SPECIFICATION FOR VERTICAL DRAINS AND SURCHARGE

1.0 GENERAL

This work comprises of supply and installation of prefabricated vertical drains, geotextile separator inclusive of drainage blanket and surcharging in accordance to the Specifications and Drawings.

1.1 MATERIALS

1.1.1 Prefabricated Vertical Drains

1.1.1.1 General Requirements

Prefabricated vertical drains shall be of newly manufactured materials from an approved manufacturer and consist of a polymer core enclosed within an external non-woven filter jacket, and shall comply with the requirements as indicated in Table 1a and Table 1b.

The filter jacket shall be capable of resisting all bending, puncturing and tensioning subjected during installation and design life of the drain.

The core shall be made of continuous plastic material fabricated to facilitate drainage along the axis of the vertical drain.

The prefabricated vertical drain shall be resistant against rotting, mildew, bacterial action, insect, salts, acids, alkalis, solvent and other constituents in ground water.

1.1.1.2 Transportation and Storage

The vertical drain materials shall be labelled or tagged for sample identification and other quality control purposes. Each roll shall be identified by the manufacturer by lot number, individual roll number, date of manufacture, manufacturer and product identification of the jacket and core.

During transportation and storage, the drain shall be wrapped in heavy paper, burlap or similar heavy duty protection covering. The drain shall be protected from sunlight, mud, dirt, dust, debris and other detrimental substances during transport and on site storage.

All materials which are damaged during transportation, handling or storage and do not meet the minimum requirements of the vertical drain specifications shall be rejected by the Engineer. No payment of any kind shall be made on the rejected product.

1.1.1.3 Quality Control and Testing

The actual vertical drain to be used shall be at the option of the contractor subject to the approval of the Engineer.

The Contractor shall indicate the proposed source of the materials prior to delivery to site. The contractor shall also submit samples and Manufacturer's certificates to verify the physical, mechanical and hydraulic properties of the drain to be used for Engineer's approval.

Prior to installation and at the discretion of the Engineer, individual test sample shall be cut from at least one roll selected at random to represent each batch or every 100,000 metres, whichever is lesser. Individual sample shall be no less than 3 metres in length and shall be full

width. Samples submitted for tests shall indicate the linear metres of drain and manufacturer's identifications represented by the sample.

Table 1a: Properties of Prefabricated Vertical Drain

Property		Unit	Specified Requirements	Remarks
Dimension of drain	Width	mm	100 ± 2	
	Thickness	mm	3 to 4	

Table 1b: Properties of Prefabricated Vertical Drain

Properties	Test Designation	Proposed Values
Apparent Opening Size (μm)	ASTM D4751-87	<90
Grab Tensile Strength (kN) (full width composite)	ASTM D4595-86	>0.35
Trapezoidal Tear Strength (kN)	ASTM D4533-91	>0.10
Puncture Resistance (kN)	ASTM D4833-88	>0.10
Burst Strength (kN)	ASTM D3786-80a	>900
Discharge Capacity (kinked at interior angle <15°) at 240kPa and Hydraulic Gradient of 1 m^3/yr (m^3/yr)	ASTM D4716-87	>500

Should any individual sample selected at random fail to meet the specification, then that roll shall be rejected and two additional samples shall be taken at random from two other rolls representing the same batch on 100,000 metres. If either of these two additional samples fail to comply with the specification, then the entire batch of vertical drains represented by the samples shall be rejected.

1.1.2 Geotextile Separator

1.1.2.1 General Requirements

All geotextile shall be from an approved manufacturer and shall be manufactured from polypropylene. Geotextiles shall be sufficiently durable and resistant to naturally occurring chemicals. Geotextile shall be free of any flaws which may have an adverse effect on the physical properties of the geotextiles.

Geotextile fabrics shall be non-woven needle - punched staple fiber geotextile in accordance with the Specification and shall be used as shown and described in the Drawing or as directed by the Engineer.
Geotextile shall be stabilized against ultra-violet radiation to the degree that one month's exposure of the geotextile to sunlight shall not reduce its strength to less than 90% of the specified strength rating in the Specification.

The type of geotextile fabrics as shown in the Drawing shall comply with the following properties as listed in Table 2.

