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DRAINTUBE

DESIGN GUIDANCE DOCUMENT

DESIGN, CONSTRUCTION, AND MONITORING OF DRAINTUBE™ FOR U.S. LANDFILL APPLICATIONS

Prepared for AFITEX-TEXEL inc.
File No. 3651.00

Updated on June 2015
by AFITEX-TEXEL inc.

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APPENDICES

1.0 INTRODUCTION

DRAINTUBE™, manufactured by AFITEX-TEXEL inc., combines geosynthetic and pipe technology into a product that has a variety of fluid management applications. DRAINTUBE™ combines two layers of 100 percent polypropylene or polyester geotextile that are needle punched together with perforated corrugated polypropylene pipe inserted between the layers.

AFITEX-TEXEL is based in North America with manufacturing facilities in Canada. The company is the joint venture of AFITEX Géosynthétiques, inc. and TEXEL. AFITEX Géosynthétiques, inc. is a French company that has specialized in drainage products for over 25 years and is an industry leader throughout Europe. TEXEL[1] is a Canadian company founded in 1967 that manufactures a range of nonwoven materials. DRAINTUBE™ has been used throughout Europe, Canada, and the United States on a variety of projects and for a range of uses. More than 100 million square feet have been installed since 1992. DRAINTUBE™ has been manufactured in Canada for more than 5 years.

1.1 Applications

DRAINTUBE™ has been successfully used on hundreds of projects around the world. The product is manufactured to meet project specific hydraulic characteristics and soil properties. DRAINTUBE™ combines the separating and filtering performance of geotextiles with the drainage ability of perforated pipes. Although the purpose of this document is to describe the landfill gas management applications of DRAINTUBE™, there are a wide range of other applications for DRAINTUBE™. Examples of other DRAINTUBE™ applications are provided below.

Roadwork and Civil Engineering

- Replaces clean stone and geotextile separators in a standard road section to provide effective drainage for roads, parking lots, walls, tunnels, roof gardens, and other earthwork projects.
- Results in lower costs, faster construction, less excavation and/or backfill, and better performance.

Tailings and Mining Applications

- Provides liquid and gas drainage for waste storage covers/caps.
- Provides drainage for tailings dams, which increases the overall stability.
- Provides leachate drainage in metals extraction using heap leaching techniques.
- Promotes groundwater drainage under storage ponds.

[1] TEXEL is a division of ADS inc.

Sports Field Applications

- Replaces the layer of stone and geotextile separators in a traditional synthetic sports field section and provides effective drainage.
- Results in cost reductions, an easier installation, variable design options, and improved performance.

Environmental Applications

- Provides drainage for landfill closures.
- Replaces part of granular layer and protective geotextile within leachate collection system at the bottom of the landfill.
- Provides groundwater and/or gas drainage under lined ponds.
- Promotes vapor collection and removal from under buildings.
- ***Provides landfill gas collection from below the cap and at the landfill surface, or replaces landfill gas collection trenches.***

1.2 Landfill Gas Collection

The application of DRAINTUBE™ for landfill gas (LFG) collection is the focus of this design guidance document. LFG is produced during the decomposition of putrescible material in landfills by microorganisms. LFG is typically 40 to 60 percent methane with the remainder consisting of carbon dioxide with limited amounts of nitrogen, oxygen, and other compounds. Methane is a greenhouse gas that has 21 times more of an impact on climate change than carbon dioxide.[2] LFG must be removed from the landfill to avoid odors, and to limit the migration of methane to the atmosphere or nearby structures, which would result in an explosive hazard.

Typically, LFG is controlled by an active or passive gas system. A passive system consists of vents that emit LFG into the atmosphere; whereas an active system extracts LFG by applying a vacuum to a network of collection wells and trenches. In an active system, LFG is collected and sent to a destruction device, such as a flare, where it is combusted and the methane is converted to carbon dioxide. LFG can be used as a "green" fuel source for engines and boilers, or can be processed into a compressed natural gas for vehicle use.

There are three main applications for DRAINTUBE™ in LFG collection and control – (i) as the gas collection layer within the final cover system; (ii) as an interim measure to intercept surface emissions; and (iii) in place of gas collection trenches. For each application, DRAINTUBE™ is connected to a collector pipe using the Quick Connect system so that vacuum can be applied.

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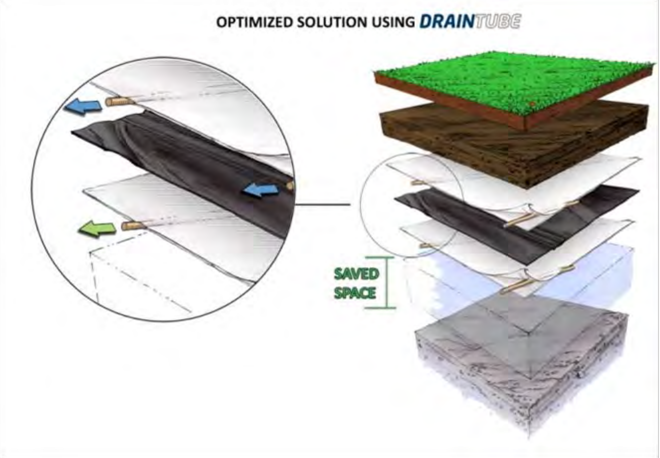
[2] "Overview of Greenhouse Gases: Methane Emissions," United States Environmental Protection Agency, http://epa.gov/climatechange/ghgemissions/gases/ch4.html.

1.2.1 Final Cover System



Some states require that the final cover system of a landfill include a granular gas venting layer below the cap geomembrane. While the required thickness of this section may vary from state to state, DRAINTUBE™ can be used to completely replace the layer. It can also be used above the geomembrane as a drainage media for stormwater that has infiltrated into the cover system. In either case, DRAINTUBE™ may allow for a reduced thickness of a standard final cover section, thereby increasing the capacity of the landfill.

1.2.2 Surface Emissions

DRAINTUBE™ can also be installed at the surface of the landfill in areas that do not yet have final cover, but may have fugitive LFG emissions that need to be collected and/or reduced. DRAINTUBE™ can be installed at the surface and covered with a plastic sheet/geomembrane to increase the collection efficiency and limit air intrusion. When used in surface applications, DRAINTUBE™ and overlying geomembrane must be properly anchored to protect the product.

By intercepting fugitive emissions that are being emitted from the surface of the landfill, odors may be reduced. Additionally, by applying a vacuum to the installed DRAINTUBE™, surface emissions in areas of concern can be reduced and the results of surface emission scans for methane readings can be improved.[3]

1.2.3 In Place of LFG Collection Trenches

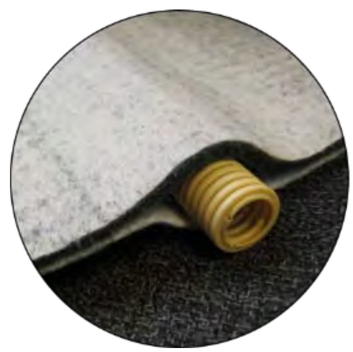
Construction of a typical LFG collection trench involves significant waste excavation and relocation, and the purchase and installation of perforated high-density polyethylene (HDPE) pipe and drainage aggregate. The perforated pipe is typically connected to solid HDPE pipe and a wellhead, through which vacuum is modulated. DRAINTUBE™ offers an economical alternative to typical trenches by eliminating the waste trenching and relocation, the perforated HDPE pipe, and the aggregate. DRAINTUBE™ can be rolled out over prepared waste and covered with additional waste. The waste within a foot of the installed DRAINTUBE™ should have no large protruding items that could damage the geotextile. A vacuum can be applied to the installed DRAINTUBE™ just as it would be applied to a typical LFG collection trench.

[3] Surface emission scans are required for certain landfills as defined by the New Source Performance Standards (NSPS) for MSW Landfills (40 CFR 60 Subpart WWW) or by state environmental agencies.

Construction of a typical gas collection trench

Installation of DRAINTUBE™

2.0 DRAINTUBE™ SPECIFICATIONS



DRAINTUBE™ consists of two nonwoven, needle-punched geotextiles; one serving as a drainage layer and the other as a filter layer. The geotextiles are comprised of short fibers of 100 percent polypropylene or polyester. The two geotextiles are needle punched together with uniformly spaced gaps for the perforated corrugated pipe. The corrugated polypropylene pipe is perforated with two holes per corrugation at 180 degree spacing, rotated 90 degrees per valley.

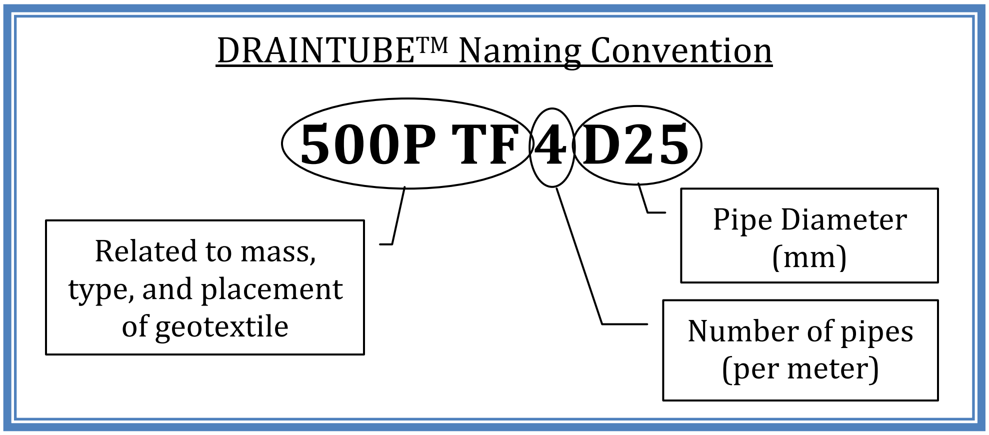
2.1 Manufacturing

Depending on the hydraulic performance requested, there are many variations of the product that can be manufactured and supplied. DRAINTUBE™ is produced in approximately 13 foot (ft) wide rolls. Testing of DRAINTUBE™ is performed at regular intervals during manufacturing to assure consistency of the material. The geotextiles are tested for mass per area, thickness, tensile strength, elongation, and tear strength at a frequency of 1 test per 107,639 square feet (ft^2) (10,000 square meters, m^2) of material produced. In addition, the geotextiles are tested for puncture strength and bursting strength at a frequency of 1 test per 861,113 ft^2 (80,000 m^2) of material produced. Additional, yearly testing of the geotextiles is performed, which includes ultraviolet light (UV) resistance, permeability/permittivity, transmissivity/flow rate, wetability, apparent opening size (AOS) and filtration opening size (FOS).

Material specifications for the various DRAINTUBE™ products are presented on the individual data sheets (available online or in Appendix A for select products).

2.2 Naming Convention

Each DRAINTUBE™ product has an identifying series name that explains the components of the product and can help guide the product selection for a particular application.



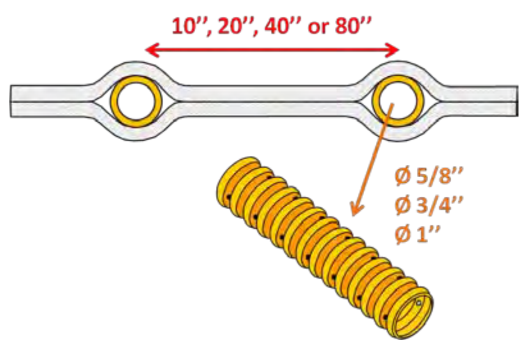
Type of Material and Placement

DRAINTUBE™ is available with geotextiles having a variety of mass per unit area options ranging from 8 to 70 ounces per square yard (oz/yd²). The product data sheet should be reviewed for the exact mass per unit area as some of the values were rounded for ease of the naming convention. Typically, DRAINTUBE™ is manufactured using a polypropylene nonwoven geotextile with a combination of other materials such as polypropylene or polyester nonwoven geotextiles, or a thin polyethylene film.

Depending on the application, the geotextile components of DRAINTUBE™ can act as a capillary and/or filtration layer; or a cushion, separation, and/or stabilization layer.

Spacing of Pipes and Pipe Diameter

The perforated polypropylene plastic pipe component of DRAINTUBE™ is available in a range of diameters and may be inserted at various spacing within the product. The spacing of the pipes is designated by the number of pipes per unit width of the product; which in this case, is 1 meter (m). DRAINTUBE™ is available in pipes per unit width of 0.5, 1, 2, or 4, which correspond to a pipe spacing of approximately 80 inches (2 m), 40 inches (1 m), 20 inches (0.5 m), and 10 inches (0.25 m), respectively.

