre		
Minimum Detention Storage Required	104.8 acre-feet		
Detention Storage Provided	141.1 acre-feet		
Detention Storage Rate (Provided)	0.74 acre-feet/acre		
	10% (10-yr)	*4% (25-yr)*	*1% (100-yr)*
Design Water Surface Elevation (Based on SAM, INC. Site BM)$^{(1)}$	104.1 feet	104.9 feet	106.4 feet
Maximum Allowable Outflow (cfs)	158.0 cfs	195.6cfs	255.8 cfs
Maximum Outflow Provided (cfs)	82.4 cfs	109.9 cfs	147.1 cfs

Environmental Review & Permitting

The Harris County Flood Control District's Environmental Department requires that the U.S. Army Corps of Engineers be contacted to determine if a permit is required for any portions of this project located within any existing or proposed HCFCD right-of-way. The type of permit required (if any) must be stated on the site plans. Actual copies of approved Corps of Engineers permits necessary for work within HCFCD rights-of-way must be submitted with the HCFCD permit application and be given to the HCFCD Property Management Department at least 48 hours prior to construction.

TEW:HEH:tmw

cc: Carl Woodward, P.E., HCFCD
Alem Gebriel, P.E., Ph.D., HCFCD

Memo 12-18-12 Drainage & Detention Analysis for Fairbanks Landfill Expansion.doc

Prepared for:

USA Waste of Texas Landfills, Inc.

PERMIT AMENDMENT APPLICATION
PART III – SITE DEVELOPMENT PLAN
ATTACHMENT 2H

INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

FAIRBANKS LANDFILL
MSW PERMIT NO. 1565B
HOUSTON, HARRIS COUNTY, TEXAS

Prepared by:

Geosyntec consultants

Texas Board of Professional Engineers Firm Registration No. F-1182
3600 Bee Caves Road, Suite 101
Austin, Texas 78746
(512) 451-4003

8/26/2013

SCOTT M. GRAVES
86557

FOR PERMIT PURPOSES ONLY

August 2013

TABLE OF CONTENTS
INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

SCOTT M. GRAVES
86557
8/26/2013
FOR PERMIT PURPOSES ONLY

DRAWINGS

APPENDICES

1. INTRODUCTION

The purpose of this document is to provide a plan for controlling erosion and sediment on intermediate cover for the Fairbanks Landfill Expansion. Erosion control is necessary to maintain the integrity of the intermediate cover and to prevent off-site discharge of sediments. This Intermediate Cover Erosion and Sediment Control Plan (ICESCP) has been developed to address the requirements identified in Title 30 Texas Administrative Code (30 TAC) §330.305.

As required by 30 TAC §330.305(d), the Fairbanks Landfill Expansion has been designed to provide effective erosional stability to top deck surfaces and external side slopes during all phases of landfill operation, closure, and post-closure care. Top deck surfaces and external side slopes are:

- those above grade slopes that directly drain to the facility surface water management system (i.e., areas where the surface water directly flows to a perimeter channel or surface water pond);
- those slopes that have received intermediate or final cover; and
- those surfaces that have either reached their permitted elevation, or will subsequently remain inactive for longer than 180 days.

Slopes that drain to areas of ongoing waste placement, pre-excavated areas, areas that have received only weekly cover, or areas under construction which have not received waste are not considered external side slopes.

The top deck surfaces and external side slopes will be covered with weekly cover, intermediate cover, or final cover. The definitions of each of these cover systems and their respective erosion and sediment control practices are provided below.

1.1 Weekly Cover

Weekly cover is defined in 30 TAC §330.165(b) for Type IV landfills. Weekly cover consists of six inches of well-compacted earthen material (or approved alternative) not previously mixed with garbage, rubbish, or other solid waste. The rate of cover must be no less than weekly, unless the Texas Commission on Environmental Quality (TCEQ) Executive Director approves another schedule. The placement and erosion control practices for weekly cover areas are addressed in the Site Operating Plan (SOP).

1.2 Intermediate Cover

Intermediate cover is defined in 30 TAC §330.165(c). Intermediate cover consists of at least 12 inches of suitable earthen material and is graded and maintained to prevent erosion and ponding of water. All areas that have received waste but will be inactive for longer than 180 days will be provided with intermediate cover. Information regarding the erosion and sediment control practices for intermediate cover is provided in Section 3 of this ICESCP. Additional information regarding placement, maintenance, and repair of intermediate cover is located in Section 5 of this ICESCP and Section 24 of the SOP.

1.3 Final Cover

Final cover is defined in 30 TAC §330, Subchapter K. The final cover system for the Fairbanks Landfill is described in the Closure Plan located in Attachment 7 of the Site Development Plan (SDP). As areas of the landfill reach final grade, the final cover system and the permanent surface water management system will be installed, which includes vegetated top deck and side slopes, drainage terraces, and downchute channels. The long-term erosional stability of the final cover slopes is demonstrated using the Revised Universal Soil Loss Equation (RUSLE) and is presented in Attachment 3E of the SDP. Additionally, the erosional stability of the side slope drainage terraces, top deck drainage terraces, and downchutes is demonstrated based on calculated flow velocity and is presented in Attachment 2D, as well. Maintenance requirements for areas with final cover during operations and after closure are addressed, respectively, in Section 24 of the SOP and Section 3 of the Post-Closure Plan Attachment 8 of the SDP).

1.4 Landfill Perimeter Areas

The permanent surface water management system design includes features in the landfill perimeter areas outside the footprint of the disposal area. Runoff will be conveyed from the landfill to perimeter drainage channels and culverts and ultimately routed to the two on-site surface water ponds. These features provide for positive, non-erosive drainage of runoff from the landfill and surrounding site areas. Perimeter drainage channels will be utilized during development and operation of the Fairbanks Landfill, and will ultimately convey surface water runoff from the final cover or intermediate cover slopes. The erosional stability of the permanent drainage channels is demonstrated based on calculated flow velocity and is presented in Attachment 2E. Maintenance requirements for perimeter drainage features are addressed in Section 3 in the Post-Closure Plan located in Attachment 8 of the SDP.

2. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DESIGN

As required by 30 TAC §330.305(d), the landfill design must provide effective erosional stability to top deck surfaces and external side slopes. An Intermediate Cover Erosion Analysis was performed and is included in Appendix 2H-1 of this ICESCP.

2.1 Permissible Soil Loss and Non-Erodible Velocity

A permissible soil loss of 50 tons/acre/year is used as the design criteria to which the calculated soil loss for intermediate cover is compared. This is based on previously-issued draft guidance from TCEQ [*Guidance for Addressing Erosional Stability During All Phases of Landfill Operation (Draft)* (TCEQ, 2007)]. It is noted that this draft guidance was never finalized by TCEQ and is currently not available on TCEQ's website or in print. Thus, it is not believed to be a formal regulatory requirement – but nevertheless is used for this plan. Also, for the purposes of the site-specific erosion and sediment control design, the permissible soil loss is the "permissible soil loss for comparable soil-slope lengths and soil-cover conditions" referred to by 30 TAC §330.305(d)(2). For comparison purposes, 50 tons/acre is equivalent to a soil thickness of 0.25 in. (six mm) for a soil with a typical bulk density of 110 pcf.

The permissible non-erodible velocity of five (5) ft/sec is used as the design criteria to which the estimated flow velocities are compared. *Storm Water Management Guidelines for Construction Activities* (TxDOT, 2002) indicates that flow velocities should not exceed four (4) ft/sec in sandy soils or five (5) ft/sec in more cohesive soils. Five (5) ft/sec is appropriate for this facility because it is anticipated that intermediate cover will be constructed of cohesive soils that are readily available at the site.

2.2 Intermediate Cover Erosion Analysis Results

The Intermediate Cover Erosion Analysis is presented in Appendix 2H-1 of this ICESCP. The Revised Universal Soil-Loss Equation (RUSLE) is used in the Intermediate Cover Erosion Analysis to calculate the annual soil loss. Results from the Intermediate Cover Erosion Analysis indicate that adequate erosional stability of the intermediate cover on the top deck and side slopes can be achieved with stabilized soil surfaces and surface water diversions. To achieve effective erosional stability, the maximum parallel offset (horizontal) of the temporary diversion structures is 600-ft on the top deck. The maximum parallel offset for the external 4H:1V side slopes is dependent on the ground cover attained on the interim cover. For 60%, 70%, and 80% ground cover on the interim cover system, the maximum parallel offset of terraces on the external 4H:1V side slopes is 175-ft, 300-ft, and 750-ft, respectively. These distances are based on a soil stabilization practice method that provides a cropping management factor (C) of 0.042 or less on the top deck and external side slopes. These C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering 60% or greater of the surface of the intermediate cover.

3. EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES (BMPS)

Based on the Intermediate Cover Erosion Analysis presented in Appendix 2H-1 of this ICESCP, soil stabilization and surface water diversion BMPs are required for erosional stability of the intermediate cover on the top deck surface and external side slopes during landfill operations. Drawing 2H-1 depicts a plan view of the site to show an example configuration of a landfill development phase, showing the areas requiring erosion and sediment controls addressed in this plan. Descriptions of the required soil stabilization and drainage controls are provided below. Optional BMPs that may be used in addition to the required BMPs at the landfill operator's discretion are also described.

3.1 Soil Stabilization

The purpose of soil stabilization is to provide a ground cover that limits the rainfall impact energy, provides a limited amount of water storage through rainfall interception, and limits sheet flow runoff velocity by increasing surface roughness. In the natural condition, soil is stabilized by native vegetation. As previously described, the temporary soil stabilization practice must provide a maximum C value of 0.042 for intermediate cover. These C values correspond to ground cover consisting of grass, grass-like plants, mulch, or organic matter at least two inches deep covering at least 60% of the surface of the intermediate cover. Intermediate cover will be installed in accordance with the requirements of the SOP, will be stabilized with at least 60% ground cover within 180 days following installation, and will be maintained until final cover is installed or waste filling operations resume. Placement of intermediate cover and stabilization activities will be documented in the Site Operating Record. Details of the soil stabilization BMPs that will be implemented are listed below.

- Vegetation – Vegetation, as a BMP, is the sowing or sodding of fast-germinating annual or perennial grasses, grains, or legumes to provide a vegetative stabilization for disturbed areas. With leaves and stems above ground and fibrous roots below ground, vegetation can provide an effective and long-lasting ground cover. Lack of water and lack of or improper use of soil amendments will usually result in poor vegetation establishment. Seed may be applied to the landfill surface by broadcasting, drilling, hydraulic methods such as hydroseeding or hydromulching, or other methods. Vegetation types, rates of application, and other specifications for establishing vegetation are left to the discretion of the landfill operator, but should be in accordance with temporary vegetation BMP standards or guidelines published by relevant State or local agencies, appropriate for the area. An example of a standard vegetation specification is published in TxDOT (2004), the *Texas Department of Transportation (TxDOT) Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges*, Item 162 (sodding) and Item 164 (seeding). Use of this particular standard specification is not required but is provided as an example of a common and widely-used specification that provides vegetation-related BMPs. Intermediate cover must achieve a relatively uniform ground cover of at least 60% within 180 days following placement. If vegetation establishment at the minimum density specified above cannot be achieved (due to drought, temperatures, or other unforeseen conditions), then additional soil stabilization BMPs (e.g., mulch) will be implemented until the required vegetation density is achieved.

- Mulch – Mulching is the application of a layer of organic, biodegradable material which is spread over areas where vegetation is not yet established. Types of mulch include compost, shredded wood, straw, or manufactured products. Mulch may be distributed over the ground surface dry or hydraulically applied as slurry. If applied dry, the mulch must be tracked into the surface to prevent the mulch from being washed away. If mulch is to be used as the only soil stabilization feature (i.e., without vegetation), a two-inch (minimum) thick layer of “primary grind” mulch is required. Note that “primary grind” mulch is mulch obtained from the primary run from an industrial tub grinder. Primary grind mulch is very coarse mulch that mats together and resists washing away. It is noted that this technique has been used successfully in stabilizing intermediate cover side slopes at similar landfill projects within Texas. Types of mulch slurries include hydromulch, bonded fiber matrix (BFM), flexible growth medium (FGM), as well as other commercially available products. Slurry mixtures typically include a tackifier or binder which increases the strength and durability of the mulch. Seed can also be added to the slurry, in which case the ground surface would be stabilized with a mulch/vegetation composite. If mulch is used in lieu of vegetation for intermediate cover, then the mulch will be applied to cover all of the area requiring stabilization within 180 days of intermediate cover installation. If mulch is used in conjunction with vegetation, then the mulch will be applied to areas where the vegetation fails to establish, or the mulch will be used as a supplemental layer to encourage vegetative growth while providing some degree of soil stabilization until vegetation becomes established.

3.2 Surface Water Diversions

The purpose of a surface water diversion structure is to limit the length of slope over which surface water runoff can travel as sheet flow or shallow concentrated flow. The diversion concentrates and laterally conveys surface water in a non-erosive manner to the perimeter ditch or downchute. Surface water diversion BMPs that will be implemented are listed below.

- Side Slope Drainage Terraces – The proposed final grading plan includes tack-on terraces on the external 4H:1V side slopes of the landfill. These terraces will be constructed of intermediate cover overlying waste and will have a flow line (or longitudinal) slope of approximately 3%. The surface of the intermediate cover within the terrace will be stabilized with vegetation or mulch. Rolled erosion control products may also be used for stabilization of the drainage terraces. Details showing the required dimensions and spacing of the built-in terraces are provided on Drawing 2H-2. Design calculations for these side slope drainage terraces on the intermediate cover surface are provided in Appendix 2H-2.