Table 2: Properties of Geotextile Separator

ITEM	PROPERTIES	TEST METHOD	UNIT	VALUE
1	Unit mass	ASTM D5261-92	g/m^2	>135
2a	Wide width tensile strength	ASTM D4595-86	KN/m	>8.0
2b	Elongation at break	ASTM D4595-86	%	>40
3	Trapezoidal tear strength	ASTM D4533-91	N	>240
4	CBR puncture resistance	DIN 54307	N	>1800
5	Permeability at 100mm head	BS 6906/3	$1/m^2/s$	>200
6	Apparent pore size 0_{95}	ASTM D4751-87	Micron	<150

The Contractor shall in additional provide the following information, for the approval of the Engineer, for the acceptance of the geotextile fabric for the works.

a) Manufacture's Certificate which shall include:
- Name of manufacturer
- Product name and type
- Accreditation from international Institutes

b) Test Certificate which shall include:
- Mass Per Unit Area
- Wide Width Tensile Strength (longitudinal/transverse)
- Elongation (Longitudinal/transverse)
- Apparent Pore Size (095)
- Trapezoidal Tear Strength
- CBR Puncture Resistance
- Permeability

The tests shall be carried out in accordance with the Codes of Practices and Standards as provided within this Specification, unless otherwise approved by the Engineer.

Prior to installation and at the discretion of the Engineer samples of each $100{,}000m^2$ of geotextile fabric shall be selected for routine tests at approved testing laboratories.

The properties to be tested shall comprise index properties including unit mass, mechanical properties including tensile strength, CBR Puncture Resistance and hydraulic properties including pore size and permeability. Where the individual samples fail to satisfy the requirements of this Specification on the geotextile fabric, the roll from which the sample is obtained shall be rejected. Two additional samples shall then be selected from two other rolls from the same batch of geotextile fabric. If either of these two additional samples fail to comply with the requirements, the entire batch represented by the samples shall be rejected.

1.1.2.2 Geotextile Packaging and Storing

The geotextile rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultra-violet exposure prior to placement. Each roll shall be labelled or tagged to

provide product identification sufficient for field identification as well as inventory and quality control purposes. If stored outdoors, they shall be elevated and protected with a waterproof cover.

1.1.3 Drainage Blanket

The sand drainage layer shall consist of hard, clean, crushed rock or gravel having a grading with the limits specified below.

Table 3: Properties of Drainage Blanket

B.S Sieve Size	Percentage by weight passing
63.00mm	100
37.50mm	85 to 100
20.00mm	0 to 20
10.00mm	0 to 5

The sand drainage material for depositing in water shall be deposited without the associated use of compaction plant.

The sand drainage layer shall be built up evenly in horizontal layers each of not more than 300mm thick. Filling shall commence from the lowest level, and each layer shall cover the full area of the intended total fill area at that level before deposition of the subsequent layer commences.

1.2 INSTALLATION

1.2.1 Prefabricated Vertical Drain (PVD)

1.2.1.1 Equipment

Prefabricated Vertical Drain (PVD) shall be installed with approved modern equipment of a type which will cause a minimum of disturbance of the sub-soil during the installation operation and maintain the mandrel in a vertical position.

PVD shall be installed using a mandrel or sleeve and shall be inserted (i.e. pushed or vibrated) into the soil. The mandrel or sleeve shall protect the drain material from tears, cuts, and abrasion during installation, and shall be retracted after each drain is installed.

The size and shape of the mandrel or sleeve shall be as close as possible to the size and shape of the drains in order to minimise disturbance to the soil. The length of the mandrel shall be not less than the maximum length of the drain. The mandrel shall be capable of making a clean puncture through any geotextile if necessary.

The mandrel or sleeve shall be provided with an anchor plate or similar arrangement at the bottom to prevent the soil from entering the bottom of the mandrel during the installation of the drain and to anchor the drain tip at the required depth at the time of mandrel withdrawal. The dimension of the anchor shall conform as closely as possible to the dimensions of the mandrel so as to minimize soil disturbance. The Engineer shall determine the acceptability of the anchorage system and procedure.

1.2.1.2 Approval

4 weeks prior to the beginning of trial of PVD installation, the Contractor shall submit full details of the materials, equipment, sequence and method proposed for PVD installation to the Engineer for review and approval. Approval by the Engineer of installation sequence and methods shall not relieve the Contractor of his responsibility to install drains in accordance with the plans and specifications.

Prior to the installation of PVD, the Contractor shall demonstrate that the equipment, method, and materials produce a satisfactory installation in accordance with these specifications. For this purpose, the Contractor will be required to install 2 trial drains totalling approximately 16 liner metres at locations designated by the Engineer.