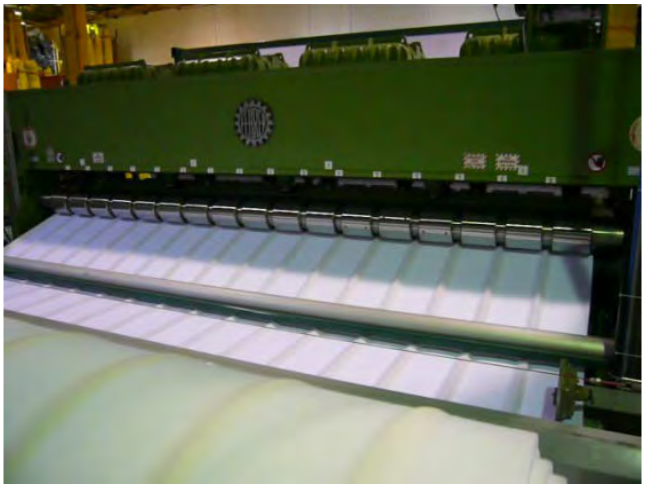


Pipe diameters are available in three sizes; 5/8 inch (16 millimeters, mm), 3/4 inch (20 mm) and 1 inch (25 mm). These diameters are designated by the letter "D" and the diameter in millimeters at the end of the product name.

2.3 Performance and Testing

DRAINTUBE™ has been tested for a variety of performance applications including transmissivity, durability, and interface friction angle. The results of this research has been published and presented at a variety of professional conferences and is available online or by request.

2.3.1 Transmissivity



The specific transmissivity for each product is stated on product data sheets, available online, and in Appendix A for select products. DRAINTUBE™ has been tested under high compressive loads, and the results indicate that the transmissivity of the product is gradient sensitive rather than load or time sensitive. When the product is properly confined, increasing the normal load does not significantly affect the transmissivity at loadings up to 50,000 pounds per square foot (psf). Additionally, the test data indicates no change in transmissivity over the first 100 hours such that there appears to be little affect due to creep (a creep reduction factor of 1.0 was calculated).[4] Based on these results, DRAINTUBE™ should maintain its transmissivity during the active life (i.e., filling period) of typical US landfills and should not be adversely affected by the weight of the waste mass during post-closure.

As expected, the transmissivity of DRAINTUBE™ is proportional to the number of pipes per unit width. In other words, the properties that are measured on one pipe and calculated for a unit width of one meter, can be multiplied by the number of pipes per unit width to find the transmissivity of a product with increased number of pipes.[5]

2.3.2 Durability

As previously mentioned, DRAINTUBE™ can sustain high loads and maintain performance goals. Along with those benefits, the product has been tested and shown to exhibit comparable or better resistance to oxidation and similar or better durability than typical plastic geonets.[6]

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4 Saunier, Pascal, William Ragen, and Eric Blond, "Assessment of the Resistance of Drain Tubes Planar Drainage Geocomposites to High Compressive Loads," *International Conference on Geosynthetics* (Brazil) Vol. 3, p. 1131, May 23-27, 2010.

5 Blond, Eric, Pascal Saunier, Traik Daqoune, and Stephane Fourmont, "Assessment of the Effect of Specimens Dimensions on the Measured Transmissivity of Planar Tubular Drainage Geocomposites," 66th Canadian Geotechnical Conference and the 11th Joint CGS/IAH-CNC Groundwater Conference, Sept. 29, 2013 to Oct. 3, 2013.

6 Beaumier, David and Eric Blond, "Durability of Polypropylene Tubes 'DRAINTUBE'," Sageos, division of CTT Group, June 2, 2008.

2.3.3 Friction Angle

Interface friction angle testing was performed by GAI-LAP certified laboratories on a variety of DRAINTUBE™ products and other materials typically used for landfill final cover systems. The overall results are summarized in the table below. Engineers are encouraged to base their design on parameters derived from tests performed on site-specific materials under anticipated conditions.

Material Tested	**Typical Friction Angle (°) with DRAINTUBE™**
Interface Sand/Granular Soil	Directly related to the internal friction angle of the soil.
Textured Geomembrane	28-30[7]
Bituminous Geomembrane	36
Gripnet Geomembrane	35
Geosynthetic Clay Liner	23
Low permeability soil	Directly related to the internal friction angle of the soil.

3.0 DESIGN METHODS AND CONCEPTS

The design methods and concepts involved in choosing a DRAINTUBE™ product for a specific LFG collection application are presented in the following section. Example technical specifications for DRAINTUBE™ are provided in Appendix B.

3.1 Within a Landfill Final Cover System –DRAINTUBE 404 ST2 D25

Solid waste regulations vary from state to state, as do the typical and required specifications for final cover systems at landfills. In some states, such as Vermont, Maine, and New York, the final cover system is required to include a gas venting layer. The intent of the gas venting layer is to provide a conduit for LFG to travel to vents or gas wells so that gas pressure does not develop below the cover system. Typically, this layer is required to be constructed using granular material exhibiting a transmissivity of 1.52×10^{-6} to 3.05×10^{-6} square meters per second (m^2/sec), which is based on a hydraulic conductivity of 1×10^{-3} centimeters per second (cm/s) and a layer thickness ranging from 6 to 12 inches.

The chart below depicts the transmissivity of the DRAINTUBE 404 ST D25 product (considering multiple pipe options) compared to the typical required performance values for a granular gas venting layer. When comparing the transmissivity of geosynthetics to that of a granular collection layer, equivalency should be evaluated considering the design slope and length of the layer materials. The transmissivity of some geosynthetic collection layer materials may not be considered equivalent to a granular collection layer when slope and drainage length are considered.[8]

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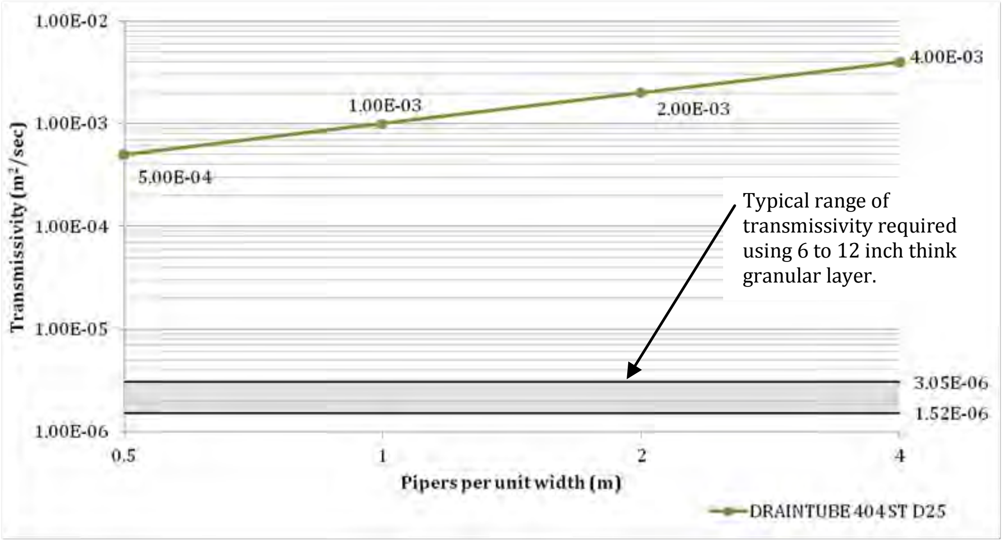
[7] Blond, Eric, Guy Elie, "*Interface Shear-Strength Properties of Textured Polyethylene Géomembranes*", Sea to Sky Geotechnique, September 20, 2006.

[8] Giroud, J.P., A. Zhao, and R. Bonaparte, "*The Myth of Hydraulic Transmissivity Equivalency Between Geosynthetic and Granular Liquid Collection Layers,*" Geosynthetics International, Vol. 7, Nos. 4-6, 2000.



There are many DRAINTUBE™ products that can replace the entire gas venting layer. DRAINTUBE 404 ST2 D25 is generally suggested for this application as it cost effectively provides reasonable durability, interface friction, and transmissivity (for soil materials, the product of hydraulic conductivity and layer thickness). DRAINTUBE 606 ST D25 can also be used to address site specific mechanical issues and increase the puncture resistance of the material.

Before using any product, the project-specific requirements and state regulations should be reviewed against the DRAINTUBE™ data sheets (available online or in Appendix A for select products) as there are many variations of DRAINTUBE™ that can be used to meet specific needs and hydraulic performance goals.

When used as the gas venting layer, DRAINTUBE™ is installed in the same manner as other geotextiles/geomembranes that are part of the cover system. Because of the reduced thickness of the layer, landfill owners/operators may realize increased landfill capacity by installing DRAINTUBE™ in place of a soil layer.

3.2 Surface Emissions – DRAINTUBE 500P TF2 D25

In areas of a landfill where surface emissions of LFG are posing odor, regulatory, safety, or other concerns, DRAINTUBE™ can be installed at the surface to collect LFG. The design for this application depends on the size and shape of the area of concern. DRAINTUBE™ can be installed as necessary, and additional extraction locations should be considered when the installed product exceeds about 246 ft (75 m). Also, for this application, a plastic sheet/geomembrane should be placed over the entire

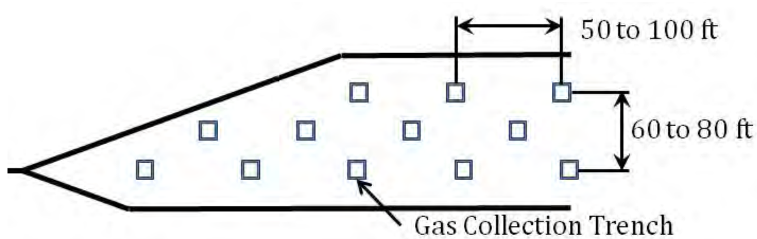
DRAINTUBE™ installation to limit the amount of oxygen intrusion (see photo). The sheet/geomembrane should be appropriately anchored to limit uplift from LFG emissions and wind. Anchoring can be achieved using on-site soil, sand bags, or other appropriate materials placed on top of the DRAINTUBE™ and the overlying plastic sheet/geomembrane.

A perimeter anchor trench system may be beneficial to facilitate long term installations. The anchor trench system should be designed in accordance with industry practice. The anchor trenches allow for the possible extension of DRAINTUBE™ and the overlying plastic sheet/geomembrane. Perimeter and intermediate anchoring location(s) within the product installation area should reduce the potential for material uplift and wind damage. Additional installation guidelines are discussed in Section 4.0 of this document.

The DRAINTUBE 500P TF2 D25 product is recommended for surface installations because of its durability (i.e., greater mass per unit area). Because LFG collection will be near the surface of the landfill, the vacuum applied may need to be limited to reduce air infiltration from the atmosphere. The number of pipes can be reduced to one per 40 inches of width if air intrusion is of concern. This will reduce the collection efficiency of the overall DRAINTUBE™ installation; however, vacuum can be controlled at the wellhead, based on the composition of the gas being collected.

3.3 In Place of Gas Collection Trenches – DRAINTUBE 500P LFG4 D25

Typical landfill gas collection trenches are spaced 50 to 100 feet apart horizontally in the waste mass of a landfill and 30 to 40 feet vertically, as shown to the right. Each collection trench has a zone of influence, in which the vacuum that is applied to the trench is influencing the movement of LFG within the landfill. Maintaining this spacing is important for efficient LFG collection. Typically, gas collection trenches are designed to include:



- A 3-ft wide by 3 to 5-ft deep trench into existing waste along the length of the gas collection trench;
- A 6-inch diameter perforated HDPE pipe along length of the trench; and
- Drainage aggregate within trench section.

Some trench designs include a geotextile placed between the aggregate and the waste.

DRAINTUBE™ eliminates the entire trench section and can be installed directly over prepared waste in the area requiring LFG collection. Depending on the LFG coverage desired, multiple 13-ft wide rolls of DRAINTUBE™ can be installed side-by-side length wise. As previously noted, additional vacuum locations should be considered when the installed product exceeds one roll length, about 246 ft (75 m). Depending on site conditions and operational preferences, DRAINTUBE™ can be deployed in two ways (Alternate A and B), as depicted on the Typical Details in Appendix C.