- Top Deck Drainage Terraces – Top deck drainage terraces are open channels used to collect flow from top deck surfaces and convey it to the temporary downchute channels along the side slopes in a non-erosive manner. Top deck drainage channels are designed as v-shaped channels with 3H:1V and 3% side slopes and a flowline slope of approximately 0.15%. Details showing the required dimensions and layout of the drainage features are provided on Drawing 2H-2. Design calculations for the top deck drainage terraces on the intermediate cover surface are provided in Appendix 2H-2.

- Temporary Downchutes – Temporary downchutes (also known as downdrains or let-downs) are open channels used to collect flow from surface water diversion structures and convey it down the side slope in a non-erosive manner. Downchutes will be constructed using soil berms to create an above-grade channel, or will be excavated to create a depressed channel (in which case a minimum of one foot of intermediate cover will be maintained beneath the downchute). The bottom and side slopes of the temporary downchute channel will be lined with turf reinforcement mat, geomembrane, reno mattress/articulated block, or other alternative lining material to prevent erosion. If an alternative lining material is used, the lining material must have a Manning's n equal to or less than 0.04. The lining material must be able to tolerate the anticipated velocity and tractive stress at the design flow rate and corresponding calculated depth of flow. All equivalency evaluations performed pursuant to these criteria will be placed in the Site Operating Record. A rip rap apron will be installed at the downstream end of the downchutes to provide erosion protection. Details showing the required dimensions and information on these structures are provided on Drawing 2H-2. Design calculations for these temporary structures are provided in Appendix 2H-2.

3.3 Optional Erosion and Sediment Control BMPs

As demonstrated in the Intermediate Cover Erosion Analysis included in Appendix 2H-1, the soil stabilization and surface water diversion BMPs specified above in Sections 3.1 and 3.2 are the only BMPs required to limit soil loss in accordance with 30 TAC §330.305(d). No other BMPs are required. However, other erosion and sediment control BMPs may be implemented during landfill operations at the operator's discretion in order to reduce soil losses even further than required or to provide temporary erosion and sediment controls during the period between installation of intermediate cover and establishment of vegetation or mulch on the top deck and external side slopes. Examples of optional BMPs that may be implemented are listed below.

- Silt Fence – Silt fence consists of filter fabric supported by wire mesh netting or other backing stretched between either wooden or metal posts with the lower edge of the fabric securely embedded in the soil. Silt fence may be located as needed to intercept and filter sheet flow. Typical locations of silt fence include along the toe or crest of external side slopes and should be installed at a fairly level grade. Silt fence may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the silt fence should not exceed the manufacturer's specification, but in no case shall the drainage area be greater than 0.5 acre per 100 ft of fence. A typical silt fence detail is provided on Drawing 2H-3.

- Biodegradable Logs – Biodegradable logs (or filter socks) consist of a biodegradable core material contained in a synthetic mesh sock or tube and are installed above, across, or below slopes to intercept and filter sheet flow. The logs are anchored to the surface using stakes or other methods and should be installed at a fairly level grade. Biodegradable logs may not be used in areas of concentrated flow (e.g., channels and diversions). The maximum drainage area to the biodegradable logs should not exceed 0.5 acre per 100 ft of log. A typical biodegradable log detail is provided on Drawing 2H-3.

- Organic Berms – Organic berms (or organic filter berms) are linear berms constructed of mulch or a mix of mulch and compost. Organic berms may be located as needed to intercept and filter sheet flow. Typical locations of organic berms include along the toe or crest of external side slopes. Organic berms may not be used in areas of concentrated flow (e.g., channels, terraces, and diversions). The maximum drainage area to the organic berms should not exceed 0.5 acre per 100 ft of berm. A typical organic berm detail is provided on Drawing 2H-3.

4. INTERMEDIATE COVER INSTALLATION AND STABILIZATION SCHEDULE

The schedule for installation of intermediate cover and associated erosion and sediment control BMPs is as follows:

- Areas with weekly cover that remain inactive for periods greater than 180 days will receive intermediate cover.
- Intermediate cover diversion structures and downchutes will be installed as soon as practical following placement of intermediate cover, but in no case more than 180 days from when intermediate cover is installed.
- Intermediate cover will be stabilized with vegetation or mulch as soon as practical following placement of intermediate cover. A minimum of 60% land cover (corresponding to cropping management factor of at least 0.042) will be established over the intermediate cover areas within 180 days from intermediate cover construction.
- The intermediate cover and temporary erosion control structures will be maintained as detailed in Section 5 below (the Intermediate Cover Erosion and Sediment Control Maintenance Plan).
- Final cover will be constructed incrementally as the site develops. Temporary erosion control features will be removed as permanent erosion control structures are constructed.

5. INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL MAINTENANCE PLAN

The landfill operator will restore and repair the intermediate cover areas and their erosion and sediment control features in the event of washout or failure. Excess silt buildup, weeds and other debris that are adversely affecting flow in diversion structures will be removed to restore their design configuration, followed by re-stabilizing the disturbed areas as appropriate. Site inspections by landfill personnel will be performed weekly in accordance with the facility's Texas Pollutant Discharge Elimination System (TPDES) Multi-Sector General Permit. Written records of these inspections and maintenance activities will be maintained in the Site Operating Record, as further discussed in the Site Operating Plan (SOP).

The following items will be evaluated during the inspections:

- erosion of intermediate cover areas, perimeter ditches, diversion channels, downchutes, and other drainage features;
- settlement of intermediate cover areas, diversion channels, downchutes, and other drainage features;
- silt and sediment build-up in diversion channels, perimeter ditches, downchutes, and surface water ponds;
- presence of ponded water on intermediate cover or behind diversion structures;
- obstructions in drainage features;
- presence of erosion or sediment discharge at off-site surface water discharge locations; and
- functionality of temporary erosion and sediment control features.

Maintenance activities will be performed to correct damaged or deficient items noted during the site inspections. These activities will be performed as soon as possible after the inspection. Damaged or deficient items will be corrected within seven days of detection unless access is restricted due to weather, ground conditions, and other site-specific conditions.

Maintenance activities will consist of the following, as needed:

- placement of additional vegetation or mulch;
- placement, grading, and stabilization of additional soils in eroded areas or in areas which have settled;
- replacement of riprap or other structural armoring;

- removal of obstructions from drainage features;
- removal of silt and sediment build-up from the erosion and sediment controls;
- removal of ponded water on the intermediate cover or behind diversion structures;
- repairs to erosion and sedimentation controls; and
- installation of additional erosion and sedimentation controls, as needed.

Inspection, maintenance, and recordkeeping frequencies and techniques are discussed below.

- Site inspections by landfill personnel will be performed weekly.
- Documentation of the inspection will be included in the Site Operating Record.
- Documentation of maintenance activities that were performed to correct damaged or deficient items noted during the site inspections will be included in the Site Operating Record.
- Landfill personnel will be trained to perform inspections, install, and maintain erosion and sediment control features.

6. REFERENCES

TCEQ (2007). *Guidance for Addressing Erosional Stability During All Phases of Landfill Operation (Draft)*, Texas Commission on Environmental Quality, 14 February 2007.

TxDOT (2002). *Storm Water Management Guidelines for Construction*, Texas Department of Transportation.

TxDOT (2004). Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Texas Department of Transportation, 1 June 2004.

PERMIT DRAWING

-N-

0 200' 400'
SCALE IN FEET

LEGEND

100 — EXISTING GROUND ELEVATION (FT, MSL) (GENERAL NOTES 1,2)
EXISTING ROAD
EXISTING WATER LINE
N 13893000 E 3069000 — STATE PLANE COORDINATES (GENERAL NOTE 2)
44 — SITE GRID
PROPERTY BOUNDARY
PERMIT BOUNDARY
PROPOSED COMBINED LANDFILL FOOTPRINT
250 — PROPOSED GROUND ELEVATION (FT, MSL)
180 — INTERIM WASTE SLOPE
CELL EXCAVATION AREA
LANDFILL AREA
▨ STABILIZATION (NOTE 4)
DOWNCHUTE CHANNEL

NOTES:

1. THIS PLAN REPRESENTS A "SNAPSHOT" OF GENERAL CONDITIONS FOR INTERMEDIATE COVER EROSION AND SEDIMENT CONTROLS DURING DEVELOPMENT OF PHASE 3 AND MAY NOT REFLECT THE EXACT CONFIGURATION OF THE LANDFILL OR LOCATION OF CONTROLS. ACTUAL EROSION AND SEDIMENT CONTROL FEATURES WILL VARY BASED ON LANDFILL DEVELOPMENT.
2. DETAILS AND INFORMATION ON THE REQUIRED SPACING OF INTERIM DRAINAGE TERRACES IS PROVIDED ON DRAWING 2H-2. THE DESIGN CALCULATIONS ARE PRESENTED IN APPENDIX 2H-2.
3. DIVERSION STRUCTURES MUST BE INSTALLED AND STABILIZED WITHIN 180 DAYS FOLLOWING PLACEMENT INTERMEDIATE COVER.
4. STABILIZATION MAY CONSIST OF VEGETATION, MULCH, OR COMBINATION OF BOTH. THE STABILIZATION MUST OBTAIN AT LEAST 60% COVERAGE WITHIN 180 DAYS FOLLOWING PLACEMENT OF INTERMEDIATE COVER. IF MULCH IS USED AS THE ONLY STABILIZATION FEATURE, A MINIMUM LAYER THICKNESS OF 2 INCHES IS REQUIRED AND AT LEAST 50% (BY BULK VOLUME) MUST CONSIST OF PARTICLES WITH DIMENSIONS EQUIVALENT TO THAT OBTAINED FROM THE PRIMARY RUN FROM AN INDUSTRIAL TUB GRINDER.
5. THE EXISTING TOPOGRAPHIC BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 26 MARCH 2012 AND PREPARED BY DALLAS AERIAL SURVEYS (DAS), INC.
6. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL) AS DEFINED BY THE USGS NATIONAL GEODETIC VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM 83 (NAD-83) 1983.

SCOTT M. GRAVES
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8/26/2013

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REV	DATE	DESCRIPTION	DRN	APP
-	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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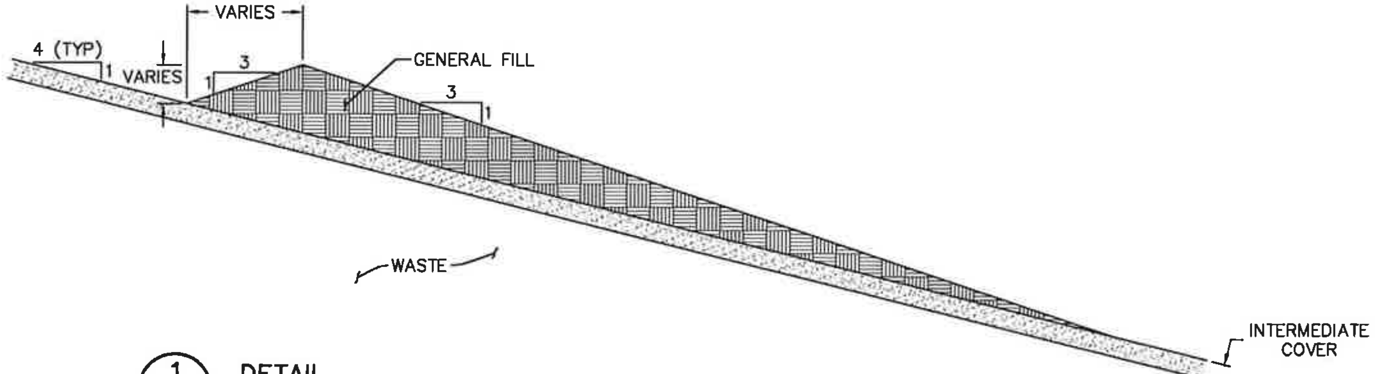
TITLE:
EXAMPLE INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL PLAN

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.:	TXL0263	DESIGN BY:	SMG	REVIEWED BY:	SMG	PART NO.:	DRAWING:
FILE:	0263P2H-1	DRAWN BY:	JJV	APPROVED BY:	SMG	III	2H-1

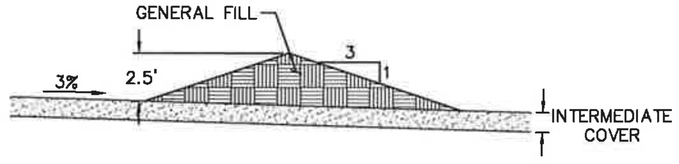
DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2H-1.dwg PLOTTED: Aug 23, 2013 - 11:57am



① 2H-2 DETAIL
INTERIM SIDE SLOPE DRAINAGE TERRACE (NOTE 1)

SCALE: 1" = 10'

0 5' 10'
SCALE IN FEET



② 2H-2 DETAIL
INTERIM TOP DECK DRAINAGE TERRACE (NOTE 2)

SCALE: 1" = 10'

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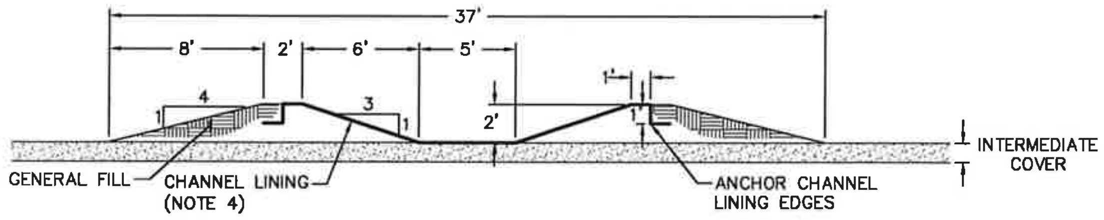
SCALE IN FEET



③ 2H-2 DETAIL
TYPICAL INTERIM DRAINAGE DOWNCHUTE CROSS SECTION

SCALE: 1" = 10'