Approval by the Engineer of the method or equipment used to install the trial drains shall not constitute, necessarily, acceptance of the method for the remainder of the project. If, at any time, the Engineer considers that the method of installation does not produce satisfactory PVD, the Contractor shall alter his method and/or equipment as necessary to comply with these specifications.

1.2.1.3 Installation Procedure

PVD shall be located, numbered and pegged out by the Contractor using a baseline and benchmark indicated by the Engineer. The Contractor shall take all reasonable precautions to preserve the pegs and is responsible for any necessary re-pegging. The as-installed location of the PVD shall not vary by more than 150mm from the plan locations designated on the drawings.

PVD that are more than 150mm from design plan location or are damaged or improperly install, will be rejected and abandoned in place.

PVD shall be installed from the working surface to the depth shown on the drawings, or to such depth as directed by the Engineer who may vary the depths, spacing, or the number of drains to be installed, and may revise the plan limits for this work as necessary.

During PVD installation, the Contractor shall provide the Engineer with suitable means of determining the depth of the advancing drain at any given time and the length of drain installed at each location.

The Contractor shall supply to the Engineer at the end of each working day a summary of the PVD installed that day. The summary shall include drain type, locations and length (to nearest 50mm) of PVD installed at each location.

Equipment for installing PVD shall be plumbed prior to installing each drain and shall not deviate from the vertical more than 1 in 50 during installing of any drain.

PVD shall be installed using a continuous push using static weight or vibration.

Installation techniques using driving will not be permitted. Jetting techniques will be permitted only after receiving written approval from the Engineer.

The installation shall be performed, without any damage to the drain during advancement or retraction of the mandrel. In no case will alternate raising or lowering of the mandrel during advancement be permitted. Raising of the mandrel will only be permitted after completion of a drain installation.

The mandrel penetration rate should be between 150mm and 600mm per second.
The completed PVD shall be cut off neatly 300mm above the working grade, or as otherwise specified on the contract drawings.

The Contractor shall observe precautions necessary for protection of any field instrumentation devices.

The Contractor shall replace, at his own expense, any instrumentation equipment that has been damaged or become unreliable as a result of his operations prior to continuing with drain installation or other construction activities.

1.2.1.4 Pre-augering/Obstructions

The Contractor shall be responsible for penetrating any overlying material as necessary to install the drains.

Where obstructions are encountered below the working surface which cannot be penetrated by the installation equipment, the Contractor shall complete the drain from the elevation of the working surface to the obstruction and notify the Engineer prior to installing any more drains. At the direction of the Engineer and under his review, the Contractor shall attempt to install a new drain within 600mm horizontally from the obstructed drain. A maximum of two attempts shall be made as directed by the Engineer. If the drain still cannot be installed to the design tip elevation, the drain location shall be abandoned and the installation equipment shall be moved to the next location, or other action shall be taken as directed by the Engineer.

The Contractor shall be responsible for penetrating overlying fill material as necessary to satisfactorily install the PVD. Satisfactory installation may require clearing obstructions defined as any man-made or natural object or strata that prevents the proper insertion of the mandrel and installation of the PVD.

The Contractor may use augering, spudding, or other approved methods to lossen the soil and any obstruction material prior to the installation of PVD. The obstruction clearance procedure is subjected to the approval of the Engineer; however, such, approval shall not relieve the Contractor of his responsibility to clear obstructions in accordance with the specification.

If augering is the selected method, the augers shall have a minimum outside diameter equal to the largest horizontal dimension of the mandrel, shoe or anchor, whichever is greater.

1.2.1.5 Splicing

Splicing of PV drain material shall be done by stapling in a workmanlike manner and so as to ensure structural and hydraulic continuity of the drain. At the splice, upper portion of the jacket shall be external to the lower portion.

A maximum of 1 splice per drain installed will be permitted without specific permission from the Engineer.

The jacket and core shall be overlapped a minimum of 150 mm at any splice.

1.2.2 Geotextile Separator (deleted)

Prior to the laying of the geotextile fabric, site clearance shall be carried out in accordance with the Specification and Drawing or as directed by the Engineer. All voids shall be filled with suitable material and the area cleared of large stones and exposed tree root systems or other such like protrusions.