- Alternative A is the recommended, easier installation. DRAINTUBE™ is rolled out and vacuum is applied to a collector pipe along the width of the roll on one end.
- Alternative B is a more complicated and slower installation, but provides increased vacuum capability. The collector pipe is installed along the entire length of the collection area, instead of the width. DRAINTUBE™ is then cut into 13-ft wide panels of a length sufficient to cover the subject area, and connected into the system along the collector pipe. This results in multiple 13-ft wide panel sections of DRAINTUBE™ requiring panel joining along the length of the trench.

Overall, major design components of a DRAINTUBE™ LFG collection trench should include:

- Similar spacing to typical LFG collection trenches:
  - 50 to 100 ft horizontally; and
  - 30 to 40 ft vertically.
- Well-graded base of select waste (free of waste objects that could damage the DRAINTUBE™ components during installation, such as sharp metal), sloped at 2 percent (minimum) away from the collector pipe.
- If a minimum of 2 percent slope away from the collector pipe is not attainable, condensate will need to be managed. A condensate drain can be installed at one end of the collector pipe. See Appendix C for a typical detail.
- A minimum of 3 ft of waste, which is free of items that could damage the components, should be placed on top of DRAINTUBE™ prior to operating a compactor over the area (The size and weight of the waste compactor as well as the length of the compactor teeth should be considered when designing the thickness of the initial waste layer over any DRAINTUBE™ product),
- The diameter of the collector pipe should be selected based on the anticipated LFG flow rate and velocity (a 6-inch diameter HDPE pipe is typical).
- **DRAINTUBE 500P LFG4 D25** is recommended for this application:
  - Maximum pipe diameter and number of pipes per unit width; and
  - High mass per unit area for durability;

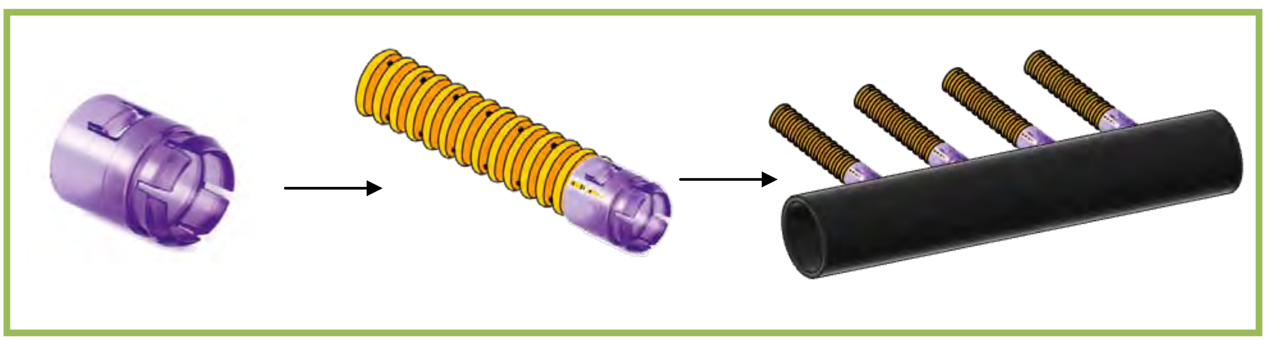
4.0 INSTALLATION CONSIDERATIONS

There are few considerations associated with installing DRAINTUBE™, which is one of the benefits of using the product. For LFG collection applications, there are no geosynthetic testing requirements required by the manufacturer. The *Installation Guideline for DRAINTUBE™ for Liquid and LFG Collection*, provided in Appendix D, presents the recommended handling, storage, installation, connections, and repair methods for DRAINTUBE™ products. Generally, the product is rolled over the proposed area and connections are made into the existing gas collection system, which provides the vacuum source. The same LFG collection wellhead or remote wellhead that is used for a typical gas collection trench can be used with DRAINTUBE™.

Three recent installations of DRAINTUBE™ are summarized in Appendix E and include two surface installations in Vermont and New Hampshire as well as the installation of a gas collection trench in New Hampshire.

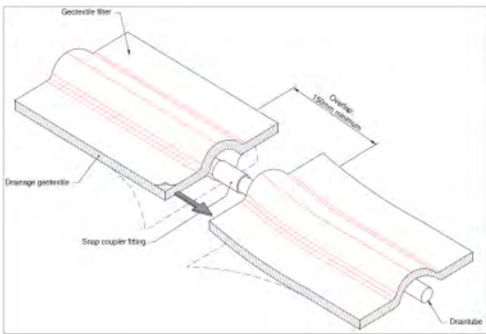
4.1 Quick Connect System

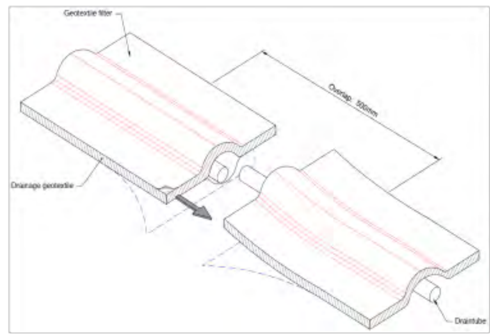
For each of the three LFG applications described in Section 3.0, the Quick Connect System is used to connect the perforated pipes to the LFG system conveyance piping. As illustrated below, the DRAINTUBE™ perforated pipes are fitted with snap-on connectors, which are inserted into pre-drilled holes in the HDPE conveyance pipe. Additional installation information is available in Appendix D as well as shown on the typical details in Appendix B. Videos illustrating the Quick Connect System are available at www.youtube.com/user/DRAINTUBEVideos.



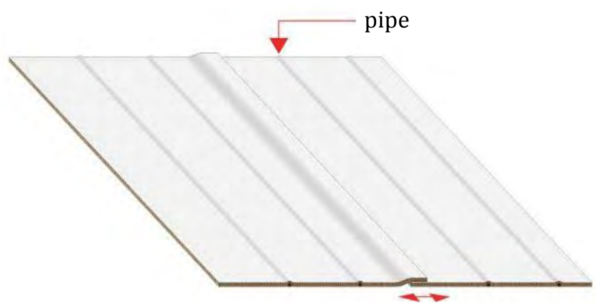
4.2 Panel Joining

Multiple rolls of DRAINTUBE™ may be used during one installation and may require panel joining. When one roll is connected to another roll to create a longer roll, the perforated pipes must also be connected. The pipe are joined using mechanical connectors, or the pipes can be overlapped, as depicted below. Under high compressive loads, such as those at a landfill, mechanical connectors are the preferred method. The filter layer of the geocomposite must be rolled back to make the pipe connection and should be seamed, welded, or overlapped for completion. Additional information is provided in Appendix D.





If panels need to be connected along the long edge, as shown in the illustration to the right, a minimum overlap of 2 to 4 inches is required. The overlap can be secured with sewn seams or hot welds. Welds should be no greater than 6 feet apart. Additional information is provided in Appendix D and shown in the typical details of Appendix C.



4.3 Installer Qualifications

As noted in the Technical Specifications in Appendix B, DRAINTUBE™ installers should meet the following qualifications.

- Installer should have demonstrated experience in the installation of DRAINTUBE™, have installation staff trained by the manufacturer, or work under the guidance of the manufacturer's representative;
- Installer should be trained and experienced in field handling, storing, deploying, and installing geosynthetic materials; and
- Installer should have at least four years of experience in sewing geotextiles and have completed at least four projects that required geotextile sewing.

4.4 Quality Assurance

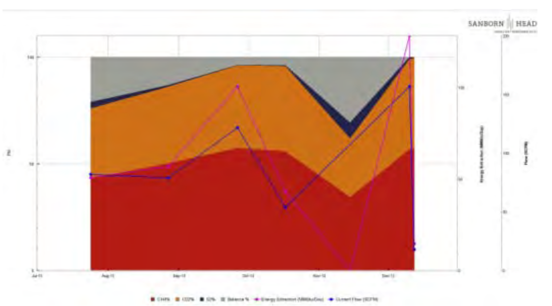
It is recommended that a representative of the owner or engineer observe and document the unloading, storage, deployment, and installation of DRAINTUBE™. If required by a construction quality assurance (CQA) plan, samples can be taken for conformance testing, although such testing is not required by the manufacturer. Each sample should be at least 2 ft (610 mm) long and taken across the full width of the DRAINTUBE™ roll.

During installation, observations should be made that document the connections have been made properly and care is taken to properly connect the system to the vacuum source.

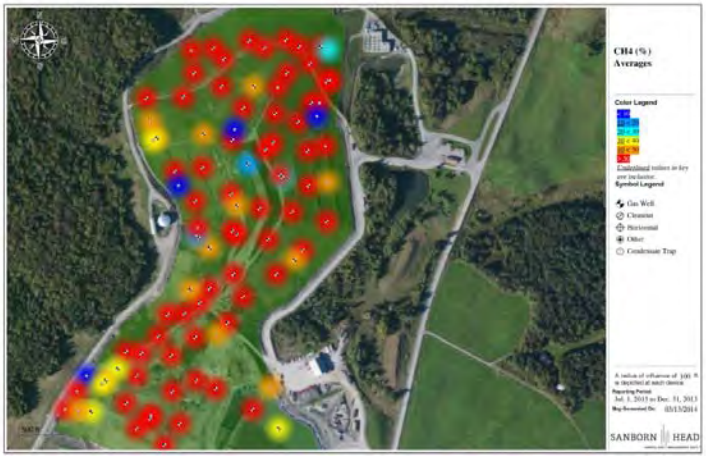
5.0 MONITORING

Once DRAINTUBE™ has been installed and connected to a vacuum source, vacuum can be applied in the same manner as a typical LFG well, trench, or other extraction point. Care should be taken to slowly apply vacuum while observing the gas quality and flow when first bringing a new extraction feature online. The amount of vacuum applied will be contingent on system constraints as well as gas quality at the extraction locations. General considerations for operation are listed below.

- Gas quality, applied vacuum, and temperature should be routinely monitored using a gas analyzer and extraction monitor. The LFG extraction rate should be adjusted based on monitoring results by partially opening or closing the valve on the wellhead.
- If using DRAINTUBE™ as a replacement for a gas collection trench, LFG monitoring and adjustment is performed to optimize extraction of LFG.
  - Ideally, LFG should contain 50 percent methane and applied vacuum should be adjusted accordingly to reach this quality. Vacuum should be maintained at the wellhead to provide for collection of the LFG.
- If using DRAINTUBE™ within the final cover system, or for surface emissions, gas quality may never be consistent or of good quality (i.e., approximately 50 percent methane).
  - A vacuum should be maintained at the wellhead to provide proper collection of the LFG; and
  - Focus should be kept on reducing surface emissions or collecting LFG from the final cover system, rather than producing good quality LFG. These systems are close to the atmosphere and should be expected to have air intrusion into the system.



It is strongly recommended that the data collected through LFG monitoring be stored and reviewed to help improve landfill operations. Some data may need to be recorded and used for regulatory and reporting requirements. There are interactive, internet-based, landfill gas evaluations tools that can be used to efficiently store, manage, and analyze landfill gas data on both small (individual well) and large (gas collection and control system performance) scales (see http://sanbornhead.com/what-we-do/services/solid-waste/interactive-landfill-gas-data-evaluation-tool for more information).



The data can be uploaded by technicians and remotely monitored by environmental managers and landfill owners, and used to graph historic trends, detect issues with particular wells, manage maintenance, and provide interactive maps to evaluate data trends and problem areas of the landfill.

Please request additional information from DRAINTUBE™ on available products and services.

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APPENDIX A

PRODUCT DATA SHEETS

DRAINTUBE 404 ST D25 series

The product consists of two 4 oz/sy geotextile layers comprised of short synthetic fibers of 100% polypropylene which are needlepunched together. Corrugated PP pipes with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley are inserted between the geotextile layers at uniform intervals.
The geotextiles are UV resistant at 70% after 500 hrs (AASHTO M288-05 requirement).