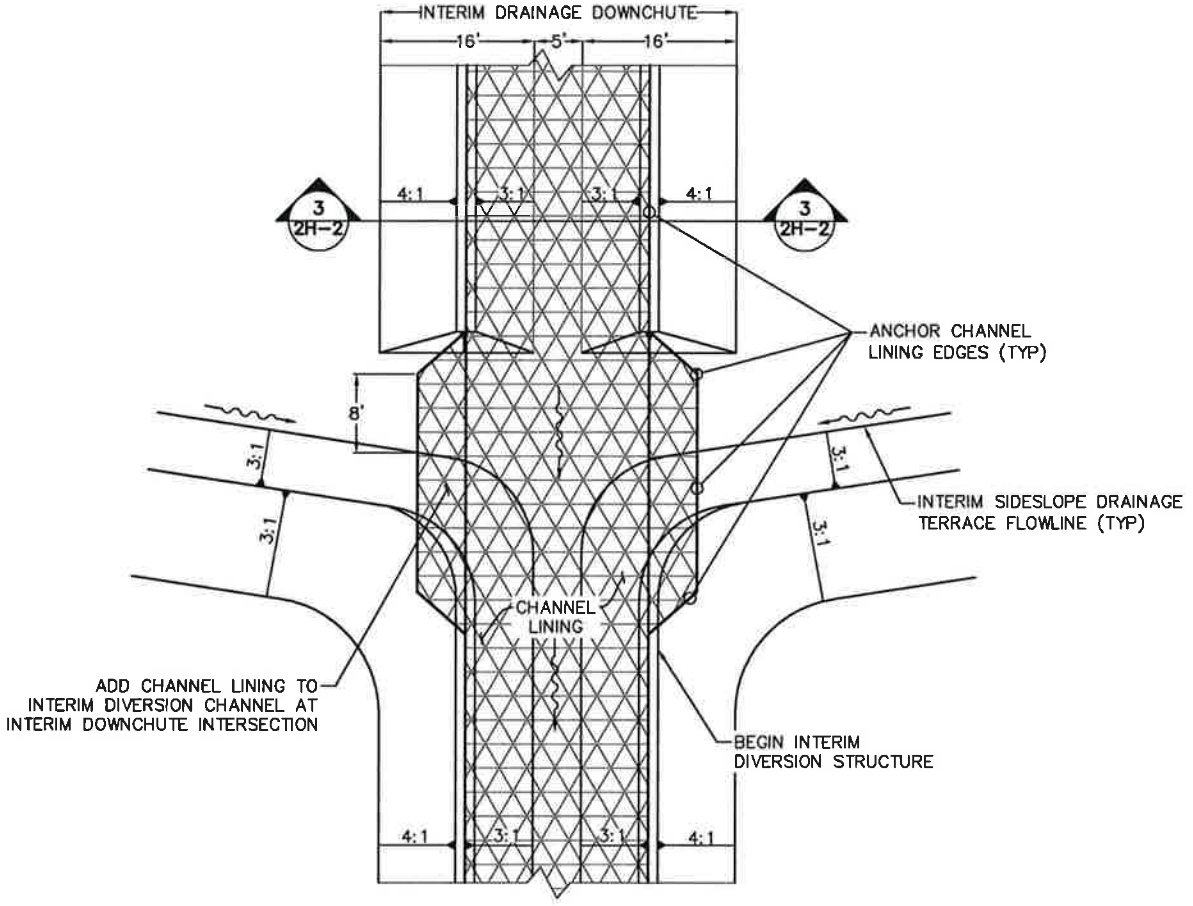
0 5' 10'
SCALE IN FEET

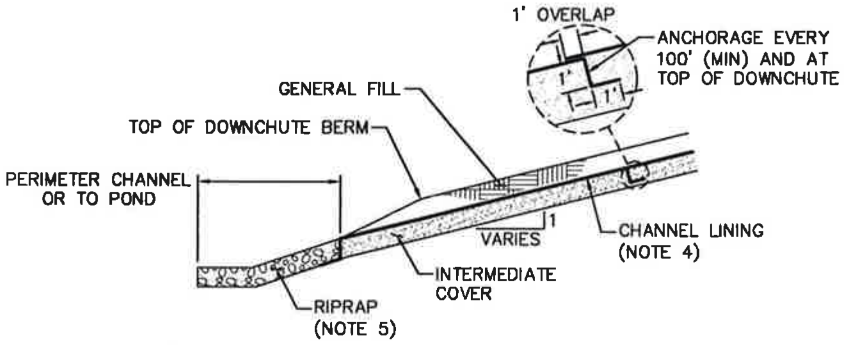
NOTES:

1. THE INTERIM DIVERSION STRUCTURES CONSTRUCTED ON SIDE SLOPES SHALL BE SPACED ACCORDING TO THE MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING TABLE (SEE BELOW) AND INTERIM COVER STABILIZATION METHOD. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 3%.
2. THE DIVERSION STRUCTURES CONSTRUCTED ON 3% TOP DECK SURFACES SHALL BE SPACED A MAXIMUM OF 600 FT HORIZONTALLY. THE FLOWLINE SLOPE OF THE CHANNEL SHALL BE APPROXIMATELY 0.15%.
3. ROLLED EROSION CONTROL PRODUCTS IF USED WITHIN THE DIVERSION CHANNELS MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
4. THE BOTTOM AND SIDESLOPES OF THE DOWNCHUTE CHANNEL WILL BE LINED WITH TURF REINFORCEMENT MAT, GEOMEMBRANE, RENO MATTRESS, OR OTHER ALTERNATIVE LINING MATERIAL TO PREVENT EROSION. IF AN ALTERNATIVE LINING MATERIAL IS USED, THE LINING MATERIAL MUST HAVE A MANNING'S N LESS THAN 0.057. THE LINING MATERIAL MUST BE ABLE TO TOLERATE THE ANTICIPATED VELOCITY AND TRACTIVE STRESS AT THE DESIGN FLOW RATE AND CORRESPONDING CALCULATED DEPTH OF FLOW. ALL EQUIVALENCY EVALUATIONS PERFORMED PURSUANT TO THESE CRITERIA WILL BE PLACED IN THE FACILITY OPERATING RECORD.
5. RIPRAP APRON SHALL BE A MINIMUM OF 2' THICK AND SHALL HAVE D_{50} = 12" AND D_{MAX} = 24"; APRON WIDTH = 24' MIN.

MAXIMUM ALLOWABLE DRAINAGE TERRACE SPACING

INTERIM COVER STABILIZATION METHOD	REQUIRED MINIMUM GROUND COVER	MAXIMUM ALLOWABLE TERRACE SPACING		CHANNEL DEPTH (FT)
		3% TOP DECK	25% SIDE SLOPES	
GRASS	60%	600-FT	175-FT	2.0
GRASS & MULCH	70%	600-FT	300-FT	2.0
MULCH	80%	600-FT	750-FT	2.5





④ 2H-2 DETAIL
TYPICAL INTERIM DOWNCHUTE

SCALE: 1" = 5'

0 5' 10'
SCALE IN FEET

⑤ 2H-2 DETAIL
TYPICAL INTERIM DRAINAGE DIVERSION STRUCTURE AND DOWNCHUTE INTERSECTION

SCALE: 1" = 20'

0 10' 20'
SCALE IN FEET

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8/26/2013

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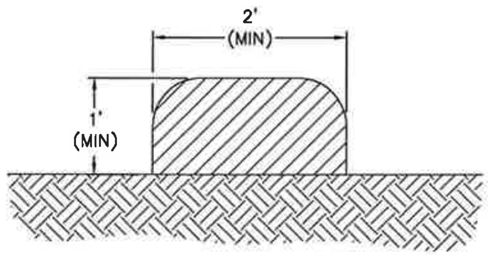
TITLE:
INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS I

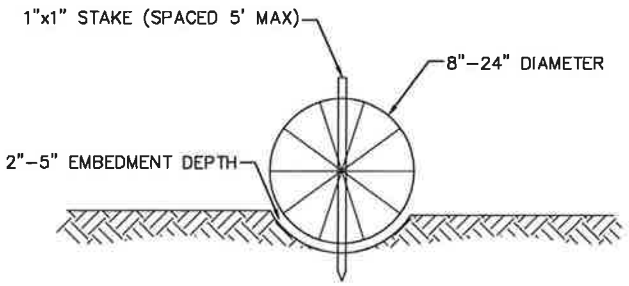
PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PROJECT NO.: TXL0263	DESIGN BY: SMG	REVIEWED BY: SMG	PART NO.: III	DRAWING: 2H-2
FILE: 0263P2H-2	DRAWN BY: JJV	APPROVED BY: SMG		

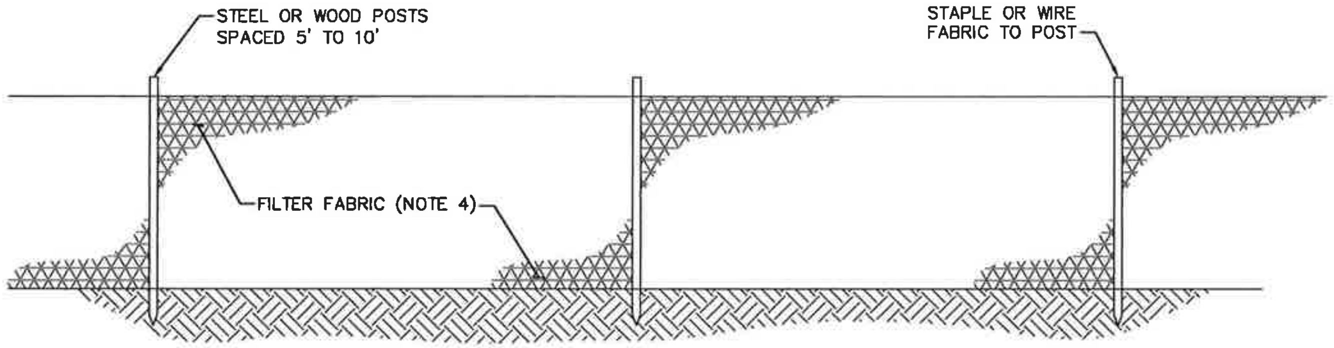
DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dage-Rev0\0263P2H-2.dwg PLOTTED: Aug 23, 2013 - 12:03pm



6
2H-3
DETAIL
ORGANIC BERM
SCALE: 1" = 2'
0 1' 2'
SCALE IN FEET



7
2H-3
DETAIL
BIODEGRADABLE LOG
SCALE: 1" = 2'
0 1' 2'
SCALE IN FEET



8
2H-3
DETAIL
SILT FENCE
SCALE: 1" = 2'
0 1' 2'
SCALE IN FEET

NOTES:

1. THE EROSION AND SEDIMENT CONTROL FEATURES SHOWN ON THIS FIGURE ARE OPTIONAL AND MAY BE IMPLEMENTED DURING LANDFILL OPERATIONS AT THE OPERATOR'S DISCRETION IN ORDER TO REDUCE SOIL LOSSES EVEN FURTHER THAN REQUIRED OR TO PROVIDE TEMPORARY EROSION AND SEDIMENT CONTROLS DURING THE PERIOD BETWEEN INSTALLATION OF THE INTERMEDIATE COVER AND ESTABLISHMENT OF VEGETATION OR MULCH ON THE EXTERNAL SLOPES.
2. IF USED, THE OPTIONAL EROSION AND SEDIMENT CONTROL FEATURES MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS, THE DETAILS SHOWN ON THIS FIGURE, OR OTHER PUBLISHED SOURCE (E.G., TXDOT OR MUNICIPAL OR COUNTY GOVERNMENT AGENCY).
3. THE MAXIMUM DRAINAGE AREA TO THE SILT FENCE, ORGANIC BERM, AND BIODEGRADABLE LOG SHALL NOT EXCEED THE MANUFACTURER'S RECOMMENDATION, BUT IN NO CASE SHALL THE DRAINAGE AREA BE GREATER THAN 0.5 ACRE PER 100 FT. THESE OPTIONAL FEATURES MAY NOT BE USED IN AREAS OF CONCENTRATED FLOW (FOR EXAMPLE, DITCHES, CHANNELS, AND TERRACES).
4. THE LOWER EDGE OF THE SILT FENCE FILTER FABRIC SHALL BE SECURELY EMBEDDED IN THE SOIL.
5. ORGANIC BERMS MAY BE CONSTRUCTED OF MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.
6. BIODEGRADABLE LOGS MAY CONSIST OF MUSH SOCKS FILLED WITH MULCH, WOODCHIPS, BRUSH, COMPOST, OR SHREDDED WOODWASTE.

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8/26/2013

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REV	DATE	DESCRIPTION	DRN	APP
–	AUG. 2013	INITIAL SUBMITTAL TO TCEQ	JJV	SMG

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TITLE:
INTERMEDIATE COVER EROSION AND SEDIMENT CONTROL DETAILS II

PROJECT:
FAIRBANKS LANDFILL
PERMIT AMENDMENT APPLICATION – PERMIT NO. MSW-1565B

PERMIT DRAWING

PROJECT NO.: TXL0263	DESIGN BY: SMG	REVIEWED BY: SMG	PART NO.:	DRAWING:
FILE: 0263P2H-3	DRAWN BY: JJV	APPROVED BY: SMG	III	2H-3

DRAWING: Austin P:\CADD\Projects\F\Fairbanks Landfill\Permit\Expansion (TXL0263)\Drawings\Dwgs-Rev0\0263P2H-3.dwg PLOTTED: Aug 23, 2013 - 2:28pm

APPENDIX 2H-1

INTERMEDIATE COVER EROSION ANALYSIS

INTERMEDIATE COVER EROSION ANALYSIS

SCOTT M. GRAVES
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8/26/2013

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 21

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the intermediate cover erosion analysis for the Fairbanks Landfill. This package provides calculations for the annual soil loss from the external-facing intermediate cover top deck and side slope surfaces under potential interim conditions during operations. In addition, estimates of overland flow velocities on the previously mentioned slopes are provided for the purpose of assessing whether the surface water velocities will remain below permissible non-erodible velocities.

