MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT PHASE 2 (MCWAP-2)

TENDER NO 054/2024/PMID/MCWAP2/RFB

PART C3.1
SPECIFICATION

SECTION 27

DRAINAGE AND EROSION PROTECTION

PART C3.1
SPECIFICATION

SECTION 27
DRAINAGE AND EROSION PROTECTION

TABLE OF CONTENTS

LIST OF TABLES

SECTION 27

DRAINAGE AND EROSION PROTECTION

27.1 SCOPE

This Section covers all work required for the construction of open drains, subsurface drains, prefabricated culverts, pipes, manholes, catch-pits and other permanent drainage structures, and stonework (pitching) and erosion protection as shown on the Drawings or as directed by the Engineer (Employers design).

This Specification, Section 27, needs to be read in conjunction with the remainder of the Specification.

Please Note: Aspects of the Standard Specifications for Road and Bridge Works for State Road Authorities, Committee of Land Transport Officials (COLTO), South Africa, have been used as an industry standard guideline only. It is not used as a standardised specification.

27.2 ABBREVIATIONS, DEFINITIONS AND REFERENCES

27.2.1 Abbreviations

AASHTO	:	American Association of State Highway and Transportation Officials
ACB	:	Articulated Concrete Blocks
COLTO	:	Committee of Land Transport Officials
CSIR	:	Council for Scientific and Industrial Research
EN ISO	:	European Norm and International Standards Organisation
HDPE	:	High Density Poly Ethylene
OD	:	Outer diameter
PVC	:	Polyvinyl Chloride
SANS	:	South African National Standard
TMH	:	Technical Methods for Highways

27.2.2 Definitions

a) **"Articulated Concrete Block Systems"** means preformed concrete blocks that are interconnected through a combination of form and/or cables. The blocks are able to "articulate" along their adjoining faces, allowing the system to conform to changes in the subgrade while maintaining the protective cover. Open-cell forms allow vegetation to be established, improving stability and aesthetic appeal.

b) **"Catchwater drain or bank"** means a longitudinal drain or bank for diverting water.

c) **"Concrete pipe culverts"** mean prefabricated concrete pipes with circular sections.

d) **"Culvert"** means a structure other than a bridge, which provides an opening under a berm, carriageway or median for drainage or other purposes.

e) **"Geotextile"** means a synthetic-fibre filter fabric used for separation, filtration and drainage.

f) **"Inlet and Outlet drain"** means a channel along which water is to be led into or discharged from culverts, stormwater conduits and minor bridges.

g) **"Mitre drain and bank"** means a drain constructed at an angle to the centre line of a road to divert water away from side drains. Mitre drains include mitre banks placed across side drains.

h) **"Portal culverts"** or **"rectangular culverts"** means prefabricated concrete culverts other than pipe culverts.

i) **"Side drain"** means an open longitudinal drain situated adjacent to and at the bottom of cut or fill slopes.

j) **"Subsurface drain"** means a buried conduit constructed to intercept and remove subsurface water and includes any pipes and permeable material used in the construction of the drain.

k) **"Technical Methods for Highways (TMH)"** means a manual published by the CSIR. This Specification refers to TMH1 – Standard Methods of Testing Road Construction Materials, 1996.

27.2.3 References

When reference is made to a Code of Practice, Specification or Standard, the reference shall be taken to mean the latest edition or replacement at time of tender of the Code, Specification or Standard; including addenda, supplements, modifications and revisions thereto. Where a previous version is intentionally used, it will be indicated as such. Where reference is made to a Code, Specification or Standard that has subsequently been withdrawn and not replaced, the intended content will remain relevant unless confirmed otherwise in writing by the Engineer.

27.3 OPEN DRAINS AND BANKS

27.3.1 General

Open drains to channel surface water runoff and channels to direct the course of streams shall be constructed as shown on the Drawings or as directed by the Engineer. In the construction of the drainage system, particular attention shall be paid to the prevention of soil erosion.

Drains shall be provided where required at inlets and outlets to culverts as shown on the Drawings or as directed by the Engineer. Where necessary earth banks, pitching or other measures designed to prevent scour or erosion shall be built as shown on the Drawings or as directed by the Engineer. Any pitching of drains shall be undertaken in accordance with the requirements of Clause 27.8.

27.3.2 Construction of Open Drains

Open drains shall be constructed true to line, grade and cross-section and shall be maintained for the duration of the Contract. Care shall be exercised to avoid excavation below the required grade for the drains and any such excavation carried out below the required grade shall be backfilled with suitable material and compacted to at least 90% of modified AASHTO density without additional payment.