	Standard	Reference	MARV	Unit
Geotextiles properties				
Mass per unit area	ASTM D5261		4.0 (136)	oz/sy (g/m^2)
Thickness	ASTM D5199	Under 2 kPa	43 (1.1)	mil (mm)
Grab Tensile	ASTM D4632	MD & XMD direction	106 (470)	lbs (N)
Grab Ellongation		Min-Max value	50-105	%
Puncture (CBR)	ASTM D6241		306 (1360)	lbs (N)
UV Resistance (after 500 hrs)	ASTM D4355		70	%
Apparent Opening Size (1)	ASTM D4751		50 (300)	US sieve (µm)
Flow rate (2)	ASTM D4491		140	gal/min/ft^2
Permittivity (2)			2.00	sec^{-1}
Mini-pipe properties				
Outside Diameter	ASTM D2122-98	Nominal value	0.97 (25)	inch (mm)
Pipe stiffness at 5% deflection	ASTM D2412-02		435 (3000)	psi (kPa)
Spacing between pipes	10 to 80 inches (up to 4 pipes per meter of width)			
Geocomposite properties				
Transmissivity (3)	ASTM D4716	**Product**	**m^2/s**	**gpm/ft (l/min/m)**
		DRAINTUBE 404 ST0.5 D25	5.00E-04	2.42 (30.0)
Compression load = 10,000 psf		DRAINTUBE 404 ST1 D25	1.00E-03	4.83 (60.0)
Hydraulic gradient = 0.1		DRAINTUBE 404 ST2 D25	2.00E-03	9.66 (120.0)
Seating Time = 100 hours		DRAINTUBE 404 ST4 D25	4.00E-03	19.32 (240.0)
Puncture (CBR)	ASTM D6241		460 (2040)	lbs (N)

Packaging	Standard roll dimensions	Length	246.06 (75)	ft (m)
		Width	13.06 (3.98)	ft (m)
		Roll weight	211 - 409	lb
		Inside diameter of roll	95	mm

Unless noted, the printed values are "Minimum Average Roll Values" (MARV) in the weakest direction as the typical value minus two standard deviations according to a normal distribution and a confidence interval of 95 %.
(1) Maximum Average Roll Values (MaxARV) | (2) Tested on the filter in the area of the pipe after assembly | (3) Typical Value - Transmissivity measured on a 250 mm wide specimen installed as follows : sealed sand / geocomposite / geomembrane / sealed sand, with one pipe (confined in sand) installed in the middle of the test chamber in the longitudinal direction. The given transmissivity is obtained from a linear relationship between the number of pipes and the measured transmissivity.

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DRAINTUBE 606 ST D25 series

The product consists of two 6 oz/sy geotextile layers comprised of short synthetic fibers of 100% polypropylene which are needlepunched together. Corrugated PP pipes with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley are inserted between the geotextile layers at uniform intervals.
The geotextiles are UV resistant at 70% after 500 hrs (AASHTO M288-05 requirement).

	Standard	Reference	MARV	Unit
Geotextiles properties				
Mass per unit area	ASTM D5261		6.0 (203)	oz/sy (g/m^2)
Thickness	ASTM D5199	Under 2 kPa	67 (1.7)	mil (mm)
Grab Tensile	ASTM D4632	MD & XMD direction	160 (712)	lbs (N)
Grab Ellongation		Min-Max value	50-105	%
Puncture (CBR)	ASTM D6241		450 (2000)	lbs (N)
UV Resistance (after 500 hrs)	ASTM D4355		70	%
Apparent Opening Size (1)	ASTM D4751		70 (212)	US sieve (µm)
Flow rate (2)	ASTM D4491		125	gal/min/ft^2
Permittivity (2)			1.65	sec^{-1}
Mini-pipe properties				
Outside Diameter	ASTM D2122-98	Nominal value	0.97 (25)	inch (mm)
Pipe stiffness at 5% deflection	ASTM D2412-02		435 (3000)	psi (kPa)
Spacing between pipes	10 to 80 inches (up to 4 pipes per meter of width)			
Geocomposite properties				
Transmissivity (3) Compression load = 10,000 psf Hydraulic gradient = 0.1 Seating Time = 100 hours	ASTM D4716	**Product**	**m^2/s**	**gpm/ft (l/min/m)**
		DRAINTUBE 606 ST0.5 D25	5.00E-04	2.42 (30.0)
		DRAINTUBE 606 ST1 D25	1.00E-03	4.83 (60.0)
		DRAINTUBE 606 ST2 D25	2.00E-03	9.66 (120.0)
		DRAINTUBE 606 ST4 D25	4.00E-03	19.32 (240.0)
Puncture (CBR)	ASTM D6241		675 (3000)	lbs (N)
Packaging	Standard roll dimensions	Length	246.06 (75)	ft (m)
		Width	13.06 (3.98)	ft (m)
		Roll weight	299 - 497	lbs
		Inside diameter of roll	95	mm

Unless noted, the printed values are "Minimum Average Roll Values" (MARV) in the weakest direction as the typical value minus two standard deviations according to a normal distribution and a confidence interval of 95 %.
(1) Maximum Average Roll Values (MaxARV) | (2) Tested on the filter in the area of the pipe after assembly | (3) Typical Value - Transmissivity measured on a 250 mm wide specimen installed as follows : sealed sand / geocomposite / geomembrane / sealed sand, with one pipe (confined in sand) installed in the middle of the test chamber in the longitudinal direction. The given transmissivity is obtained from a linear relationship between the number of pipes and the measured transmissivity.

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DRAINTUBE 500P TF2 D25

The product consists of a drainage layer and a filter layer comprised of short synthetic fibers of 100% polypropylene or polyester which are needlepunched together. Corrugated PP pipes with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley are inserted between the drainage layer and the filter at uniform intervals.

	Standard	Reference	MARV	Unit
Mechanical properties				
Mass per unit area	ASTM D5261		14.7 (500)	oz/sy (g/m^2)
Thickness	ASTM D5199	Under 2 kPa	169 (4.3)	mil (mm)
Grab Tensile	ASTM D4632	MD & XMD direction	326 (1450)	lbs (N)
Grab Ellongation	ASTM D4632	Min-Max value	70-140	%
Tear Strength	ASTM D4533	MD & XMD direction	135 (600)	lbs (N)
Puncture Strength	ASTM D4833	Tested on geocomposite	157 (700)	lbs (N)
Mini-pipe properties				
Outside Diameter	ASTM D2122-98	Nominal value	0.97 (25)	inch (mm)
Pipe stiffness at 5% deflection	ASTM D2412-02		435 (3000)	psi (kPa)
Spacing between pipes	20 inches (2 pipes per meter of width)			
Hydraulic properties				
Apparent Opening Size (1)	ASTM D4751	Tested on the filter	80 (180)	US Sieve (µm)
Permittivity (2)	ASTM D4491	Tested on the filter	1.80	sec^{-1}
Transmissivity (3)	ASTM D4716	Compression load = 10,000 psf Hydraulic gradient = 0.1 Seating Time = 100 hours	2.00E-03	m^2/s
			9.66 (120.0)	gpm/ft (l/min/m)
Packaging	Standard roll dimensions	Length	246.06 (75)	ft (m)
		Width	13.06 (3.98)	ft (m)
		Roll weight	447 (203)	lbs (kg)
		Inside diameter of roll	95	mm

Unless noted, the printed values are "Minimum Average Roll Values" (MARV) in the weakest direction as the typical value minus two standard deviations according to a normal distribution and a confidence interval of 95 %.

(1) Maximum Average Roll Values (MaxARV) | (2) Tested on the filter in the area of the pipe after assembly | (3) Typical Value - Transmissivity measured on a 250 mm wide specimen installed as follows : sealed sand / geocomposite / geomembrane / sealed sand, with one pipe (confined in sand) installed in the middle of the test chamber in the longitudinal direction. The given transmissivity is obtained from a linear relationship between the number of pipes and the measured transmissivity.

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DRAINTUBE 500P LFG4 D25

The product consists of a drainage layer and a filter layer comprised of short synthetic fibers of 100% polypropylene or polyester which are needlepunched together. Corrugated PP pipes with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley are inserted between the drainage layer and the filter at uniform intervals.

	Standard	Reference	MARV	Unit
Mechanical properties				
Mass per unit area	ASTM D5261		14.0 (475)	oz/sy (g/m^2)
Thickness	ASTM D5199	Under 2 kPa	169 (4.3)	mil (mm)
Grab Tensile	ASTM D4632	MD & XMD direction	326 (1450)	lbs (N)
Grab Ellongation		Min-Max value	70-140	%
Tear Strength	ASTM D4533	MD & XMD direction	135 (600)	lbs (N)
Puncture Strength	ASTM D4833	Tested on geocomposite	157 (700)	lbs (N)
Mini-pipe properties				
Outside Diameter	ASTM D2122-98	Nominal value	0.97 (25)	inch (mm)
Pipe stiffness at 5% deflection	ASTM D2412-02		435 (3000)	psi (kPa)
Spacing between pipes	10 inches (4 pipes per meter of width)			
Hydraulic properties				
Apparent Opening Size (1)	ASTM D4751	Tested on the filter	80 (180)	US Sieve (µm)
Permittivity (2)	ASTM D4491	Tested on the filter	1.80	sec^{-1}
Transmissivity (3)	ASTM D4716	Compression load = 10,000 psf Hydraulic gradient = 0.1 Seating Time = 100 hours	4.00E-03	m^2/s
			19.32 (240.0)	gpm/ft (l/min/m)

Packaging	Standard roll dimensions	Length	246.06 (75)	ft (m)
		Width	13.06 (3.98)	ft (m)
		Roll weight	543 (247)	lbs (kg)
		Inside diameter of roll	95	mm

Unless noted, the printed values are "Minimum Average Roll Values" (MARV) in the weakest direction as the typical value minus two standard deviations according to a normal distribution and a confidence interval of 95 %.

(1) Maximum Average Roll Values (MaxARV) | (2) Tested on the filter in the area of the pipe after assembly | (3) Typical Value - Transmissivity measured on a 250 mm wide specimen installed as follows : sealed sand / geocomposite / geomembrane / sealed sand, with one pipe (confined in sand) installed in the middle of the test chamber in the longitudinal direction. The given transmissivity is obtained from a linear relationship between the number of pipes and the measured transmissivity.

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APPENDIX B

TECHNICAL SPECIFICATIONS

SPECIFICATIONS FOR DRAINTUBE™ DRAINAGE GEOCOMPOSITES

The following sample specification provides guidance for preparing site-specific specifications for using DRAINTUBE™ as a drainage geocomposite. This information is provided for reference purposes only and is not intended as a warranty or guarantee. Afitex-Texel assumes no liability in connection with the use of this information. Please contact Afitex-Texel for current product information.

SECTION [*insert Section Number*]
DRAINTUBE™ DRAINAGE GEOCOMPOSITE

PART 1 – GENERAL

1.1 SCOPE OF WORK

A. This specification covers the requirements for the manufacture, fabrication, supply, and installation of DRAINTUBE™ Drainage Geocomposite. The DRAINTUBE™ Drainage Geocomposite and its individual components shall meet or exceed the requirements of this specification. The manufacture, handling, storage, and installation shall be performed in accordance with the procedures provided in this specification.

B. Contractor shall provide all labor, materials, tools, and equipment and perform all operations necessary to furnish, deploy, and install DRAINTUBE™ Drainage Geocomposite in the areas indicated on the Drawings or as required by ENGINEER or OWNER.

1.2 REFERENCES

A. ASTM International (latest version):

1. D2122 Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
2. D2412 Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
3. D4355 Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture, and Heat in a Xenon Arc Type Apparatus
4. D4491 Standard Test Method for Water Permeability of Geotextiles by Permittivity
5. D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
6. D4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
7. D4632 Standard Test Method for Grab Breaking and Elongation of Geotextiles
8. D4716 Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
9. D4751 Standard Test Methods for Determining Apparent Opening Size of Geotextile
10. D4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
11. D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

12. D5199 Standard Test Method for Measuring Nominal Thickness of Geosynthetics
13. D5261 Standard Test Method for Measuring the Mass per Unit Area of Geotextiles
14. D5321 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
15. D6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
16. D7005 Determining the Bond Strength (Ply-Adhesion) of Geocomposites

B. Canadian General Standards Board (CAN/ONGC):

1. CAN/CGSB – 148.1-10-94 Methods of Testing Geosynthetics, Geotextiles – Filtration Opening Size
2. CAN/CGSB – 4.2-26.3-95 Textile Fabric – Determination of Resistance to Water Penetration Hydrostatic Pressure Test

1.3 QUALIFICATIONS

A. Installer shall have demonstrated experience in the installation of DRAINTUBE™ Drainage Geocomposite, have installation staff trained by the manufacturer, or work under the guidance of the manufacturer's representative.

B. CONTRACTOR shall be trained and experienced in field handling, storing, deploying, and installing geosynthetic materials. Alternatively, CONTRACTOR shall engage an experienced Subcontractor who shall meet the experience requirements.