2 PROJECT BACKGROUND

The landfill intermediate cover system includes a surface water management system. Intermediate cover placement of the landfill is expected to be completed as areas reach final elevations and await the construction of the final cover system. The intermediate cover system is comprised of a top deck surface and side slopes designed with temporary drainage features until the final cover system is constructed. The top deck of the landfill will have a surface slope of approximately 3%, and flow into top deck drainage terraces. The side slopes of the intermediate cover on external-facing slopes will be constructed with a grade of 4 horizontal to 1 vertical (4H:1V) (i.e., 25%). The landfill's surface water management system includes the following permanent and temporary drainage features: top deck drainage terraces, downchute channels, side slope drainage terraces, perimeter drainage channels, and surface water ponds. The proposed surface water diversion structures will convey flow from the top deck to the downchute channels and into the perimeter drainage channels. The proposed side slope drainage terraces will collect and convey surface water runoff from the side slopes to the downchute channels. The perimeter drainage channels will also convey flow from these diversion structures to surface water ponds located to the northeast and south of the landfill.

Texas Commission on Environmental Quality (TCEQ) previously-published draft guidance suggested using a permissible soil loss of 50 tons/acre/year on the intermediate cover. It is noted that this draft guidance was never finalized by TCEQ and is currently not available on TCEQ's website or in print. Thus, it is not believed to be a formal regulatory requirement and the number is somewhat arbitrary (no technical literature could be located establishing the reason for this value). Nevertheless a permissible soil loss of 50 tons/acre/year is adopted for the purposes of these calculations. Also, overland flow velocities are evaluated to verify that the predicted velocity of runoff is maintained below the permissible erodible velocity of the intermediate cover soil, which is established as five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

3 CALCULATION METHODOLOGY

The method to calculate the soil erosion loss over the project area was obtained from the guidance document *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)* (USDA, 1996) as well as previously published information provided by USDA. This document presents the Revised Universal Soil Loss Equation (RUSLE) and guidance for each of the equation's parameters. The RUSLE is described as follows:

$$A = R \times K \times LS \times C \times P$$

where:

A = the computed spatial average annual soil loss (tons/acre/year),

R = the average annual rainfall runoff erosivity factor,

K = the soil erodibility factor,

LS = the topographic factor,

C = the cover management factor, and

P = the erosion control practice factor.

The overland flow velocities are estimated using guidance provided in TxDOT (2009) and USDA (2010). TxDOT (2009) indicates that sheet flow velocities (for distances up to 525 ft) may be estimated based on slope and surface conditions, as shown in Figure 2H-1-1. For overland flow distances beyond 300 ft (i.e., shallow concentrated flow), the velocity can be estimated an equation provided by USDA (2010), as follows:

$$V = K_v \times S^{1/2}$$

where:

V = velocity (ft/s),

K_v = velocity factor, and

S = slope (ft/ft).

The velocity factor (K_v) is selected from the description of the surface cover as provided in Table 2H-1-1. Figure 2H-1-2 may also be applied to calculate the shallow concentrated flow velocity shown above. The estimates of overland flow velocity are compared to the permissible non-erodible velocity of five (5) ft/sec for cohesive soil as recommended by TxDOT (2002).

4 RUSLE PARAMETERS

4.1 Rainfall Runoff Erosivity Factor (R)

The rainfall runoff erosivity factor is defined as the average annual rainfall erosion index specific for the project area. Based on USDA (1996), the value of R was determined to be approximately 450 for Houston, Texas, as shown in Figure 2H-1-3.

4.2 Soil Erodibility Factor (K)

The soil erodibility factor is a function of the physical and chemical properties of the soil and is specific to the source of the cover material. The soil erodibility factor can be thought of as the ease with which soil is detached by splash during rainfall or by surface flow. The soils to be used for the intermediate cover system of the landfill are expected to be based on the native soils available at the project site or locally. The soils at the project location were assessed from the Harris County soil survey (USDA, 2004) as a combination of Gessner loam (Ge), Addicks loam (Ad), and Wockley fine sandy loam (Wo) with the Gessner formation constituting the majority of the site and nearby surroundings.

The Soil Data Mart tool provided by the Soil Survey Geographic (SSURGO) Database (NRCS, 2012) was consulted for Harris County to determine the corresponding soil erodibility factors for the site. The value of K for Gessner Loam represents a representative average value of nearby soils (Gessner, Addicks, and Wockley) near the surface, and is listed as 0.37. The provided estimate considers the erodibility of fine-earth fraction for material less than two mm in size (using the Kf erosion factor provided in Table 2H-1-2).

4.3 Topographic Factor (LS)

The slope length factor and slope steepness factor are typically combined into one topographic factor, LS, to facilitate field application of these equation components. USDA (1996) presents values of the LS factor for slope lengths in feet up to 1,000 feet and percent slopes up to 60%, as shown in Table 2H-1-3. To manage surface water runoff from the intermediate surface slopes and terraces, temporary surface water diversion structures will be installed on the intermediate cover system. The surface water diversion features will be placed to limit soil erosion.

The average slope length on the intermediate cover system was used to determine the LS factor. This length provides an estimate of soil loss over the entire intermediate cover system. The top deck surface slope will consist of a 3% grade along a length of approximately 600 ft. The intermediate cover system consists of a 4H:1V (i.e., 25%) side slope with periodic “tack-on” side slope drainage terraces. Three options are evaluated for ground coverage scenarios: 60%, 70%, and 80% ground coverage. The reason for evaluating different ground coverage percentages is to provide flexibility to the operator on the resulting required terrace spacing, based on the ground coverage that the facility is able to achieve. The following LS factors are selected from Table 2H-1-3 and apply to the average length along the top deck and side slopes of the intermediate cover system of the landfill:

- Top Deck – 3% slope over a length of 600 ft, LS = 0.96;
- Side Slopes (60% Cover) – 25% slope over a length of 175 ft, LS = 7.09;
- Side Slopes (70% Cover) – 25% slope over a length of 300 ft, LS = 10.81; or
- Side Slopes (80% Cover) – 25% slope over a length of 750 ft, LS = 22.07.

4.4 Cover Management Factor (C)

The cover management factor is a function of the type of land cover, based on three factors: (i) the vegetative cover in direct contact with the soil surface, (ii) the canopy cover, and (iii) the effects at and beneath the surface. The intermediate cover is categorized as Pasture, Range, and Idle Land, which C values provided in Table 2H-1-4 (USDA, 1977). The land cover is assumed to have no appreciable canopy and a ground cover surface that is grass, mulch, grass-like plants, decaying compacted duff, or litter at least two inches deep. It is noted that the terms “duff” and “litter” are terms used by USDA and refer to types of organic ground cover material, not waste. For these conditions, the “C” values in Table 2H-1-4 vary depending on the percent ground cover. For 60% ground cover of grass the C value is 0.042. For 70% ground cover of grass/mulch, by interpolating on the table, the C value is 0.0275. For 80% ground cover of grass/much, the C value is 0.013. These three ground cover scenarios will be evaluated herein.

4.5 Erosion Control Practice Factor (P)

The erosion control practice factor considers topographical practices that will reduce erosion by altering runoff drainage patterns. This factor generally applies to agricultural cropping practices and is not anticipated for the landfill. Therefore, the P factor is assumed to be equal to one.

5 OVERLAND FLOW VELOCITY PARAMETERS

5.1 Watercourse Slope

The watercourse slopes for estimating the maximum overland flow velocities are as follows:

- Top Deck – 3% slope;
- Side Slopes – 4H:1V (25%) slope

5.2 Surface Condition

For overland flow velocity calculation purposes, the surface condition of the intermediate cover is assumed to be: (i) minimum percent ground cover 60%; (ii) no appreciable canopy; and (iii) ground cover at surface is grass, grass-like plants, decaying compacted duff, or litter at least two inches deep. Only the 60% ground cover scenario is evaluated, since a 70% (or greater) ground cover will result in lower velocities. For estimating overland flow velocities for flow distances less than 525 ft using TxDOT (2009), estimates are provided for the following surface conditions (listed in order of increasing velocity):

- Forest with heavy ground litter and meadow
- Fallow or minimum tillage cultivation
- Short grass pasture and lawns
- Nearly bare ground
- Grassed waterway
- Paved area (sheet flow) and shallow gutter flow

The surface conditions most applicable to the intermediate cover conditions are "nearly bare ground" and "short grass pasture and lawns." To estimate the overland flow velocity for 60% ground coverage, a weighted average flow velocity is calculated from the "nearly bare ground" and "short grass pasture and lawns" flow velocities based on the ground coverage of each cover condition. Note that this surface condition is applicable for grass and grass-like plants. For ground cover consisting of decaying compacted duff or litter (e.g., mulch), the most applicable representative surface condition for velocity calculation purposes is “forest with heavy ground litter and meadow”. While the mulch-covered slopes of the landfill are not situated in a forest, the mulched surface will have a surface condition (or “roughness”) that is best compared to “heavy ground litter” found in a forest (i.e., decaying duff and litter, twigs, etc.).

For estimating shallow concentrated flow velocities for flow distances more than 300 ft using USDA(2010), a velocity factor (K_v) of 9.965 is selected from Table 2H-1-1 for a “Nearly Bare & Untilled” surface. The velocity factor is applied with the slope to estimate the velocity of the interim cover condition for shallow concentrated flow (after 300-ft of sheet flow).

RESULTS

6.1 RUSLE

Applying the RUSLE with the parameters defined above, the computed soil loss in tons/acre/year is calculated as follows:

$$A = R \times K \times LS \times C \times P$$

Top Deck Slopes, 60% ground cover:

$$A = 450 \times 0.37 \times 0.96 \times 0.042 \times 1 = 6.71 \text{ tons/acre/year}$$

Side Slopes, 60% ground cover, 175-ft slope length between terraces:

$$A = 450 \times 0.37 \times 7.09 \times 0.042 \times 1 = 49.58 \text{ tons/acre/year}$$

Top Deck Slopes, 70% ground cover:

$$A = 450 \times 0.37 \times 0.96 \times 0.0275 \times 1 = 4.40 \text{ tons/acre/year}$$

Side Slopes, 70% ground cover, 300-ft slope length between terraces:

$$A = 450 \times 0.37 \times 10.81 \times 0.0275 \times 1 = 49.50 \text{ tons/acre/year}$$

Top Deck Slopes, 80% ground cover:

$$A = 450 \times 0.37 \times 0.96 \times 0.013 \times 1 = 2.08 \text{ tons/acre/year}$$

Side Slopes, 80% ground cover, 750-ft slope length between terraces:

$$A = 450 \times 0.37 \times 10.81 \times 0.013 \times 1 = 47.77 \text{ tons/acre/year}$$

As shown above, the calculated annual soil loss from the intermediate cover on the top deck and side slope surfaces are less than the 50 tons/acre/year permissible rate of soil loss for interim conditions. These results show that if 60% ground cover is present, the side slope terraces should be placed no greater than 175-ft apart. If 70% ground cover is present, the side slope terraces may be placed up to 300-ft apart. If 80% ground cover is present during interim conditions, the side slope terraces may be placed up to 750-ft apart. It is expected that 60%, 70%, and 80% ground cover can be achieved with grassing, a combination of grassing and mulching, and mulching, respectively. Table 2H-1-5 summarizes allowable side slope terrace spacing under each ground cover option.

6.2 Erodible Velocity

As mentioned previously, sheet flow velocity estimates using Figure 2H-1-1 are performed only for the more conservative condition of having only 60% ground cover. The estimated velocities are as follows:

Top Deck Slopes (3%): For overland flow (length up to 300 ft) – 1.8 ft/sec (for bare ground) and 1.3 ft/sec (for grass).

The weighted average value for the overland flow velocity for 60% ground cover is calculated as:

$$\text{Top Deck Overland Flow Velocity} = 1.8 \times 0.40 + 1.3 \times 0.60 = 1.5 \text{ ft/sec}$$

For distances greater than 300-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation (and shown in Figure 2H-1-2) is calculated as:

$$\text{Top Deck Shallow Concentrated Flow Velocity, } V = 9.965 \times 0.03^{1/2} = 1.73 \text{ ft/s}$$

Side Slopes (25%): 5.0 ft/sec (for bare ground) and 3.5 ft/sec (for grass).

The weighted average value for the overland flow velocity for 60% ground cover is calculated as:

$$\text{Side Slope Overland Flow Velocity} = 5.0 \times 0.40 + 3.5 \times 0.60 = 4.1 \text{ ft/sec}$$

For distances greater than 300-ft on the top deck, where flow becomes shallow concentrated flow, the velocity estimates using the previously mentioned equation (and shown in Figure 2H-1-2) is calculated as:

$$\text{Side Slope Shallow Concentrated Flow Velocity, } V = 9.965 \times 0.25^{1/2} = 4.98 \text{ ft/s}$$

As shown above, the estimated flow velocities are less than 5.0 ft/sec.

7. CONCLUSIONS

The ground surface cover condition and maximum terrace spacing requirements are computed above and summarized in Table 2H-1-5. Based on the calculations presented herein, the following conclusions are drawn:

- For the conditions analyzed herein, the calculated soil loss from the intermediate cover is less than the permissible soil loss of 50 tons/acre/year, which is acceptable.

- For the conditions analyzed herein, the estimated velocities for the top deck and side slope surfaces were calculated to be less than the permissible non-erosive velocity of five (5) ft/sec, which is acceptable.
- To provide effective erosional stability on the external facing 3% top deck slope surfaces, a horizontal spacing of 600-ft between temporary diversion structures is acceptable for a 60% or greater ground cover of grass/mulch or the like.

- To provide effective erosional stability on the external facing 25% side slopes when there is a 60% ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 175-ft.