Geotextile fabric shall be installed to the shape and requirements as specified herein or as shown and described on the Drawings. The geotextile shall be unrolled smoothly on the prepared ground as approved by the Engineer and generally in a direction perpendicular to the edge of the platform, embankment or area of fill as approved by the Engineer. Adjacent geotextile rolls shall be overlapped and sewn in accordance with this Specification. On curves

and corners geotextile may be folded or cut to conform to the direction as approved by the Engineer. Adjacent geotextile rolls shall be overlapped and sewn in accordance with this Specification. On curves and corners geotextile may be folded or cut or conform to the direction as approved by the Engineer. Overlapping of geotextiles without sewn connections shall only be allowed by the Engineer.

Geotextile fabrics shall be placed just in advance of placement of the specified overlying fill material. Geotextiles so placed shall be covered by the relevant fill within 7 days of being placed. Installation proposals and trials as deemed required shall be carried out for approval by the Engineer prior to the acceptance of the placement method for the main works. The installation trials shall include the placement operations of the overlying fill materials, including excavation of such materials thereafter for examination of the geotextile fabric installation and fill materials placement method with respect to the prevailing ground conditions and constraints.

The geotextile fabric shall be joined using an approved portable industrial sewing machine and by sewing a double chain stitch with 'J' or 'prayer' seam (minimum lap of 50mm) with high tenacity polyester thread and a minimum of 3 stitches per 25mm shall be required. The thread shall have a breaking lead of not less than 160N. The sewn seam assembly and construction shall have equivalent strength properties for the particular geotextile fabric. Samples of such sewn seam assembly shall be tested in accordance with ASTM D4884-90 as deemed necessary by the Engineer.

Exposure of geotextile to natural elements between placement and cover shall be an aggregated period to a maximum of seven (7) days to minimize damage. The counting for this foresaid seven (7) days shall commence immediately upon the geotextile being exposed from its protective wrapping.

The specified overlying fill material on the geotextile fabric, shall be placed in accordance with the requirements shown and described in the Drawings or as directed by the Engineer. These fill materials shall be deposited in layers not exceeding 300mm loose depth and shall be spread simultaneously with the dumping in a manner to prevent any localized distress or failure of the ground.

In water logged or swampy areas, the geotextiles shall be sunk after jointing by ballasting with sufficient sandbags. To control the location of the mattress, buoys shall be fixed with ropes on the edges of the geotextile. As soon as possible after positioning, the mattress shall be ballasted.

No traffic shall travel directly on the geotextile and there shall be no sudden stops, starts or turns on the fill materials by the construction equipment or other such actions which may cause damage to the geotextile.

1.2.3 Fill Surcharge

Fill shall be placed and properly compacted according to the rate of filling indicated in the Drawings.

Extra fill shall be placed to thickness specified in the Drawings as surcharge to speed up rate of embankment settlement.

Surcharging fill shall be maintained for a period of time indicated in the Drawing and shall be removed only with the approval of or when instructed by the Engineer.

The fill be capable of being compacted to the requirements as indicated on the drawing and shall not comprise of: -

- material from swamps, marshes and bogs;
- peat, logs, stumps, perishable and toxic material;
- material susceptible to spontaneous combustion;

- clay of liquid limit exceeding 80% and/or plasticity index exceeding 55%;
- organic content greater than 2.5% by weight on ignition.

1.3 INSTRUMENTATION

1.3.1. General

The Contractor shall install instruments to enable measurements (monitoring) of vertical movements and pore water pressure and carry out measurements (monitoring) of the movements and water pressures and water levels during the currency of the works.

The depths and locations of all instruments shall be determined by the Engineer on site. Provisional quantities are provided in the Bills of Quantities.

The Contractor shall be responsible for and shall follow the instructions of the manufacturer in the installation, calibration and testing of all measuring instruments and equipment, which shall be carried out under the direct supervision of the Engineer. The Contractor shall inform the Engineer at least 2 days prior to undertaking installation of the equipment or taking measurements. The Contractor shall make due allowances in his construction programme for delays which may arise on account of the installation of the instruments and their maintenance.

1.3.2. Settlement Gauges

Settlement gauges shall be provided and installed vertically by the Contractor in the positions directed by the Engineer for the purpose of measuring settlement taking place under the embankments. Settlement gauges shall be located at position as indicated by the Engineer and the Contractor shall be responsible for installation of all gauges as work proceed.