27.3.3 Construction of Concrete-lined Open Drains

Concrete-lined open drains shall be constructed as shown on the Drawings or as directed by the Engineer.

Excavations for these drains shall be profiled and trimmed to the lines and levels specified to ensure the accurate construction of the concrete linings. The trimmed surface shall be compacted to at least 93% modified AASHTO density to a depth of at least 150 mm.

Where excavations are in rock, overbreak shall be backfilled with mass concrete as directed by the Engineer.

27.3.4 Construction of Articulating Concrete Block (ACB) System-lined Open Drains

27.3.4.1 Materials

The ACB system shall be Armorflex® 180 or approved equivalent. The blocks to be laid by hand unless otherwise directed by the engineer.

Each block shall be factory produced, from compressed concrete, with vertical holes and two horizontal cable ducts. Concrete used in the manufacture of the blocks shall have a 28 day compressive strength of not less than 30 MPa.

Outside dimensions in millimetres shall be 340 x 300 x 110 high. Each block shall have a mass of approximately 17.1 kg. The interlocked blocks shall have a unit mass of 180 kg/m^3.

3.1 mm galvanized wire shall be used. The wires are to run at right angles to the direction of flow.

27.3.4.2 Preparation of exposed surfaces

The base of the canal will be prepared in accordance with the lines indicated on the detail drawings. The finished level shall not deviate more than 25 mm on a 3 m straight edge. In cut the trimmed excavation must be to line and level, fill must be compacted to 90% Mod. AASHTO density before being trimmed to line and level. The surface should be like a grader type finish, free from protruding roots, tree stumps, rocks, etc.

27.3.4.3 Geotextile

A UV stabilised non-woven geo fabric with minimum mass of 135 g/m^2 shall be placed on the prepared surface to the lines shown on the drawings. Overlaps must at least be 250 mm.

27.3.4.4 Laying of interlocking blocks

After the geotextile has been approved and laid, the blocks shall be laid by a half bond interlocking pattern. The cable ducts will be at right angles to the direction of water flow of the canal and the shorter dimension of the blocks shall be in the direction of flow. The minimum number of blocks should be cut along corners and bends. Laying shall always commence on the floor of the canal. Once a grid of blocks has been laid, the wires shall be fed through the cable ducts. The wires shall be of 3.1 mm diameter hot dipped galvanized fencing wire. The length of the wires shall be sufficient to allow the exposed ends to be effectively jointed. The wires must be jointed by twisting the ends neatly for a twisted stretch of minimum 100 mm. The finished level of the blocks may not deviate more than 25 mm on a 3 m straight edge. No individual block may protrude more than 10 mm proud of any adjacent blocks.

27.3.4.5 Anchoring

Anchoring by means of Y-fencing standards:

- The blocks shall be anchored in a 2 m grid with 1.4 m long Y-fencing standards driven into the ground, if so indicated on the detail drawings or specified by the engineer).

Anchoring with anchor beam:

- Specified by the engineer along a straight section of the canal. The concrete shall 400 mm deep and the beam shall be at least 400 mm deep and 250 mm wide. The concrete shall have a 28 day strength of at least 20 MPa. R8 U-bars at 340 mm centres shall be cast into the beam.

Anchoring along the sides of the canal:

- Anchoring along the top edge of the ACB lining shall be according to details on the drawings, and as specified.

Construction joints shall be provided at 5 m centres along anchor and other concrete beams.

27.3.4.6 Backfilling and grassing

As soon as the blocks have been laid, wired up and the anchors provided to the satisfaction of the engineer, the open cells and joint areas shall be filled with topsoil (removed and stored prior to commencement of construction) and the area hydroseeded according to the specification. Fertilizer as approved by the engineer shall be mixed into the soil before backfilling. Immediately after hydroseeding the hydroseeded area shall be watered, all with full compliance of Section 47: Landscaping and Rehabilitation.

27.3.4.7 Maintenance

The grass shall be maintained during the duration of the contract by watering. Damaged areas shall be repaired. Refer to Clause 27.10 and Section 47: Landscaping and Rehabilitation.

27.3.5 Construction of Banks and Mitre Drains

Mitre banks and catchwater banks shall be constructed of approved soil or gravel obtained from open-drain excavations or, if no suitable material can be obtained from that source, from suitable alternative sources, and be placed in such a way that the water will flow on the natural ground and against the bank.

The banks shall be compacted to at least 90% of modified AASHTO density in layers not exceeding 150 mm in thickness, true to the lines, levels and cross-sections, shown on the Drawings or directed by the Engineer.