- To provide effective erosional stability on the external facing 25% slopes when there is a 70% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 300-ft.
- To provide effective erosional stability on the external facing 25% slopes when there is a 80% or greater ground cover of grass/mulch or the like, the maximum horizontal spacing between terraces should be 750-ft.

8. REFERENCES

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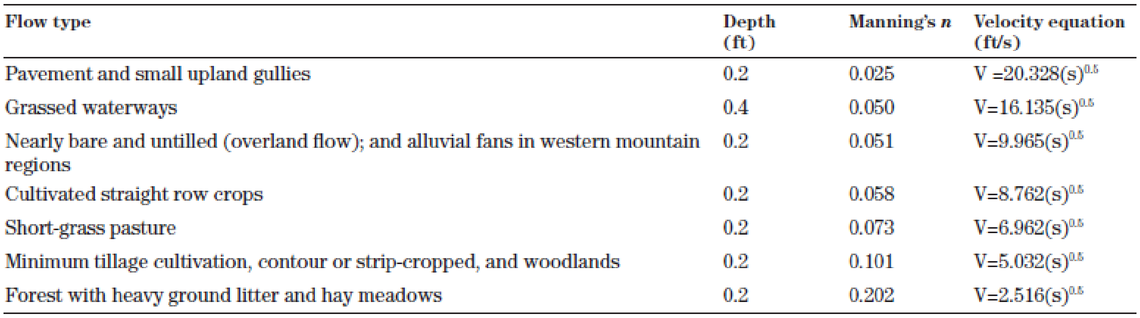
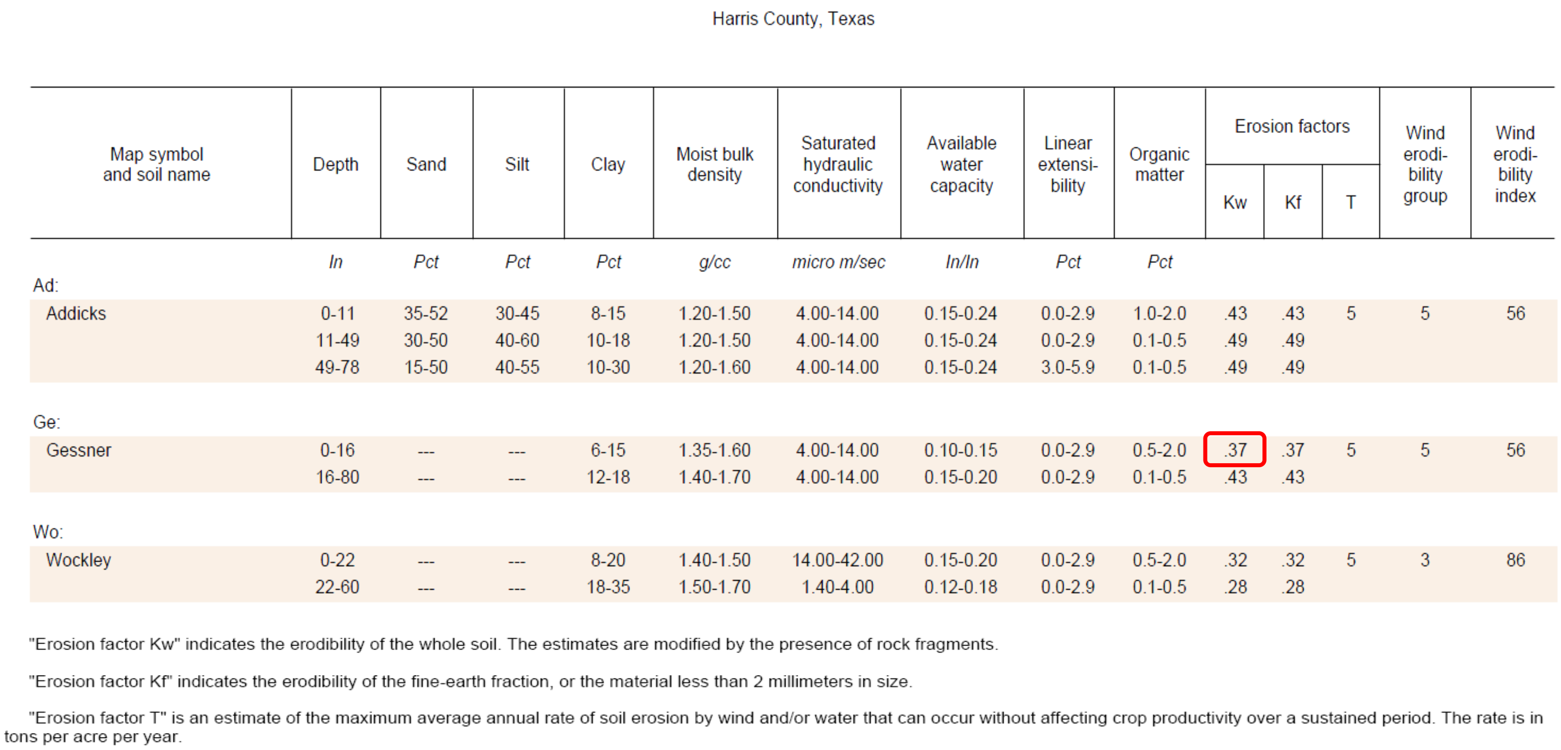
TABLES

Table 2H-1-1. Equations and Assumptions Relating Velocity to Surface Slope (from USDA, 2010)



Flow type	Depth (ft)	Manning's *n*	Velocity equation (ft/s)
Pavement and small upland gullies	0.2	0.025	$V = 20.328(s)^{0.5}$
Grassed waterways	0.4	0.050	$V=16.135(s)^{0.5}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions	0.2	0.051	$V=9.965(s)^{0.5}$
Cultivated straight row crops	0.2	0.058	$V=8.762(s)^{0.5}$
Short-grass pasture	0.2	0.073	$V=6.962(s)^{0.5}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands	0.2	0.101	$V=5.032(s)^{0.5}$
Forest with heavy ground litter and hay meadows	0.2	0.202	$V=2.516(s)^{0.5}$

Table 2H-1-2. Soil Erodibility Factor K for Gessner Soils (from NRCS, 2012)



Harris County, Texas

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	*Pct*	*Pct*	*Pct*	*g/cc*	*micro m/sec*	*In/In*	*Pct*	*Pct*					
Ad:														
Addicks	0-11	35-52	30-45	8-15	1.20-1.50	4.00-14.00	0.15-0.24	0.0-2.9	1.0-2.0	.43	.43	5	5	56
	11-49	30-50	40-60	10-18	1.20-1.50	4.00-14.00	0.15-0.24	0.0-2.9	0.1-0.5	.49	.49			
	49-78	15-50	40-55	10-30	1.20-1.60	4.00-14.00	0.15-0.24	3.0-5.9	0.1-0.5	.49	.49			
Ge:														
Gessner	0-16	---	---	6-15	1.35-1.60	4.00-14.00	0.10-0.15	0.0-2.9	0.5-2.0	.37	.37	5	5	56
	16-80	---	---	12-18	1.40-1.70	4.00-14.00	0.15-0.20	0.0-2.9	0.1-0.5	.43	.43			
Wo:														
Wockley	0-22	---	---	8-20	1.40-1.50	14.00-42.00	0.15-0.20	0.0-2.9	0.5-2.0	.32	.32	5	3	86
	22-60	---	---	18-35	1.50-1.70	1.40-4.00	0.12-0.18	0.0-2.9	0.1-0.5	.28	.28			

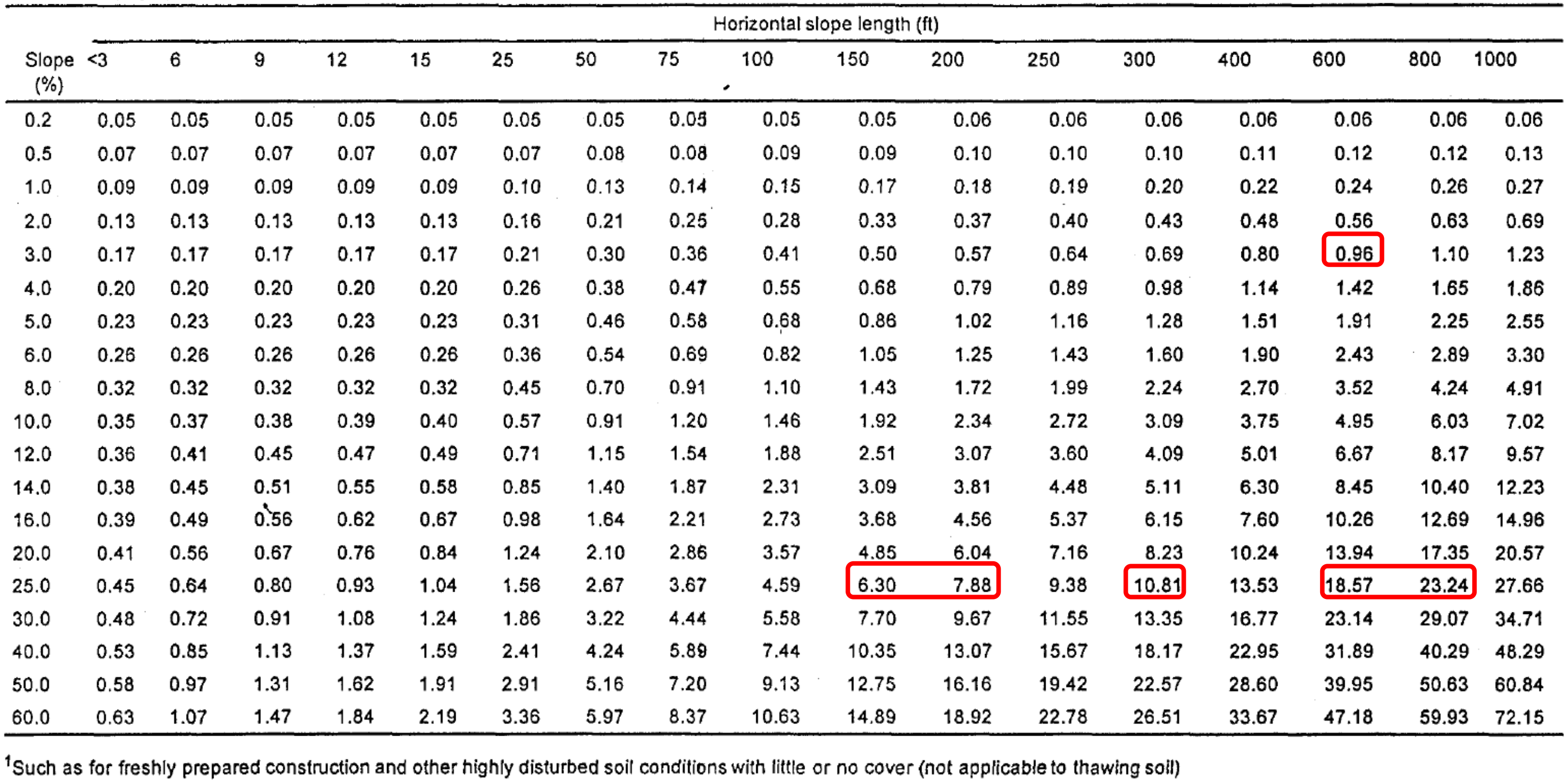
"Erosion factor Kw" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

"Erosion factor Kf" indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

"Erosion factor T" is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Table 2H-1-3. Values for Topographic Factor, LS, for High Ratio of Rill to Interrill Erosion[1]

(from USDA, 1996)

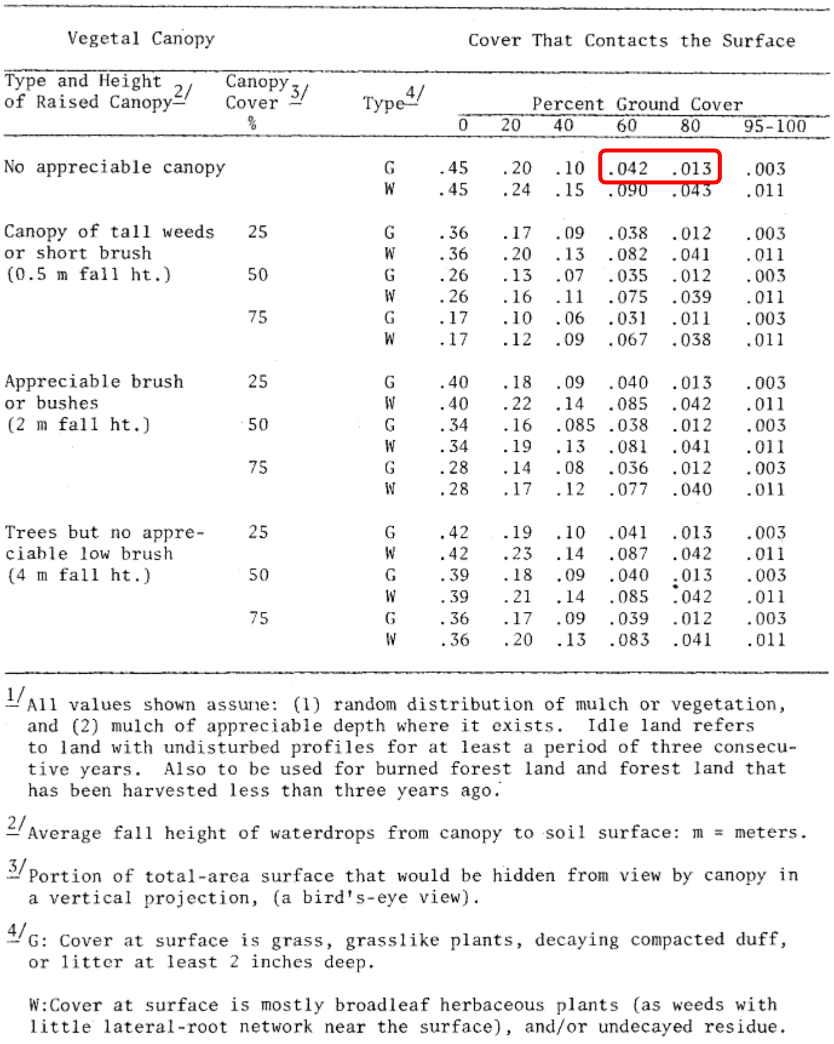


Slope (%)	Horizontal slope length (ft)																
	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