C. CONTRACTOR shall demonstrate at least four years of experience in sewing geotextiles and shall have completed at least four projects that required geotextile sewing. Alternatively, CONTRACTOR shall engage an experience Subcontractor or manufacturer's agent who shall meet the experience requirements.

1.4 QUALITY ASSURANCE

A. A representative if OWNER or ENGINEER shall observe and document the unloading, storage, deployment, and installation of the DRAINTUBE™ Drainage Geocomposite.

B. If required by a Construction Quality Assurance (CQA) Plan, then OWNER or ENGINEER shall obtain samples of the DRAINTUBE™ Drainage Geocomposite for conformance testing. Each sample shall be at least 2 feet (610 mm) long, taken across full width of the geocomposite roll for each type of material furnished for Project.

1.5 WARRANTY

A. Installation shall be warranted against defects in workmanship for a period of 1 year from the date that the installation is deemed complete.

1.6 SUBMITTALS

A. CONTRACTOR shall submit to ENGINEER for approval the manufacturer's data indicating that the properties of the proposed DRAINTUBE™ Drainage Geocomposite conform to the requirements of this Specification.

B. CONTRACTOR shall submit to ENGINEER the manufacturer's quality control test results for the DRAINTUBE™ Drainage Geocomposite produced specifically for the project and certification that the material meets the requirements of this Specification at least 15 days prior to installation of the material.

C. CONTRACTOR shall submit to ENGINEER the following at least 15 days prior to installation:
   1. Drawings showing geocomposite sheet layout, location of seams, direction of overlap, and sewn seams.
   2. Description of proposed method of deployment, sewing equipment, sewing methods, and provisions for holding geocomposite temporarily in place until permanently secured.

PART 2 – PRODUCTS

2.1 MATERIAL DESCRIPTION

A. DRAINTUBE™ Drainage Geocomposite shall consist of two non-woven geotextiles with a perforated polypropylene pipe placed between the geotextiles at a defined and uniform spacing. The geotextile shall be comprised of short synthetic fibers of 100 percent polypropylene or polyester that are needle-punched together to form a geocomposite material. The areas where the perforated pipe (Paragraph 2.1.C) will be inserted during the manufacturing process shall not be needle punched.

B. Depending on the application, the geotextile can act as a capillary and/or filtration layer, a cushion, a separation, and/or stabilization layer.

C. The perforated polypropylene pipe shall function as the primary fluid conveyance, and shall be located within the geotextile layers at the nominal spacing specified. The pipe shall be corrugated with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley.

2.2 DRAINTUBE™ DRAINAGE GEOCOMPOSITE PROPERTIES

A. The components of the DRAINTUBE™ Drainage Geocomposite specified shall meet or exceed the values provided in the Technical Data Sheet provided at the end of this Specification.

2.3 MANUFACTURING QUALITY CONTROL

A. The DRAINTUBE™ Drainage Geocomposite shall be manufactured in accordance with the Manufacturer's Quality Control Plan submitted to and approved by ENGINEER.

PART 3 – EXECUTION

3.1 INSPECTION

A. Prior to deploying any DRAINTUBE™ Drainage Geocomposite, CONTRACTOR shall carefully inspect the surface on which the material will be placed and verify that the material may be placed without adverse impact.

B. CONTRACTOR shall certify in writing that the surface on which the DRAINTUBE™ Drainage Geocomposite will be installed is acceptable. The certificate of acceptance shall be given to ENGINEER prior to commencement of DRAINTUBE™ Drainage Geocomposite installation in the area under consideration.

C. Special care shall be taken to avoid desiccation cracking or freezing of the soil surface. The soil surface shall be maintained in the required condition throughout the course of geocomposite installation.

3.2 MATERIAL STORAGE AND HANDLING

A. Rolls of DRAINTUBE™ Drainage Geocomposite shall be shipped to site in a manner that will not cause damage to the rolls.

B. CONTRACTOR shall be responsible for the handling, storage, and care of the DRAINTUBE™ Drainage Geocomposites from the time of delivery to the site until final acceptance of the completed work by ENGINEER and OWNER. CONTRACTOR shall be liable for all damages to the materials during such time.

C. CONTRACTOR shall comply with ASTM D4873 with respect to storing and handling the DRAINTUBE™ Drainage Geocomposite.

D. The rolls shall be stored flat on a smooth surface protected against dirt, mud, and excessive heat.

E. DRAINTUBE™ Drainage Geocomposite shall not be stockpiled or stored within the work area limits.

3.3 MATERIAL PLACEMENT

A. DRAINTUBE™ Drainage Geocomposite shall not be placed, seamed/joined, or repaired during periods of precipitation, excessively high winds, or in areas of ponded water or excessive moisture.

B. DRAINTUBE™ Drainage Geocomposite shall be installed in accordance with manufacturer's recommendations, and as shown on the Drawings and specified herein.

C. DRAINTUBE™ Drainage Geocomposite shall be installed in the direction of the slope such that the pipe components are oriented with the intended flow direction (typically perpendicular to the contours) unless otherwise specified by the ENGINEER.

D. The DRAINTUBE™ Drainage Geocomposite shall be kept clean prior to and during installation.

E. Folds or excessive wrinkling of deployed DRAINTUBE™ Drainage Geocomposite shall be removed to the extent practicable.

F. CONTRACTOR shall exercise care not to entrap stones, excessive dust, or foreign objects in the material.

G. DRAINTUBE™ Drainage Geocomposite shall be adequately weighted, using sand bags or equivalent until the subsequent soil or geosynthetic layer is placed. In the presence of wind, the sandbags or the equivalent shall be placed along the leading edge and removed once cover material is placed.

H. If the project contains slopes steeper than 5 horizontal to 1 vertical, special care should be taken to use full length rolls from the top of the slope. If the roll length cannot cover entire slope, then the next roll should be situated towards the toe of the slope. The locations of horizontal connections of adjacent panels should be staggered at least 10 feet apart.

I. Overlaps shall be singled down the slope and/or in the direction that backfilling will occur.

J. If the project includes an anchor trench to secure the DRAINTUBE™ Drainage Geocomposite, then the panels shall be secured in the anchor trench as indicated on the Drawings.

3.4 SEAMING AND JOINING

A. Adjacent sheets of DRAINTUBE™ Drainage Geocomposite shall be overlapped as described below.
   1. Connections at along the side of the DRAINTUBE™ Drainage Geocomposite roll shall be overlapped 4 inches, and shall be secured using sewn seams, additional overlap, or welds (hot air or flame) [*ENGINEER to select one or more alternatives*].
   2. Connection at the leading or terminating edge of the DRAINTUBE™ Drainage Geocomposite shall be overlapped such that the upper geotextile layer can be rolled back 12 to 18 inches and the end of the next roll inserted into the opening. Pipes shall be connected either using a snap coupler fitting supplied by the geocomposite manufacturer or by overlapping the pipes by 12 to 18 inches [*ENGINEER to select the alternative*].

B. Connections to an interceptor drain and/or vacuum pipe shall conform to the Drawings and be at the direction of ENGINEER.

3.5 MATERIAL PROTECTION

A. DRAINTUBE™ Drainage Geocomposite shall be covered by soil or another geosynthetic so that the material is not exposed to ultraviolet rays for more than fourteen (14) days before being covered.

B. No construction equipment shall drive directly across the DRAINTUBE™ Drainage Geocomposite without permission from ENGINEER.

C. The cover soil shall be placed on the DRAINTUBE™ Drainage Geocomposite in a manner that prevents damage to the DRAINTUBE™ Drainage Geocomposite. Placement of the cover soil shall proceed immediately following the placement and inspection of the DRAINTUBE™ Drainage Geocomposite.

D. Cover soil shall be free of angular stones or other foreign matter that could damage the DRAINTUBE™ Drainage Geocomposite. The maximum particle size of the backfill shall 2 inches or less.

E. Cover soil shall be placed from the bottom of the slope and shall not be dropped directly onto the DRAINTUBE™ Drainage Geocomposite from a height greater than 3 feet. Cover shall be pushed over the DRAINTUBE™ Drainage Geocomposite in an upward tumbling motion that prevents wrinkles in the DRAINTUBE™ Drainage Geocomposite.

F. The initial loose lift thickness shall be 12 inches. Compaction shall consist of a minimum of 2 passes over all areas. The loose lift thickness of each subsequent lift shall be no greater than 12 inches. Normal soil placement shall be allowed on areas after the second loose lift of fill has been placed and compacted.

G. Anchor trench compacting equipment shall not come into direct contact with the DRAINTUBE™ Drainage Geocomposite.

3.6 REPAIR

A. Prior to covering the deployed DRAINTUBE™ Drainage Geocomposite, each roll shall be inspected for damage.

B. Any rips, tears or damaged areas on the geocomposite shall be removed and patched.
   1. If a section of pipe is damaged during installation, add a piece of undamaged pipe of the same diameter next to the damaged pipe, extending a minimum of 8 inches beyond each end of the damaged section of pipe.
   2. If the geotextile is ripped or torn, install an undamaged piece of the same material under the hole that extends a minimum of 6 inches beyond the hole in all directions to insure that protection of the geomembrane is maintained.
   3. If the area to be repaired is more than 50 percent of the width of the panel, then the damaged area shall be cut out and replaced with undamaged material. Damaged geotextile shall replaced by the same type of geotextile.

C. [*Conformance control testing of the components of the DRAINTUBE™ Drainage Geocomposite is at ENGINEER's discretion. Should such testing be required of by ENGINEER, that the following testing is suggested.*] The components of the DRAINTUBE™ Drainage Geocomposite shall be tested for the following properties:
   1. Mass per unit area (ASTM D5261) - (every 100,000 ft^2)
   2. Thickness (ASTM D5199) - (every 100,000 ft^2)
   3. Grab Tensile and Elongation (ASTM D4632) - (every 100,000 ft^2)
   4. Puncture Resistance (ASTM D4833 or ASTM D6241)- (every lot)
   5. Transmissivity (ASTM D4716) - (every lot)
   6. Apparent Opening Size (ASTM D4751) - (every lot)

TECHNICAL DATA SHEET

Property[A]	Unit[B]	404 ST2 D25	500P TF2 D25	500P LFG4 D25	Test Method
Geocomposite Property[1]					
Index Transmissivity[2,D]	m^2/sec	2 x 10^{-3}	2 x 10^{-3}	4 x 10^{-3}	ASTM D4716
Structural Reduction Factor[3]		1.05	1.05	1.05	See Below
Geotextile Property[1,C]					
Mass Per Unit Area	oz/yd^2	4	14	14	ASTM D5261
Thickness	mil	43	169	169	ASTM D5199
Grab Tensile	lbs	106	326	326	ASTM D4632
Grab Elongation	percent	50-105	50-140	50-140	ASTM D4632
Puncture Resistance (if required)	lbs	60	157	157	ASTM D4833
Filtration Property[1,C]					
AOS (filter layer only)	US Std. Sieve	50	80	80	ASTM D4751
Permittivity	s^{-1}	2.0	1.8	1.8	ASTM D4491
Perforated Pipe[1]					
Diameter	mm/in.	25/0.97	25/0.97	25/0.97	ASTM D2122
Spacing between pipes	in	20	20	10	-

Notes:

1. Results for the finished product after all fabrication/manufacturing has been completed.
2. Value at a gradient of (ENGINEER Insert Value) when tested with boundary conditions consisting of steel plate/sand/geocomposite/geomembrane/sand/steel plate. The seating time, with a uniformly applied load of (ENGINEER Insert Value) psf shall be a minimum of 100 hours.
3. Structural Reduction Factor (SRF) is a reduction factor that must be applied on the Index Transmissivity to take into account the creep and the intrusion factors. SRF = RF_{CR} x RF_{IN}. For DRAINTUBE™ technology, RF_{CR} = 1.05 and RF_{IN} = 1.00. The SRF value is a product/technology specific value.