If so preferred by the Contractor and approved by the Engineer, mitre banks may also be constructed of hand-packed stone, provided that the gaps are filled with an approved cohesive soil.

Mitre drains are required to stop water accumulating in table drains or on the road shoulder. Mitre drains shall be constructed so that they have a broad flat base at least 1m wide. Mitre drains shall not be graded to produce a V. Mitre drains shall slope to direct the flow of water away from the road. To minimise erosion the slope shall be no greater than 0.5% on erodible soils or 1% on stable

soils. Mitre drain outlets effectively concentrate runoff, for this reason they should be located in stable undisturbed areas.

Mitre drain spacing is dependent on:

- The grade of the table drain or road.
- Soil type and erodibility.
- Rainfall.

27.4 SUBSURFACE DRAINS

27.4.1 General

Subsurface drains shall be constructed as shown on the Drawings or where ordered by the Engineer. They may be located to drain underground water, which could endanger the stability or affect the serviceability of the Works.

They may be installed in herringbone fashion, with side collectors, when flow is along the Works or in any other necessary pattern that will drain surplus water away from the Works. They may also be installed below the invert of side drains to intercept cross flows. The subsurface drains shall be graded to discharge into the surface drainage system, away from the Works, or if necessary, into plain pipes which in turn will drain away from the Works via suitable outlets as indicated on the Drawings or directed by the Engineer.

The areas to be drained may only become apparent once the excavation has been completed. It will therefore not always be possible to give the Contractor precise information in advance. The Engineer may vary the layout and dimensions specified for subsurface drains to suit the conditions applicable during the construction of the Works.

The subsurface drains shall consist of a combination of un-lined trenches, with natural permeable filter material and perforated drainage pipes or a combination geotextile lined trenches with crushed stone filter material and perforated drainage pipes.

27.4.2 Materials for Subsurface Drains

27.4.2.1 Pipes

Pipes for subsurface drains shall be one of the following types as dictated by the position of installation and as indicated on the Drawings:

a) Corrugated single wall perforated pipes, manufactured from HDPE (High Density Polyethylene);

b) Double wall, corrugated outer wall and smooth inner wall, perforated pipes manufactured from HDPE compliant with BS EN 61386-24:2010prior to perforation;

c) Perforated slotted uPVC pipes complying with SANS 791, Class 51 (normal duty); or

d) Perforated slotted uPVC pipes complying with SANS 791, Class 34 (heavy duty).

The arrangements or coverage of the slots shall not proceed beyond the top 240 degrees of the pipe and the flow channel at the invert of the pipe shall not be less than 120 degrees.

The nominal slot width shall be between 1.4 mm and 2.0 mm, and the minimum area of drainage shall be 3 360 mm^2 for 110 mm nominal OD pipes and 5 000 mm^2 for 160 mm nominal OD pipes.

Un-perforated pipes required for conveying groundwater from the subsurface drainage system to the point of discharge, shall be un-perforated pipes of the types specified above as shown on the Drawings or as directed by the Engineer.

The Contractor shall submit to the Engineer for approval, at least 28 days prior to the commencement of the specific Section of the Works, samples, specification and performance data, as applicable of all the products he intends to use.

27.4.2.2 Natural Permeable Filter Material

Natural permeable filter materials for subsoil drainage shall consist of sand of suitable gradings.

Natural permeable materials shall conform to the following requirements:

- Sand shall be clean, hard sand obtained from approved sources;
- The sand shall comply with the requirements of SANS 1083, Table 27/1: Sand for concrete, and shall be either coarse, medium or fine grade as specified; and
- The nominal maximum particle size for the various grades shall be as shown in Table 27/1.

TABLE 27/1
NATURAL PERMEABLE MATERIALS: SAND

GRADE	NOMINAL MAXIMUM PARTICLE SIZE (mm)
Coarse	4.75
Medium	2.00
Fine	0.20

When no suitable sand is available from borrow pits, the Engineer may require that it be procured from commercial sources.

The grades of sand or natural permeable filter material to be used in each case to comply with the requirements shall be as indicated on the Drawings or as directed by the Engineer. In the case of any sand, not more than 5% of the material shall pass through a 0.075 mm sieve.

27.4.2.3 Crushed Stone

Crushed stone shall comply with the requirements given in SANS 1083, Table 5: Stone for Concrete, and shall be either coarse (19.0 mm nominal size) or fine (13.2 mm nominal size) as specified. The aggregate shall be evenly graded. The aggregate crushing value of the stone shall not exceed 30 when tested in accordance with TMH1 method B1.