[1] Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil)

Table 2H-1-4. C Factor Cover Values for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland[1]

(from USDA, 1977)



Vegetal Canopy			Cover That Contacts the Surface					
Type and Height of Raised Canopy[2]	Canopy Cover[3] %	Type[4]	Percent Ground Cover					
			0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

---

[1] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

[2] Average fall height of waterdrops from canopy to soil surface: m = meters.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

[4] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

Table 2H-1-5. Summary of Maximum Allowable Drainage Terrace Spacing

Interim Cover Stabilization Method [1]	Required Minimum Ground Cover	Maximum Allowable Terrace Spacing		Calculated Velocity < Permissible Velocity?
		3% Top Deck	25% Side Slopes	
Grass	60%	600-ft	175-ft	Yes
Grass & Mulch	70%	600-ft	300-ft	Yes
Mulch	80%	600-ft	750-ft	Yes

FIGURES

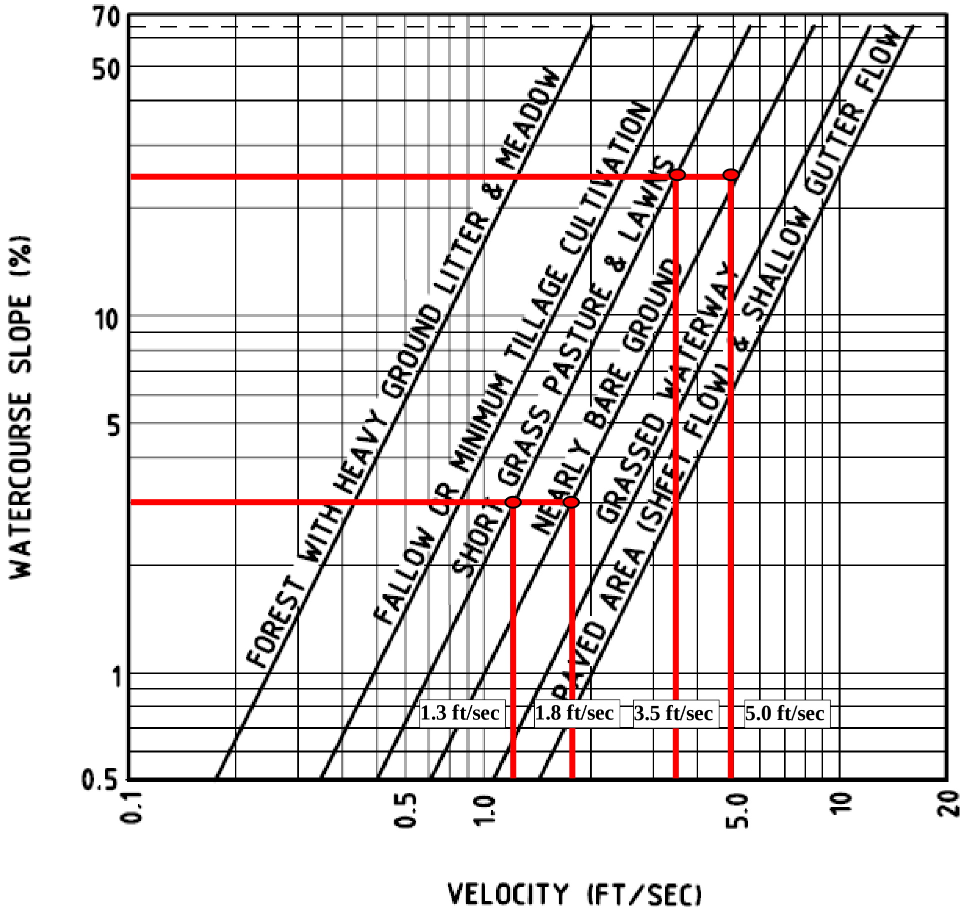


Figure 2H-1-1. Velocities for Estimating Travel Time for Sheet Flow (from TxDOT, 2009)

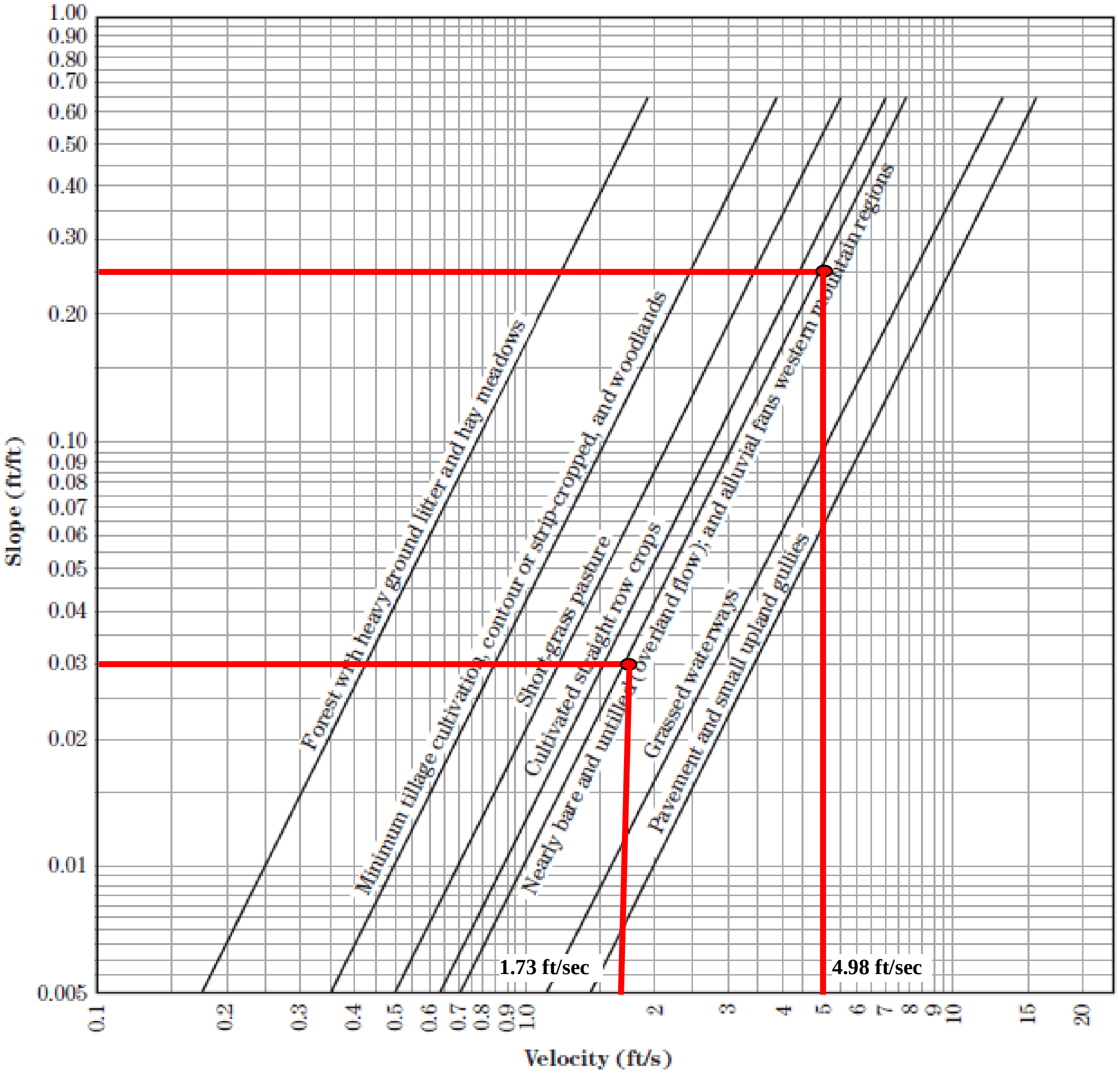


Figure 2H-1-2. Average Velocities for Estimating Travel Time for Shallow Concentrated Flow (from USDA, 2010)

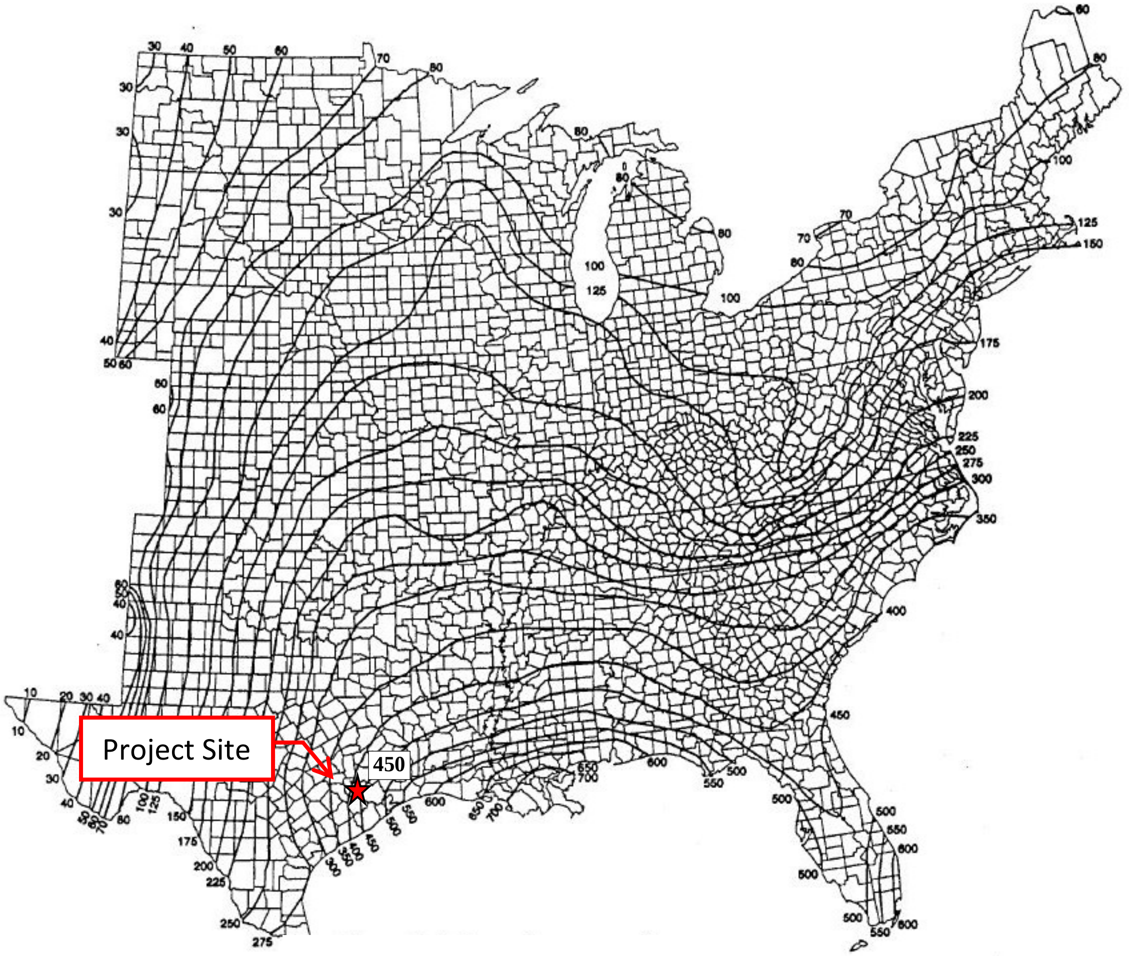


Figure 2H-1-3. Average Annual Rainfall Runoff Erosivity Factor, R, Isoerodent Map (from USDA, 1996)

APPENDIX 2H-2

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES

HYDRAULIC DESIGN OF INTERMEDIATE COVER DIVERSION STRUCTURES
FAIRBANKS LANDFILL EXPANSION

SCOTT M. GRAVES
86557

8/26/2013

SEALED FOR PERMITTING PURPOSES,
CALCULATION PAGES 1 TO 18

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

1 INTRODUCTION

The purpose of this calculation package is to present the hydraulic design of the intermediate cover diversion structures for the proposed expansion of the Fairbanks Landfill. This package provides calculations for the peak runoff discharges flowing to diversion structures and the sizing design of intermediate cover surface water diversion structures, including side slope drainage terraces, top deck drainage terraces, and downchute channels.

2 CALCULATION METHODOLOGY

The following sections describe the calculation methodology applied to design the temporary diversion structures for the intermediate cover.

2.1 Hydrology

Per 30 TAC §330.305(f)(1), the peak runoff discharge to each temporary diversion structure is calculated by the Rational Method, as outlined in Texas Department of Transportation (TxDOT) *Hydraulic Design Manual* (TxDOT, 2009). The equation for the Rational Method is applied as follows:

$$Q = C \times I \times A \tag{1}$$

where:

Q = peak runoff discharge (cfs),

C = runoff coefficient,

I = rainfall intensity (in/hr), and

A = drainage area (acres).

The rainfall intensity is calculated by the following equation (TxDOT, 2009):

$$I = \frac{b}{\left(t_c + d\right)^e} \qquad (2)$$

where:

I = design rainfall intensity (in/hr),

t_c = time of concentration (min), and

b, d, e = coefficients for specific frequencies listed by Texas county.

2.2 Hydraulic Design of Diversion Structures

Manning's equation is applied to the calculate peak discharge rates through each intermediate cover diversion structure. Manning's equation (Chow, 1959) is expressed as:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad (3)$$

where:

Q = discharge (cfs),

n = Manning's roughness coefficient,

A = area of cross-section of flow (ft^2),

R = hydraulic radius = A/P (ft),

P = wetted perimeter (ft), and

S = longitudinal slope (ft/ft).