Notes to ENGINEER:

A *ENGINEER shall determine the material properties to be tested based on project requirements.*

B *SI units may be used in place of US Standard units.*

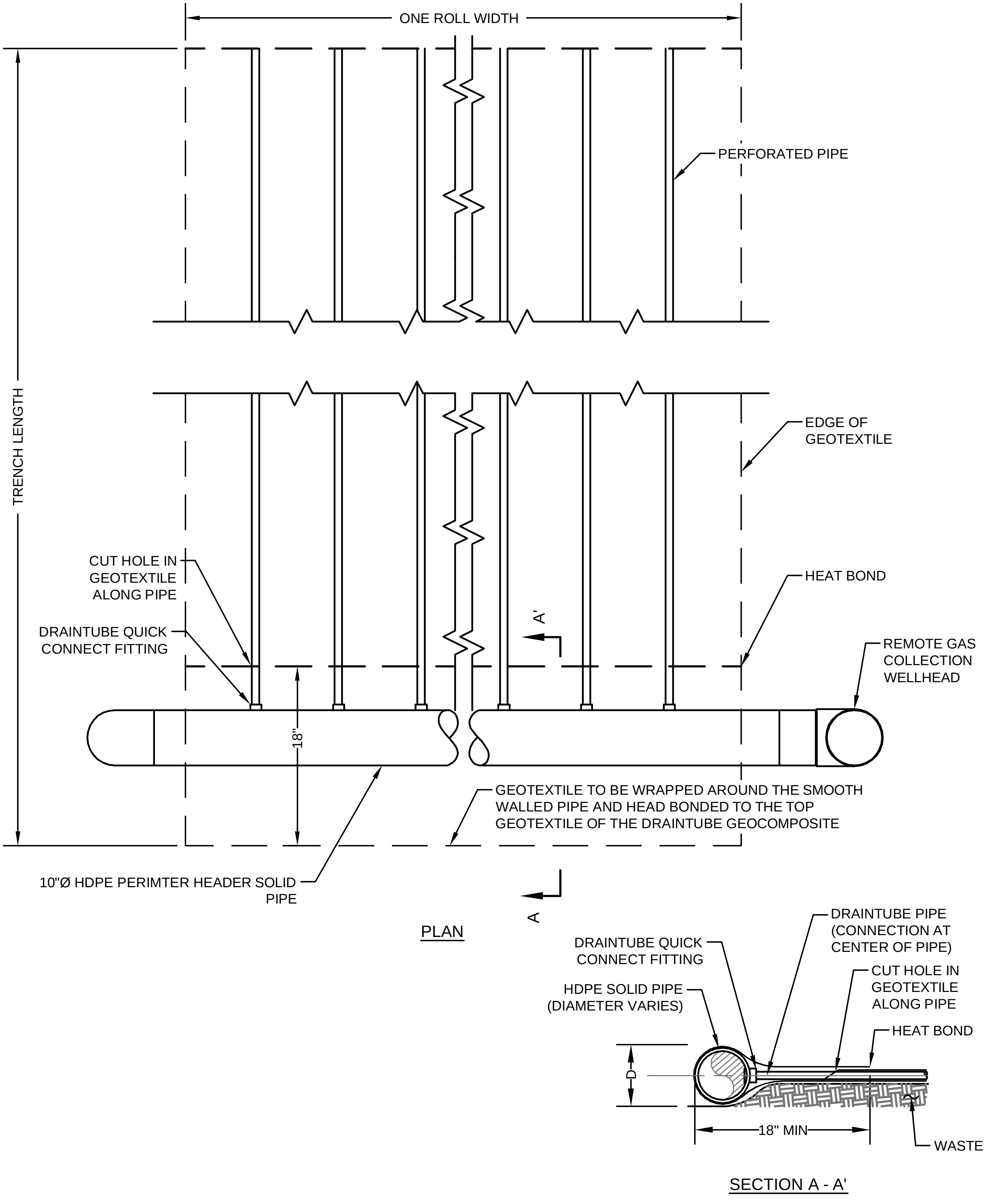
C *The filter and capillary geotextiles may have different property requirements. If so specify values for each component.*]

D *Transmissivity testing shall be conducted at a gradient of (ENGINEER Insert) with boundary conditions of steel plate/sand/geocomposite/ geomembrane/sand /steel plate. The seating time, with a uniformly applied load of (ENGINEER Insert) psf shall be a minimum of 100 hours duration.*

[END OF SECTION]

APPENDIX C

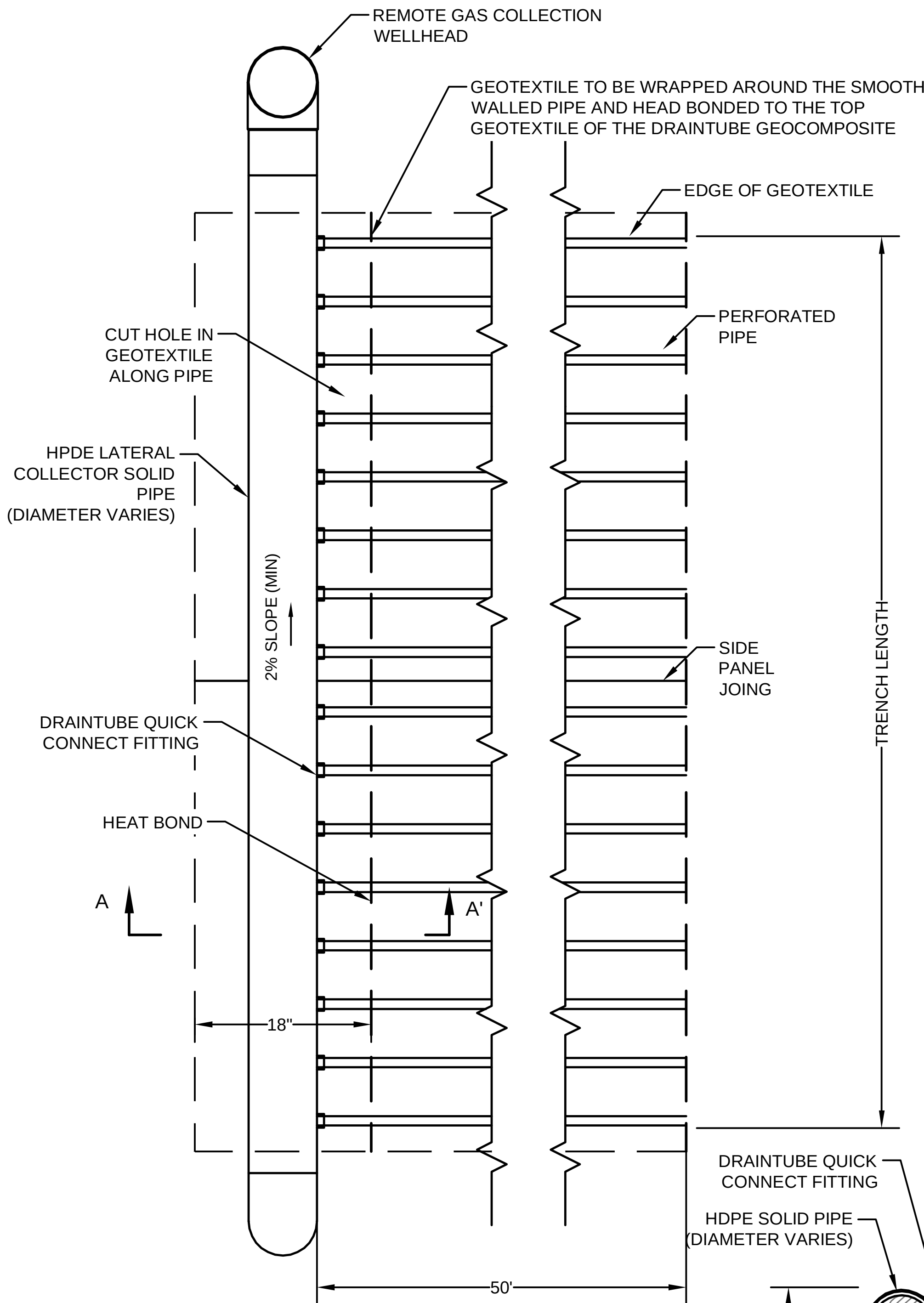
TYPICAL DETAILS



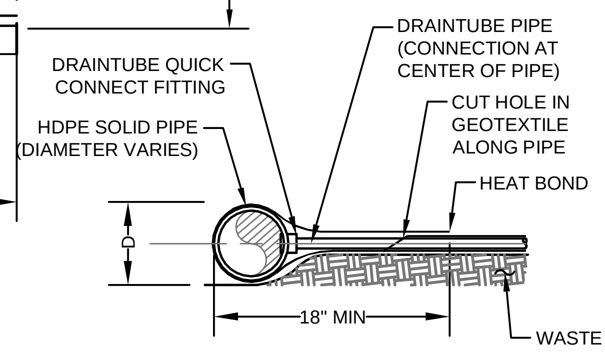
IMAGES:

DRAINTUBE™ TYPICAL DETAILS	LAYOUT ALTERNATIVE A
SANBORN HEAD	SCALE: NTS / DATE: MAR 2014 / DRAWN BY:DJD / CHECKED BY:LLD / FILE NO. 3651.00 / FIGURE NO. A

FILE: S:\CONDATA\3600s\3651.00\Graphics Files\Draintube Details - 2000\Appendix Details\DrainTube Details.dwg
LAYOUT: A
CTB FILE: SHA Standard.ctb
PLOT DATE: 3-13-14



PLAN



SECTION A - A'

DRAINTUBE™ TYPICAL DETAILS	LAYOUT ALTERNATIVE B		
SANBORN HEAD	SCALE: NTS	DRAWN BY:DJD	FILE NO. 3651.00
	DATE: MAR 2014	CHECKED BY:LLD	FIGURE NO. B

IMAGES:

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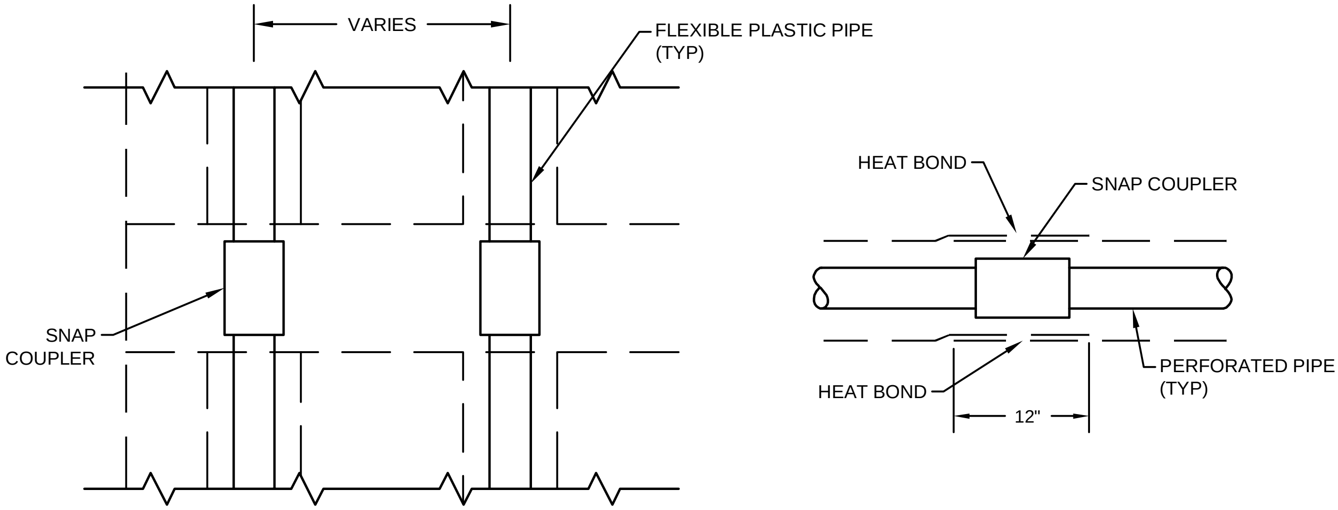
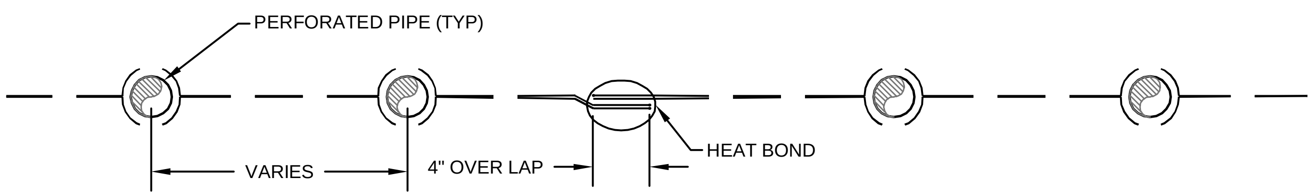
LAYOUT: B
CTB FILE: SHA Standard.ctb
PLOT DATE: 3-13-14