The Contractor shall take all necessary measures to protect settlement gauges from damage by the plant and vehicles and shall repair any such damage to the satisfaction of the Engineer at his own expense. He shall erect substantial and readily visible barriers at a distance of 750mm around each gauge ;

The Contractor shall replace any damaged settlement gauges within five days, at his own expense should any settlement gauge be damaged in such a way as to make it useless for its purpose.

1.3.3. Permanent Settlement Reference Stations

The Contractor shall be responsible for establishing permanent settlement reference stations in locations selected by the Engineer. The permanent settlement reference stations shall be located on stable ground.

1.3.4 Method of Monitoring

Monitoring of vertical movements of settlement gauges shall be by precise levelling with respect to the permanent settlement reference stations. Measurement of settlement shall be by the use of a precise level with an accuracy of 0.1mm. (Refer Appendix A).

1.3.5. Installation

The method of installation shall be the most advantageous method recommended by the manufacturer and shall be subject to the approval of the Engineer.

The Contractor shall install settlement gauges and reference settlement stations before commencement of earthworks.

1.3.6. Frequency of Measurement

a) Settlement Gauges – refer to Appendix A

1.3.7. Protection of Instruments

All instruments shall be protected against damage during the currency of the Works and the Period of Maintenance. Instruments damaged during the above shall be immediately replaced by the Contractor at his own cost.

1.3.8. Instruments Not Functioning

All instruments shall be designed to ensure proper functioning over the required period of monitoring. Instruments not functioning during the period of monitoring shall be immediately replaced by the Contractor at his own cost. The Engineer's decision as whether an instrument is functioning or not **shall be final.**

APPENDIX A

PERFORMANCE MONITORING

MEASUREMENT OF SETTLEMENT OF SUBSOIL AND FILL

1. SETTLEMENT OF SUBSOIL

Settlement of subsoil due to fill is to be measured by means of settlement plates as shown in Figure 1. Settlement plates are positioned before the fill is laid.

2. LOCATION AND PROTECTION OF SETTLEMENT PLATES

The settlements plates shall be placed at locations indicated on the drawing. They shall be located in areas that are least affected by construction vehicles and plant. They shall be properly protected with a wooden barricade, 1m high and labelled with visible reference numbers. Heavy compaction plant shall not approach within 1.5m of projecting instruments. Damaged instruments shall be replaced or repaired by the Contractor at his own expense within seven days.

3. FREQUENCY OF MEASUREMENT

The frequency or the interval of measurement is dependent on the rate of settlement of a subsoil. Close intervals are used during and shortly after fill has been laid. The intervals are increased with increase in the duration of lapse time. The following can be used as a guide:

a) During filling

- Every morning before subsequent filling commences.

b) After a formation is reached

i) For first three months

- Every alternative day

ii) For fourth and subsequent months

- Between twice a week to once a fortnight depending on the rate of settlement as shown in the example or as instructed by the Engineer, the time interval should allow reasonable settlement to be plotted.

4. SUPPLY, INSTALLATION AND MONITORING OF SETTLEMENT STATIONS

Installation of precise instrument involves the supply and installation of the instruments at positions as indicated by the Engineer.

4.1 Temporary Bench Marks

The temporary bench marks will be installed at the nearby stable structure or remote from the reclamation area and marked on an end bearing pile or similar structure.

4.2 Settlement Plates

The precise level settlement measurements shall be referenced to the temporary bench marks.

The measuring instruments shall be a precise level, capable of allowing readings to be read to

0.1mm.

5. PLOTTING

The result should be plotted during the period of measurement as shown in Figure 2.

Table 1a : Properties of Prefabricated Vertical Drain

Property		Unit	Specified Requirements	Remarks
Material	Core Filter			Continuous plastic drain core Wrapped in non-woven geotextile material
Dimension of drain	Width	Mm	100 ± 2	
	Thickness	Mm	3 to 4	
Coefficient of permeability of drain filter		M/s	$> 5 \times 10^{-5}$	
Discharge capacity of drain		M^3/s	25×10^{-6}	
Soil retention capacity		Microns	75	
Tensile strength of entire drain	Dry	kg/10cm	> 100	
	Wet	kg/10cm	> 100	
Tensile strength of filter	Dry	kg/cm	> 3	At elongation minimum 2% maximum 10%
	Wet	kg/cm	> 3	Tested at 1% strain/mm after saturation in water at 10° for 48hrs
Elongation of entire drain		%	< 10	At 100kg/10cm width
Elongation of filter	Dry	%	< 10	At 3kg/cm
	Wet			

TABLE 1

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