The tractive stresses in the channel for various depths of flow are estimated using the following equation (HCFCD, 2001):

$$\tau_o = \gamma_w RS \tag{4}$$

where:

τ_o = average tractive stress (lb/ft^2),

γ_w = unit weight of water (lb/ft^3),

R = hydraulic radius = A/P (ft), and

S = channel slope (ft/ft).

Each diversion structure is designed to convey the peak runoff discharge from the 25-year rainfall event as calculated by the Rational Method. The depth of flow, maximum velocity, and tractive stress for the design rainfall event through each channel reach is calculated using Manning’s equation and the tractive stress equation (HCFCD, 2001).

3 DESIGN PARAMETERS

The following sections describe the selected parameters applied in the calculations of the peak runoff discharge by the Rational Method and the capacity of the drainage structures by Manning’s equation.

3.1 Drainage Areas

The diversion structures on the intermediate cover are designed for the runoff from contributing drainage areas during landfill operating conditions. It is envisioned that the temporary side slope drainage terraces, top deck drainage terraces, and temporary downchutes on the intermediate cover system will be installed to the approximate the post-development (i.e., final) drainage patterns of the final cover system. Accordingly, the drainage areas contributing to each of these structures during interim conditions are selected based on the largest area that contributes to the type of structure according to the grading plan layout of the final cover grades. The largest top deck area (12.67 acres) that contributes to a single drainage terrace is selected to design the typical top deck drainage terraces on the intermediate cover. The sum of the largest top deck (12.67 acres) and side slope (17.04 acres) areas which combine to a single downchute is selected as the design drainage area (29.71 acres) for the typical downchute channel on the intermediate cover. Meanwhile, side slope drainage terraces will have a maximum spacing of 175-ft, 300-ft, or 750-ft apart depending on the ground cover applied (and resulting ground cover percentage) to the 4H:1V intermediate cover side slopes. The longest side slope drainage terrace (approximately 1,286-ft in length) is selected for the design of the typical side slope drainage terraces for each spacing. The drainage area selected for the design of side slope drainage terraces is calculated based on the longest length and the maximum spacing for each ground cover scenario for the intermediate cover side slopes.

3.2 Runoff Coefficients

A runoff coefficient (C) was selected based on information provided by TxDOT (2009) for rural watersheds, as shown in Table 2H-2-1. The runoff coefficients provided apply to storms of up to a 10-year frequency. The total runoff coefficient is based on the sum of the four runoff components in Table 2H-2-1. A runoff coefficient adjustment factor is required for higher frequency storm events. The adjustment factor, C_f, for a 25-year event is $C_f = 1.1$. The 25-year runoff coefficient is calculated using the following equation:

$$C = C_f \times (C_r + C_i + C_v + C_s) \qquad (5)$$

The following runoff coefficient is estimated for the steep 4H:1V side slope drainage areas:

$$C = 1.1 \times (0.26 + 0.12 + 0.08 + 0.12) = 0.638$$

The following runoff coefficient is estimated for the flatter (3%) top deck drainage areas:

$$C = 1.1 \times (0.20 + 0.12 + 0.08 + 0.12) = 0.572$$

The following runoff coefficient is estimated for the drainage areas contributing to the downchute channels using a weighted average of the top deck and side slope runoff coefficients per the drainage areas listed above:

$$C = (12.67 \text{ ac} \times 0.572 + 17.04 \text{ ac} \times 0.638) / (12.67 \text{ ac} + 17.04 \text{ ac}) = 0.610$$

3.3 Rainfall Intensity

The rainfall intensity (I) as applied in the Rational Method is a measure of the peak rate of rainfall (in/hr) during the design rainfall event. Equation (2) is applied to calculate the rainfall intensity after selecting the proper coefficients for the design rainfall event in the area of the facility. For a 25-year rainfall event in Harris County, the coefficients are as follows: b = 81; d = 7.7; and e = 0.724 (TxDOT, 2009).

The time of concentration is the time for runoff to flow from the most hydraulically remote point of the drainage area to the point under investigation. The time of concentration is estimated by dividing the longest drainage path by the velocity of runoff. For a conservative design approach, a minimum time of concentration of 10 minutes was used to calculate the rainfall intensity. TxDOT (2009) recommends 10 minutes for the minimum time of concentration because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high.

Based on the values above, the peak rainfall intensity for the Fairbanks Landfill Expansion is calculated by Equation (2), as follows:

$$I = \frac{b}{(t_c + d)^e} = \frac{81}{(10 + 7.7)^{0.724}} = 10.1\frac{in}{hr}$$

3.4 Manning's Roughness Coefficient

Manning's roughness coefficient (n) is a measure of the surface roughness of a pipe, conduit, channel or other hydraulic structure. As the Manning's roughness coefficient increases, the resistance to flow within a channel increases. As shown in Table 2H-2-2, Manning's roughness coefficients of 0.03 and 0.04 were selected based on an articulated concrete block lined downchute channel and grass lined drainage terraces, respectively (HCFCD, 2010). It is noted that the downchute channel lining is anticipated to be geomembrane, as shown on the details that accompany Attachment 2H. Geomembrane would be expected to have a lower roughness coefficient than 0.03 since it is smoother than articulated concrete blocks. However, the higher Manning's "n" was assumed for these calculation purposes to result in a greater calculated flow depth for a conservative confirmation of channel sizing, and to provide flexibility in the design.

3.5 Hydraulic Design

Each intermediate cover diversion structure is designed to convey the 25-year, 24-hour rainfall event. Additionally for structures that have a flow velocity of greater than five ft/s during the 25-year rainfall event, a channel lining (e.g., geomembrane, riprap, articulated concrete blocks) is required until the final cover system is constructed.

4 CALCULATIONS

The peak runoff discharge to each temporary drainage structure was calculated by the Rational Method. The results from these calculations are presented in Table 2H-2-3.

Based on the calculated runoff discharge, each temporary diversion structure was sized by applying Manning's equation. These calculations were performed using the spreadsheets presented at the end of this calculation package. The design parameters and results of the hydraulic design of each component of the intermediate cover surface water management system are summarized in Table 2H-2-4.

5 CONCLUSIONS

Results from calculations presented in this calculation package indicate that the proposed surface water diversion structures for Fairbanks Landfill Expansion intermediate cover will collect and control the runoff resulting from a 25-year, 24-hour rainfall event. These calculations indicate that the temporary downchute channels should be lined with an erosion resistant channel lining material until the final cover system is constructed.

6 REFERENCES

Chow, V.T. (1959). *Open Channel-Hydraulics*, McGraw-Hill.

HCFCD (2001). *Design Manual for Articulating Concrete Block Systems*, Houston, Texas, Harris County Flood Control District, September 2001.

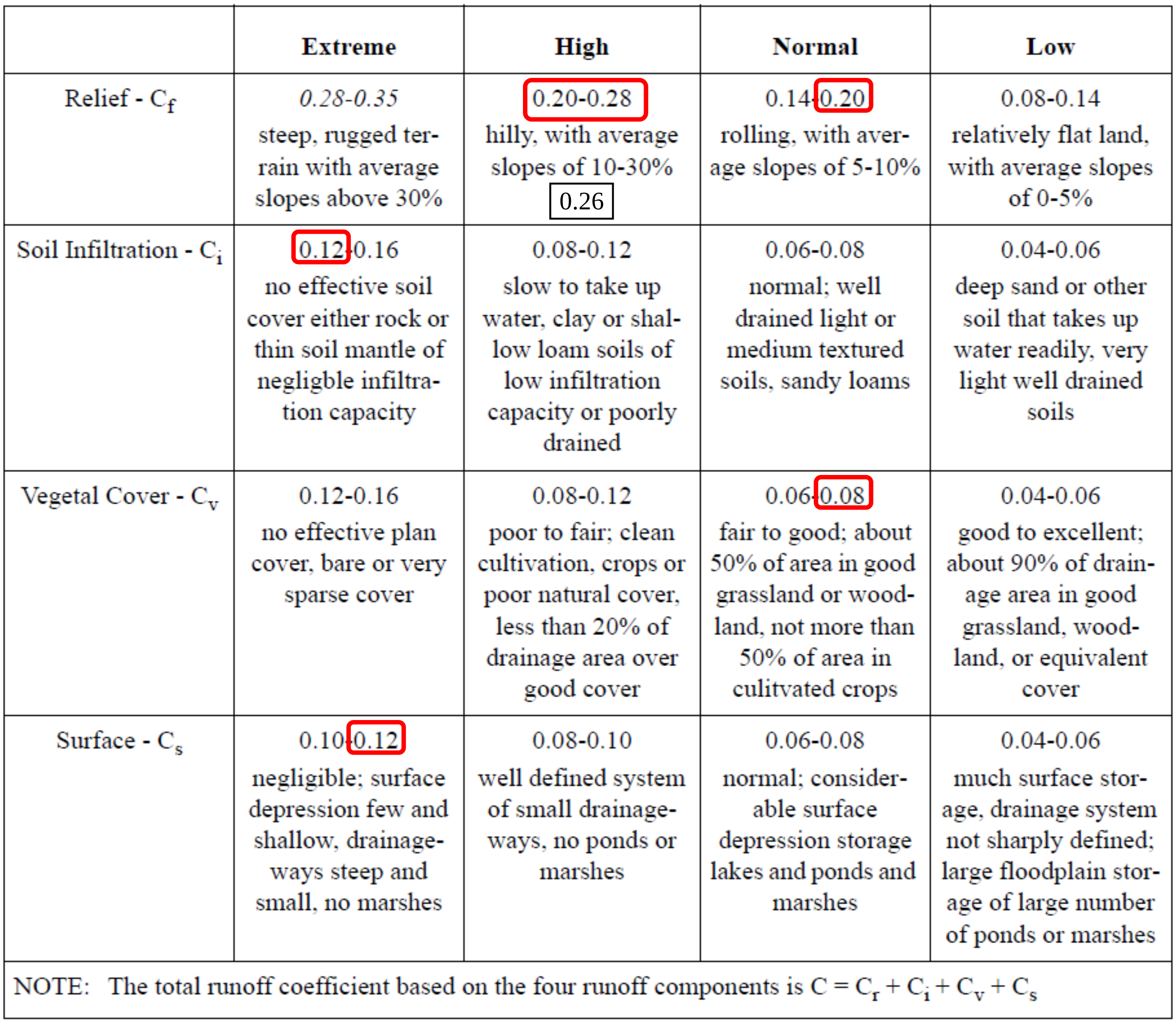
HCFCD (2010). *Policy Criteria and Procedure Manual*, Harris County Flood Control District, December 2010.

TxDOT (2009). *Hydraulic Design Manual*, Texas Department of Transportation, revised March 2009.

TABLES

Table 2H-2-1. Runoff Coefficients for Rural Watersheds

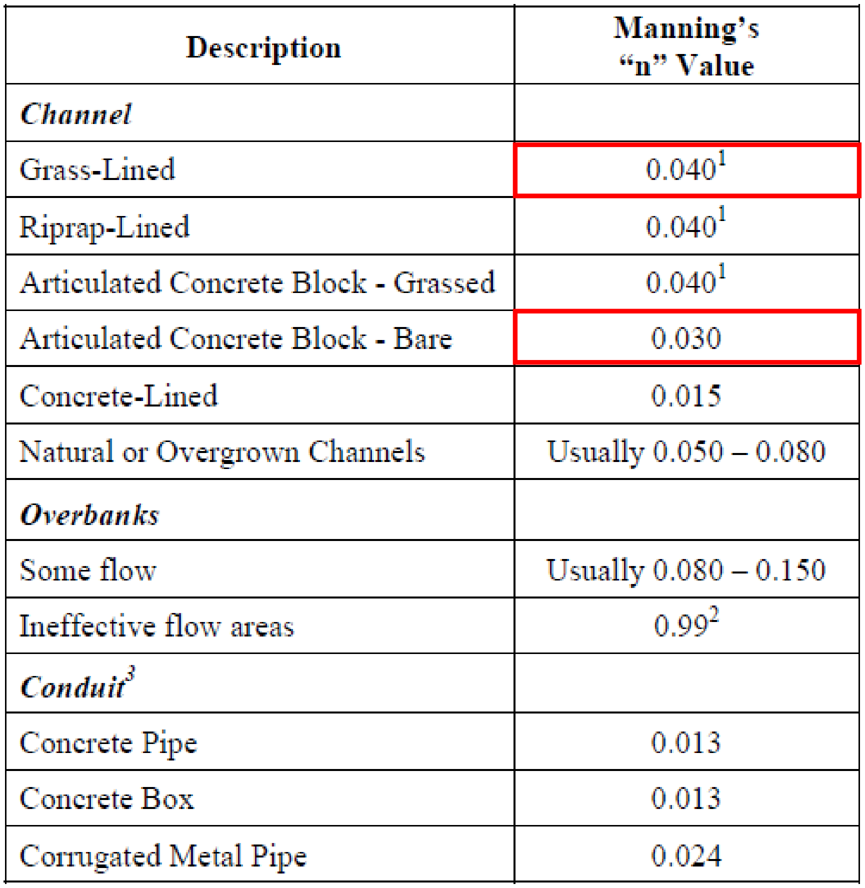
(from TxDOT, 2009)