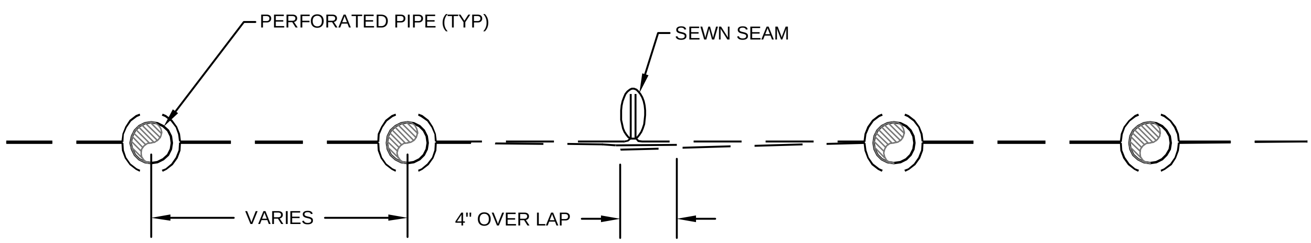


PANEL JOINING ENDS

NOT TO SCALE



DOUBLE OVERLAP OPTION



SEWN OPTION

PANEL JOINING OPTIONS FOR SIDE

NOT TO SCALE

DRAINTUBE™ TYPICAL DETAILS	PANEL JOINING		
SANBORN HEAD	SCALE: NTS	DRAWN BY:DJD	FILE NO. 3651.00
	DATE:FEB 2014	CHECKED BY:LLD	FIGURE NO. C

IMAGES:

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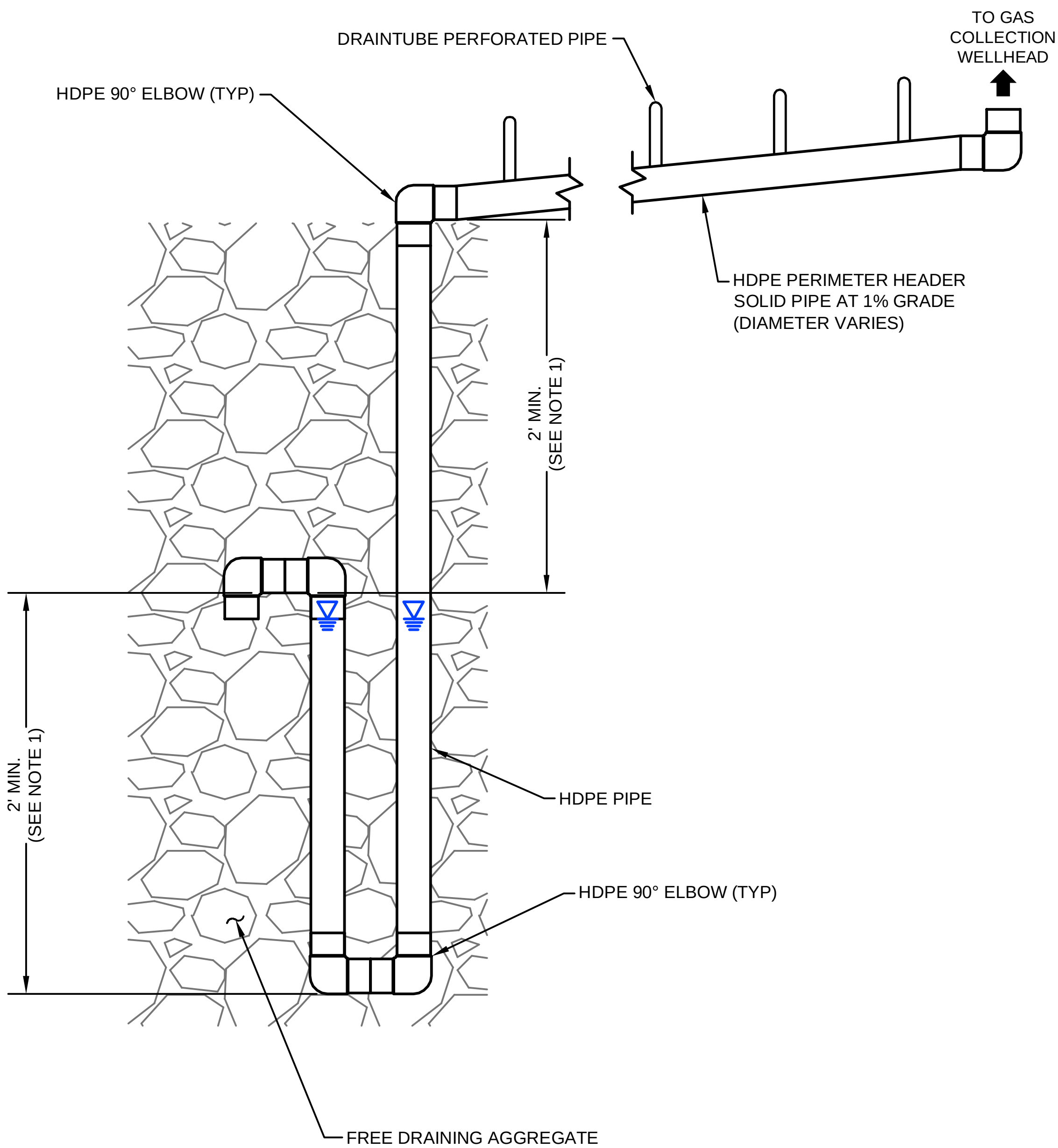
PLOT DATE: 3-13-14



NOTES:

1. DIMENSIONS TO BE SELECTED BASED ON ANTICIPATED VACUUM AND SITE CONDITIONS.
2. PRIOR TO OPERATION, FILL PIPE WITH WATER AS SHOWN.

DRAINTUBE™ TYPICAL DETAILS	CONDENSATE MANAGEMENT		
SANBORN HEAD	SCALE: NTS	DRAWN BY:DJD	FILE NO. 3651.00
	DATE: MAR 2014	CHECKED BY:LLD	FIGURE NO. D

IMAGES:

FILE: S:\CONDATA\3600s\3651.00\Graphics Files\Draintube Details - 2000\Appendix Details\DrainTube Details.dwg
LAYOUT: D
CTB FILE: SHA Standard.ctb
PLOT DATE: 3-13-14

APPENDIX D

INSTALLATION GUIDELINES DOCUMENT

DRAINTUBE

AFITEX-TEXEL Geosynthetics Inc.
485, rue des Érables
Saint-Elzéar-de-Beauce (Québec)
Canada G0S 2J0

DRAINTUBE™

Installation Guidelines

www.draintube.net

DRAINTUBE™

Liquid and LFG collection

DATE:02/06/2014

Synopsis

General Description and Requirements

The product consists of two geotextile layers comprised of short synthetic fibers of 100% polypropylene or polyester which are needlepunched together. Corrugated polypropylene pipes with two perforations per valley at 180 degree spacing and rotated 90 degrees per valley are inserted longitudinally between the geotextile layers during the manufacturing process at uniform intervals. DRAINTUBE™ is manufactured in Canada.

The specific DRAINTUBE™ product supplied varies depending on the required hydraulic performance for such conditions as: flow length, slope, permeability, flow volume and maximum hydraulic pressure. The specifications for each product are shown on specific technical data sheets.

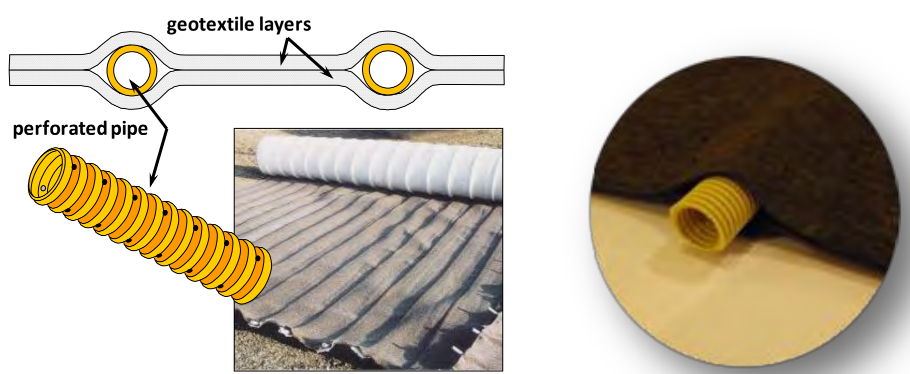
1 Handling and Storage

Rolls of DRAINTUBE™ Geocomposite shall be shipped to the jobsite in a manner that will not cause damage to the rolls. The rolls shall be stored flat on a smooth surface (no wooden pallets) away from dirt, mud and excessive heat. For more detailed handling and storage information, please refer to ASTM D4873. The contractor shall handle the rolls so that they are not damaged in any way.

2 Installation

2.1 *DRAINTUBE™ description*

DRAINTUBE™ Geocomposite is supplied on rolls 3.98 m (13 ft.) wide (figures 1 & 2).



Figures 1: DRAINTUBE™ Structure

Figure 2: DRAINTUBE™ Packaging

2.2 *Deploying DRAINTUBE™*

DRAINTUBE™ may be unrolled on a base which has been graded and compacted to the required elevation (figure 3). Insure that the product is properly oriented (figure 4).

Figure 3: Rolls of DRAINTUBE™

Figure 4: DRAINTUBE™ installation

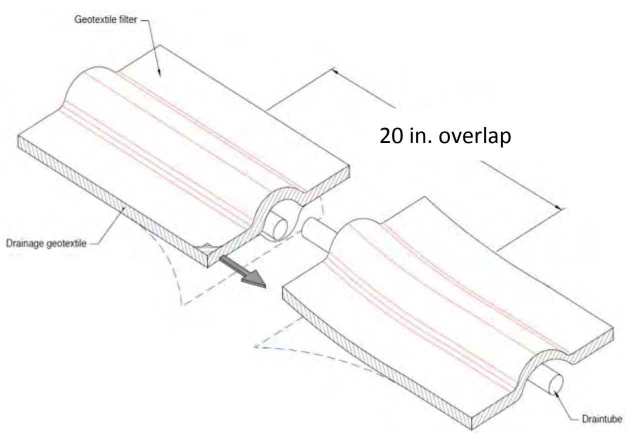
For steep slopes, the geocomposite must be properly anchored. For slopes longer than the length of a roll, only full length rolls should be used at the top. Overlaps shall be shingled down the slope and/or in the direction that backfilling will occur.

Protect underlying layers from damage during placement of the geocomposite. Use sandbags or equal to weigh down the geocomposites prior to backfilling to prevent displacement by the wind.

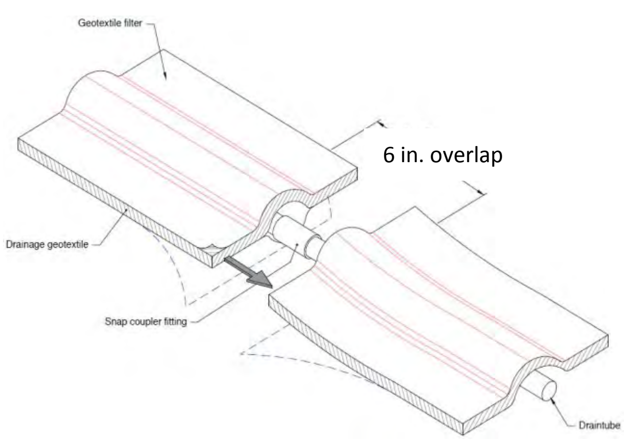
2.3 *Transverse Connections (at the end of a roll)*

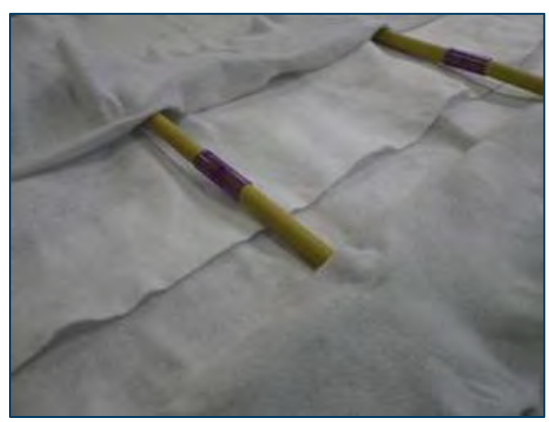
To ensure continuity of flow in the pipe between rolls, transverse joints are used. Pipe joints shall be made using mechanical connectors or overlaps at the engineers' discretion. Mechanical connections are recommended under high compressive loads.