As in the case of sand, the nominal stone size shall be indicated on the Drawings or as directed by the Engineer, and not more than 5% of the material shall pass through the 0.075 mm sieve.

27.4.2.4 Synthetic-fibre Filter Fabric (Geotextile)

The synthetic-fibre filter fabric or geotextile shall be of the nonwoven continuous filament needle punched polyester type.

The synthetic-fibre filter fabric is classified according to the mechanical properties thereof, viz its penetration load, puncture resistance and the minimum water percolation rate as measured in the permeability test. Table 27/2 shall be used for determining the grade of a synthetic-fibre filter fabric.

TABLE 27/2
GRADE CLASSIFICATIONS OF SYNTHETIC-FIBRE FILTER FABRIC

PROPERTY	GRADE			TEST METHOD
	1	2	3	
Penetration load (minimum), N	3900	2500	1600	SANS 12224
Puncture resistance (maximum), mm	14	26	32	EN ISO 13433
Water percolation (minimum), ℓ/m²/s	70	70	145	SANS 10221

Notes: The standard atmosphere for testing and the preconditioning atmosphere for all synthetic-fibre filter fabric tests (SANS tests and other) shall have a relative humidity falling within the range of 10 to 50 per cent and a temperature within the range of 15°C to 50°C.

The resistance of a synthetic-fibre filter fabric to puncture is the average diameter of the hole formed when a 45° cone with a mass of 1 kg is dropped through 500 mm on to the synthetic-fibre filter fabric fixed in the holding device. The test method and parameters shall be in accordance with EN ISO 13443.

The synthetic-fibre filter fabric shall withstand the level of aggressiveness of the soil and groundwater given below without significant loss of its strength and hydraulic properties during its design life of 25 years:

- Soil and groundwater with a pH in the range of 4 to 12 (pH to be determined by Method A20, TMH1, 1986); and
- Soil (as paste) and groundwater containing salts with a conductance of up to 1.0 S/m (conductivity to be determined by Method A21T, TMH1, 1986).

The synthetic-fibre filter fabric shall maintain at least 80% of its original strength after direct exposure to sunlight of 1 500 hours.

The synthetic-fibre filter fabric shall be entirely rot-proof and shall not support the growth of algae.

The synthetic-fibre filter fabric required shall satisfy the criteria for grade 1, 2 or 3 synthetic-fibre filter fabric as listed in the Bill of Quantities or specified on the Drawings.

The Contractor shall, at least 28 days before the installation of the synthetic-fibre filter fabric, submit to the Engineer samples of the synthetic-fibre filter fabric he proposes to use, for review and approval by the Engineer.

27.4.3 Construction of Subsurface Drainage System

27.4.3.1 Construction with Natural Permeable Material (No Geotextile Lining)

Trench excavations shall be to the dimensions and gradients as shown on the Drawings or as directed by the Engineer.

A layer of natural permeable material of the class and thickness as shown on the Drawings shall be placed on the bottom of the trench and be lightly tamped and finished to the required grade.

Pipes of the type and size specified shall then be laid and firmly bedded on the natural permeable material true to level and grade in accordance with the manufacturers' specification, with perforations at the top. Thereafter the trench shall be further backfilled with natural permeable material to such height above the pipes as shown on the Drawings or as directed by the Engineer. The permeable material shall be lightly compacted and finished to the required level. Further layers of finer natural permeable material shall then be placed, lightly compacted and finished to an even surface, as directed by the Engineer. The remainder of the trench, if any, shall be backfilled with approved impermeable material and as directed by the Engineer in layers not exceeding 200 mm and compacted to a minimum of 90% of modified AASHTO density or at least to the same density as the surrounding material. The trench shall be specially protected against the ingress of water until the impermeable layer has been completed.

Natural permeable material shall be placed in layers of not more than 300 mm at a time and be lightly compacted. The total thickness of each type of natural permeable material shall be carefully controlled, and when placing thinner layers, suitable spacers shall be used. When placing successive layers the lower layers shall not be walked on and as far as possible shall not be disturbed. Care shall be taken to prevent the contamination of natural permeable material during construction of the subsurface drains and all permeable material contaminated by soil or silt shall be removed and replaced by the Contractor without additional payment.

Any section of a subsurface drain constructed from pipes without perforation or slots shall be backfilled with impermeable backfill material as described in the foregoing. Where suitable the excavated material may be used for backfilling.