	Extreme	High	Normal	Low
Relief - C_f	*0.28-0.35* steep, rugged terrain with average slopes above 30%	0.20-0.28 hilly, with average slopes of 10-30% 0.26	0.14-0.20 rolling, with average slopes of 5-10%	0.08-0.14 relatively flat land, with average slopes of 0-5%
Soil Infiltration - C_i	0.12-0.16 no effective soil cover either rock or thin soil mantle of negligble infiltration capacity	0.08-0.12 slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 normal; well drained light or medium textured soils, sandy loams	0.04-0.06 deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover - C_v	0.12-0.16 no effective plan cover, bare or very sparse cover	0.08-0.12 poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area over good cover	0.06-0.08 fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in culitvated crops	0.04-0.06 good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface - C_s	0.10-0.12 negligible; surface depression few and shallow, drainageways steep and small, no marshes	0.08-0.10 well defined system of small drainageways, no ponds or marshes	0.06-0.08 normal; considerable surface depression storage lakes and ponds and marshes	0.04-0.06 much surface storage, drainage system not sharply defined; large floodplain storage of large number of ponds or marshes

NOTE: The total runoff coefficient based on the four runoff components is $C = C_r + C_i + C_v + C_s$

Table 2H-2-2. Manning's Roughness Coefficients (from HCFCD, 2010)



Description	Manning's "n" Value
Channel	
Grass-Lined	0.040[1]
Riprap-Lined	0.040[1]
Articulated Concrete Block - Grassed	0.040[1]
Articulated Concrete Block - Bare	0.030
Concrete-Lined	0.015
Natural or Overgrown Channels	Usually 0.050 – 0.080
Overbanks	
Some flow	Usually 0.080 – 0.150
Ineffective flow areas	0.99[2]
Conduit[3]	
Concrete Pipe	0.013
Concrete Box	0.013
Corrugated Metal Pipe	0.024

Table 2H-2-3. Intermediate Cover Peak Discharge Calculations for the 25-year, 24-hour Rainfall Event

Diversion Structure	**Spacing (ft) [2]**	**A (acres)**	**C**	**I (in/hr)**	**Q (cfs)**
Side Slope Drainage Terraces [1]	175	5.17	0.638	10.1	33.29
Side Slope Drainage Terraces [1]	300	8.86	0.638	10.1	57.07
Side Slope Drainage Terraces [1]	750	22.14	0.638	10.1	142.68
Top Deck Drainage Terraces	-	12.67	0.572	10.1	73.20
Downchutes	-	29.71	0.610	10.1	183.00

Notes:

1. The maximum side slope drainage area is estimated based on the terrace spacing shown above, and a maximum terrace length of 1,286 ft.
2. Spacing of terraces on the side slopes is varied based on the assumed ground cover scenarios, as described in Appendix 2H-1.

Table 2H-2-4. Summary of Intermediate Cover Hydraulic Design Results

Diversion Structure	Spacing (ft)	Bottom Width (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)	Channel Depth (ft)	Manning's n	Flowline Slope (ft/ft)	Design Depth of Flow (ft)	Design Velocity (ft/s)	Tractive Stress (psf)	Channel Lining Required?
Side Slope Drainage Terrace	175	0.00	3:1	4:1	2.00	0.04	0.03	1.39	4.93	1.25	No
Side Slope Drainage Terrace	300	0.00	3:1	4:1	2.00	0.04	0.03	1.70	5.64	1.53	No
Side Slope Drainage Terrace	750	0.00	3:1	4:1	2.50	0.04	0.03	2.40	7.09	2.16	No
Top Deck Drainage Terrace	-	0.00	3:1	33:1	2.50	0.04	0.0015	1.76	1.32	0.08	No
Downchute Channel	-	5.00	3:1	3:1	2.00	0.03	0.25	1.08	20.55	11.74	Yes

MANNING’S EQUATION CALCULATIONS

Design/Check: Trapezoidal/Triangular Channel

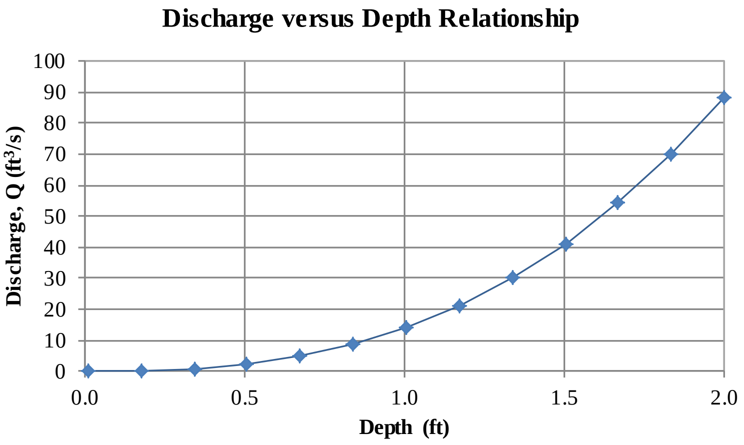
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Side Slope Drainage Terrace, 3% Slope, 175-ft Spacing**

Peak Discharge, Q_{max} = 33.29 cfs
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 4.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0300 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.18	0.0	0.01	
0.18	0.11	1.28	0.08	1.24	0.1	0.16	
0.34	0.41	2.49	0.16	1.93	0.8	0.31	
0.51	0.90	3.70	0.24	2.52	2.3	0.46	
0.67	1.59	4.91	0.32	3.04	4.8	0.61	
0.84	2.46	6.11	0.40	3.52	8.7	0.75	
1.01	3.54	7.32	0.48	3.97	14.0	0.90	
1.17	4.80	8.53	0.56	4.40	21.1	1.05	
1.34	6.25	9.74	0.64	4.80	30.0	1.20	
1.50	7.90	10.95	0.72	5.19	41.0	1.35	
1.67	9.74	12.15	0.80	5.57	54.2	1.50	
1.83	11.77	13.36	0.88	5.93	69.8	1.65	
2.00	14.00	14.57	0.96	6.28	88.0	1.80	
1.39	6.76	10.12	0.67	4.93	33.29	1.2496	DESIGN Q



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

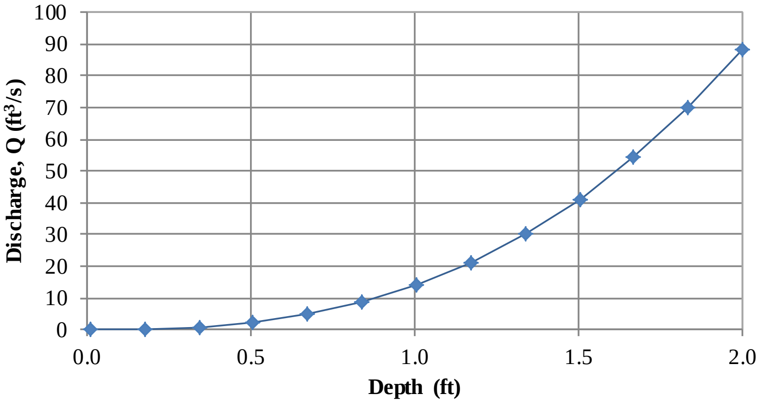
Project: Fairbanks Landfill Expansion

Ditch ID: **Side Slope Drainage Terrace, 3% Slope, 300-ft Spacing**

Peak Discharge, Q_{max}= 57.07 cfs
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 4.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0300 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.18	0.0	0.01	
0.18	0.11	1.28	0.08	1.24	0.1	0.16	
0.34	0.41	2.49	0.16	1.93	0.8	0.31	
0.51	0.90	3.70	0.24	2.52	2.3	0.46	
0.67	1.59	4.91	0.32	3.04	4.8	0.61	
0.84	2.46	6.11	0.40	3.52	8.7	0.75	
1.01	3.54	7.32	0.48	3.97	14.0	0.90	
1.17	4.80	8.53	0.56	4.40	21.1	1.05	
1.34	6.25	9.74	0.64	4.80	30.0	1.20	
1.50	7.90	10.95	0.72	5.19	41.0	1.35	
1.67	9.74	12.15	0.80	5.57	54.2	1.50	
1.83	11.77	13.36	0.88	5.93	69.8	1.65	
2.00	14.00	14.57	0.96	6.28	88.0	1.80	
1.70	10.12	12.39	0.82	5.64	57.07	1.5294	DESIGN Q

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

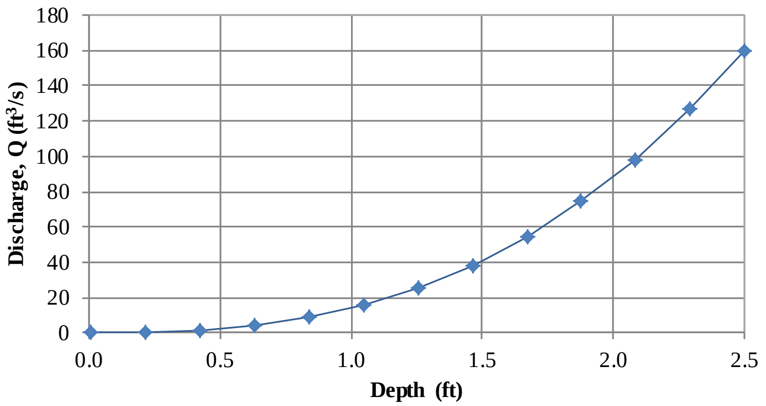
Project: Fairbanks Landfill Expansion

Ditch ID: **Side Slope Drainage Terrace, 3% Slope, 750-ft Spacing**

Peak Discharge, Q_{max}=	142.68	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	4.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.040	
Longitudinal Channel Slope, S_o =	0.0300	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.07	0.00	0.18	0.0	0.01	
0.22	0.17	1.58	0.10	1.43	0.2	0.20	
0.43	0.63	3.10	0.20	2.24	1.4	0.38	
0.63	1.40	4.61	0.30	2.91	4.1	0.57	
0.84	2.47	6.12	0.40	3.52	8.7	0.76	
1.05	3.84	7.63	0.50	4.08	15.7	0.94	
1.26	5.51	9.14	0.60	4.60	25.4	1.13	
1.46	7.49	10.65	0.70	5.10	38.2	1.32	
1.67	9.76	12.17	0.80	5.57	54.4	1.50	
1.88	12.34	13.68	0.90	6.02	74.3	1.69	
2.09	15.22	15.19	1.00	6.46	98.3	1.88	
2.29	18.39	16.70	1.10	6.88	126.6	2.06	
2.50	21.88	18.21	1.20	7.29	159.5	2.25	
2.40	20.12	17.47	1.15	7.09	142.68	2.1564	DESIGN Q

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

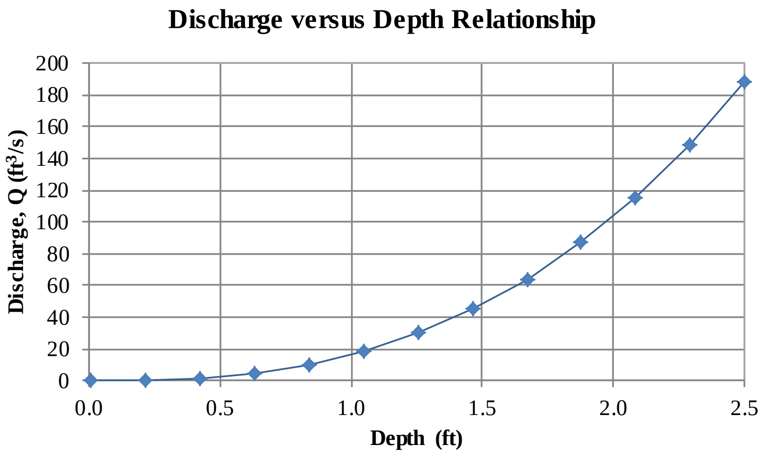
Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: Top Deck Drainage Terrace, 0.15% Slope

Peak Discharge, Q_{max} = 73.20 cfs
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 33.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.040
Longitudinal Channel Slope, S_o = 0.0015 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.36	0.00	0.04	0.0	0.00	
0.22	0.85	7.87	0.11	0.33	0.3	0.01	
0.43	3.25	15.38	0.21	0.51	1.7	0.02	
0.63	7.20	22.88	0.31	0.67	4.8	0.03	
0.84	12.70	30.39	0.42	0.81	10.2	0.04	
1.05	19.75	37.90	0.52	0.93	18.4	0.05	
1.26	28.35	45.40	0.62	1.05	29.9	0.06	
1.46	38.50	52.91	0.73	1.17	44.9	0.07	
1.67	50.20	60.42	0.83	1.28	64.0	0.08	
1.88	63.45	67.92	0.93	1.38	87.5	0.09	
2.09	78.25	75.43	1.04	1.48	115.7	0.10	
2.29	94.60	82.94	1.14	1.58	149.0	0.11	
2.50	112.50	90.44	1.24	1.67	187.7	0.12	
1.76	55.51	63.53	0.87	1.32	73.20	0.08	DESIGN Q



C

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

Project: Fairbanks Landfill Expansion

Ditch ID: **Downchute Channels; 4:1 Slope**

Peak Discharge, Q_{max}= 183.00 cfs
Bottom Width, B = 5.00 ft
Left Side Slope, Z_1 = 3.00 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.030
Longitudinal Channel Slope, S_o = 0.25 ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.05	5.06	0.01	1.15	0.1	0.15	
0.18	0.97	6.11	0.16	7.28	7.1	2.48	
0.34	2.06	7.16	0.29	10.81	22.3	4.48	
0.51	3.31	8.21	0.40	13.55	44.9	6.29	
0.67	4.73	9.26	0.51	15.86	75.0	7.96	
0.84	6.31	10.31	0.61	17.90	112.9	9.55	
1.01	8.06	11.36	0.71	19.75	159.1	11.07	
1.17	9.97	12.41	0.80	21.46	213.9	12.53	
1.34	12.04	13.45	0.90	23.07	277.8	13.96	
1.50	14.29	14.50	0.98	24.58	351.2	15.37	
1.67	16.69	15.55	1.07	26.03	434.5	16.74	
1.83	19.26	16.60	1.16	27.42	528.3	18.10	
2.00	22.00	17.65	1.25	28.77	632.8	19.45	
1.08	8.91	11.83	0.75	20.55	183.00	11.74	DESIGN Q

Discharge versus Depth Relationship