The top layer of the geocomposite is rolled back. The end of the next roll is inserted into these openings with the pipes placed side by side (figures 5) or mechanically connected (figures 6 & 7). Heat seam, sew, weld or overlap the geotextiles to complete.



Figures 5: Transverse connections without couplers





Figures 6: Transverse connections with couplers

Figure 7: Mini-pipe connection with couplers

2.4 *Side by Side Connections*

Side by Side Connections require an overlap of 2 to 4 inches minimum. To avoid displacement (due to wind, backfilling, etc.), the overlap may be secured with additional overlap or welds (lyster or other heat welds). The spacing between welds shall be no greater than 6 feet (figures 8). Connection method requirements shall be at the direction of the engineer. If necessary, seams may be sewn.

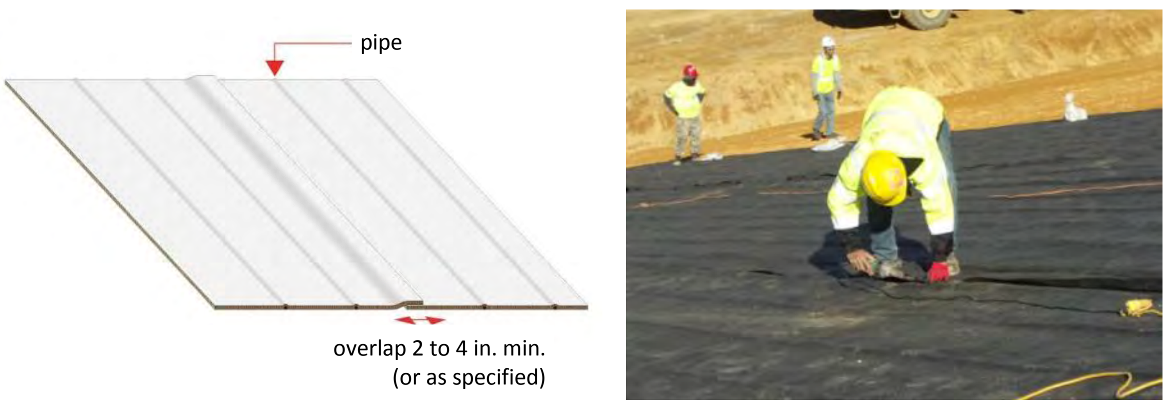
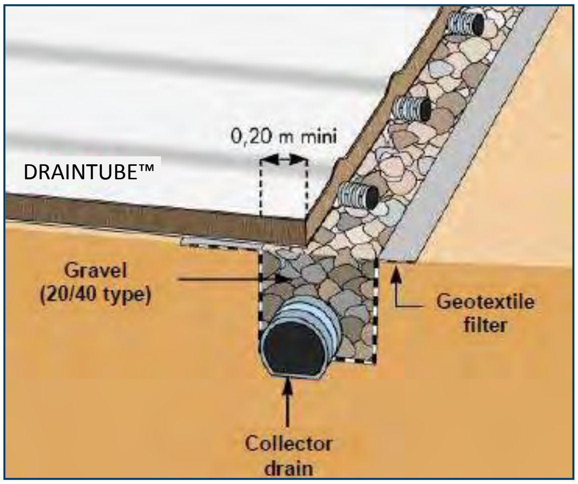


Figure 8: Side by side connections

3 TERMINATION

3.1 *Connection to liquid interceptor drains*

Connection to an interceptor drain requires an overlap of a minimum of 8 inches. (figure 9) and a geotextile cover.



Figures 9: Connection to liquid interceptor drain

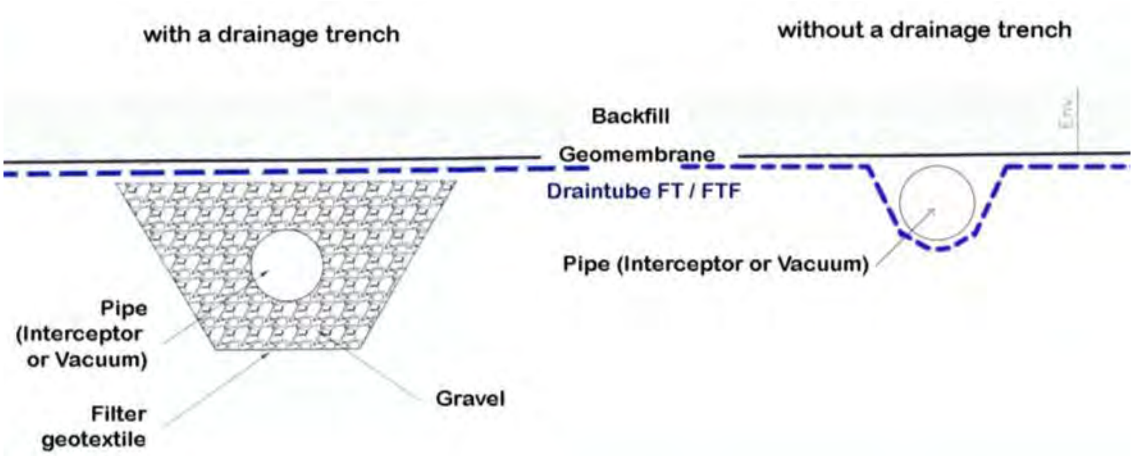
3.2 *Termination in a ditch*

To terminate in a ditch, DRAINTUBE™ should be unrolled to the edge of the ditch (figure 10).

Figure 10: Termination in a ditch

3.3 *Connection to gas interceptor drains or vacuum*

Connection to an interceptor drain or a vacuum may be made with or without a drainage trench (figures 11 & 12). The connections should be at the direction of the engineer.



Figures 11: Typical cross section for gas interceptor drain connections

Figure 12: Connection to an interceptor drain

DRAINTUBE™ can be connected directly to the collector drain using the Quick Connect™ system (figures 13 & 14). This allows a positive connection of the mini-pipes to the collector drain for vacuum applications.

Figures 13: Quick Connect™ system

Figures 14: Connection to a plain drain with Quick Connect™

4 REPAIR

Prior to covering the deployed geocomposite, each roll shall be inspected for damage. Any rips, tears or damaged areas on the geocomposite shall be removed and patched.

If a section of pipe is damaged during installation, add a piece of undamaged pipe of the same size next to the damaged pipe plus a minimum 8 inches extending beyond the damaged section of pipe at each end (see longitudinal connection).

If the protection geotextile is damaged, install an undamaged piece of the same material under the hole and extending a minimum of 6 inches beyond the hole to insure that protection of the geomembrane is maintained. Damaged filter must be replaced by another filter to properly protect the pipe.

If the area to be repaired is more than 50 percent of the width of the panel, the damaged area shall be cut out and replaced with undamaged material using the connection methods described above.

5 BACKFILL PLACEMENT

The geocomposite drainage layer shall be covered with the specified material within 14 days of deployment. The backfill shall be free of angular stones or other foreign matter which could damage the geocomposite drainage layer.

Backfill may be placed directly on DRAINTUBE™ (figures 15). Care should be taken to avoid displacement of the geocomposite. The contractor must maintain a minimum of 12 inches of backfill between DRAINTUBE™ and the backfill equipment. If approved by the Engineer, light machinery or equipment may be allowed on the geocomposite. A low ground pressure All-Terrain Vehicle (ATV) that exerts a maximum load of 6 psi may be used to install DRAINTUBE™. Vehicles, machinery, and equipment shall be operated to avoid abrupt stops, starts, and/or turns. ATV tires shall be clean and no passengers are allowed on the ATV.

Figures 15: Backfilling

The maximum particle size of the backfill should be 2 inches or less. The backfill shall be placed from the bottom of the slope and shall not be dropped directly onto the drainage layer from a height greater than 3 feet. The backfill shall be pushed over the geocomposite drainage layer in an upward tumbling motion that prevents wrinkles in the drainage layer. No equipment shall be operated on the top surface of the geocomposite drainage layer without permission from the Contracting Officer or Engineer. The initial loose lift thickness shall be 12 inches

Equipment exerting ground pressure no greater than 7 psi shall be used to place and compact the first lift of select fill. Compaction shall consist of a minimum of 2 passes over all areas. The loose lift thickness of each subsequent lift shall be no greater than 12 inches. Normal backfill placement shall be allowed on areas underlain by geocomposite after the second loose lift of fill has been placed and compacted.

Table of figures

Figures :

APPENDIX E

PROJECT EXAMPLE3

NEWSVT LANDFILL

Coventry, Vermont

Project Date: *August 2012 and November 2013*

Project Details: *Surface Emissions Application*

Installed DRAINTUBE™ on surface of landfill in two locations at the site.

Connected multiple roles of DRAINTUBE™ using snap connector system.

Connected DRAINTUBE™ to 6-inch diameter HDPE pipe using Quick Connect System and product was covered by select waste.

FOUR HILLS LANDFILL

Nashua, New Hampshire

Project Date: *September 2011*

Project Details: *Surface Emission Application*

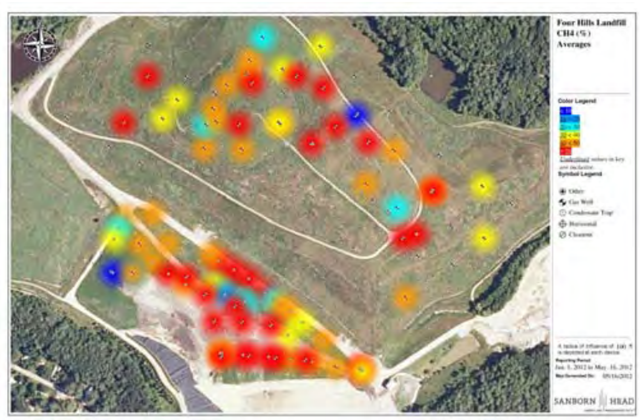
Installed approximately 375 feet (18,000 ft^2) of DRAINTUBE™

Anchor trench (2 ft wide by 2 ft deep) was constructed along the edges to secure DRAINTUBE™.

Protective plastic sheet (8-mil dura skrim) installed over DRAINTUBE™ to limit air intrusion into the system when vacuum was applied.

The system currently uses Landfill Gas Management Suite ™ (LFGMS) to monitor DRAINTUBE™ and the entire landfill GCCS system. The online-based system can store, manage, and analyze the landfill gas data and provide interactive maps of the landfill to evaluate data trends and problem areas of the landfill.

Installation complete in approximately 4 hours. The area had been prepared prior to installation by removing vegetation and grading per project requirements.



LEBANON LANDFILL

Lebanon, New Hampshire

Project Date: *September 2013*

Project Details: *Horizontal Gas Collection Trench*

Used 500P FT4 D25 product

Installed approximately 440 foot length of DRAINTUBE™ on surface of select waste

Connected multiple roles of DRAINTUBE™ using snap connector system.

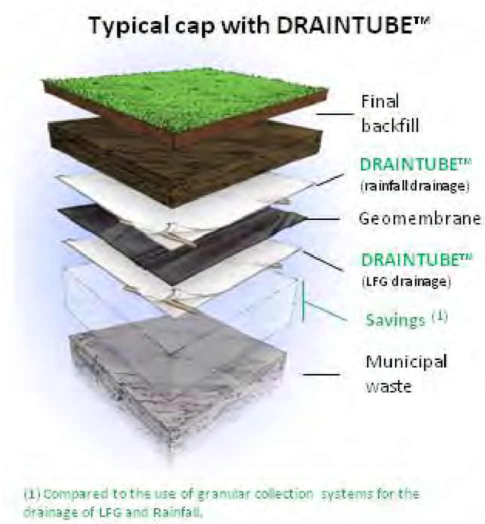
Installed a condensate management system as shown in Typical Details in Appendix C of the DRAINTUBE™ Design Guidance Document.

Connected DRAINTUBE™ to 6-inch diameter HDPE pipe using Quick Connect System and product was covered by select waste.

GRADY ROAD LANDFILL

Rockmart, Georgia

Project Date: *November 2012*



Project Details: *Within a landfill cover system*

Installed DRAINTUBE™ within the cover system of the landfill above and below the geomembrane (60 mil textured)

Cap Area = 450,000 ft^2 (per layer)

DRAINTUBE™ used to drain stormwater above cover system and extract landfill gas below the cover system.

- Cost Effective Solution
- Good Hydraulic and Mechanical Performance
- Fast and Easy Install
  - Over 100,000 ft^2 per day

Connected multiple roles of DRAINTUBE™ using snap connector system to connect the pipes at the end of each roll.