27.4.3.2 Construction with Synthetic-fibre Filter Fabric Lining (Geotextile)

Where specified in terms of the Drawings or as instructed by the Engineer, the trench shall be lined with the approved geotextile and secured flush against the trench sides.

A layer of crushed stone of the nominal size and thickness as shown on the Drawings shall be placed on the bottom of the trench and be lightly tamped and finished to the required grade.

Pipes of the type and size specified shall then be laid and firmly bedded on the crushed stone true to level and grade in accordance with the manufacturers' specification, with perforations at the top. Thereafter the trench shall be further backfilled with crushed stone to the height above the pipes as shown on the Drawings or as directed by the Engineer. The geotextile shall then be folded back to complete the top of the box forming the drain. The geotextile shall overlap by at least 300 mm or as instructed by the manufacturers.

27.4.3.3 Concrete Encasement of Drain Pipes

Where drain pipes are to be encased in concrete as shown on the Drawings or as directed by the Engineer, the pipes shall be laid true to level and grade on supports comprising in-situ concrete cradles of the same concrete strength as the encasement concrete. Care shall be taken to prevent flotation or displacement of the pipes during concreting.

27.4.3.4 Pipework

The method of laying and jointing of pipes shall be strictly in accordance with the specifications and instructions of the manufacturer of the type of pipe specified and approved.

27.4.3.5 Caps and Head Walls

The higher end of subsurface drain pipes shall be sealed off with a loose concrete cap or end caps of the same material as the pipe, where available.

At the lower end the pipe shall be built into a concrete head wall, all as shown on the Drawings, providing a positive outlet or connected to stormwater pipes or culverts.

27.4.4 Testing of Subsurface Drains

All subsurface pipes shall be tested, once earthworks or other works are completed, by flushing with clean water. If the pipes are found to be blocked, the Contractor shall clean them without additional payment.

27.5 PREFABRICATED CULVERTS

27.5.1 General

Stormwater runoff originating from open drains, slopes and streams shall be directed as required using concrete pipe, portal or rectangular culverts and shall be constructed at the locations and to the sizes, shapes and dimensions shown on the Drawings or as directed by the Engineer.

27.5.2 Materials

27.5.2.1 Culvert Units

The prefabricated culvert units shall be factory produced by a reputable manufacturer, approved by the Engineer, and shall comply with the following requirements:

(a) Precast Concrete Pipe Culvert Units

Concrete pipe units shall comply with the requirements of SANS 677. Concrete pipes shall be of the spigot and socket type using the rolling rubber ring principle or of the in-the-wall-joint type using the sliding rubber ring principle.

(b) Portal and Rectangular Precast Concrete Culvert Units

Rectangular or ribbed skew haunch portal precast concrete culvert units shall comply with the requirements of SANS 986.

Note: No precast concrete culvert units, as specified in a) or b) above, shall be transported and delivered to Site within 14 days of being cast.

27.5.2.2 Bedding Material

Bedding material and fill blanket material for pipe culverts shall be as specified in Clause 15.3.2 for Type A bedding.

27.5.2.3 Skewed Ends

Where culverts are to be constructed at a skew angle of more than 20°, the culvert units at the inlet and outlet of the culvert shall be supplied with skew ends if required. Skewed units shall be supplied by the manufacturer and cutting of skew ends on Site shall only be allowed if authorised by the Engineer in writing.

Portal and rectangular units shall be provided with skewed ends constructed from cast in-situ reinforced concrete in accordance with the details as shown on the Drawings.

27.5.2.4 Defects

All broken, bent, chipped, cracked, dented, or otherwise damaged units shall be repaired to the Engineer's satisfaction or, where this is not possible, be removed and replaced with undamaged units, all at the Contractor’s expense.

27.5.2.5 Joint Filler

Joint fillers shall be, high density, cross linked, closed cell expanded Polyethylene as specified in Clause 20.4.2.10 a).

27.5.2.6 Sealants

Sealants shall be 1-part, moisture cured, high mechanical resistant polyurethane sealant as specified in Clause 20.4.2.10 c).

27.5.2.7 Waterproof Adhesive Tape

a) Waterproof adhesive tape for sealing joints shall be 200 mm wide burlap, 340 g/m^2, pre-impregnated with a bituminous emulsion; or

b) 200 mm wide Geotextile Grade 3 (Table 27/2) pre-impregnated with a cementitious slurry consisting of the following mix:

   i) Synthetic Polymer Latex : Water - 1 : 1 (Emulsion).

   ii) Water (Emulsion) / Cement Ratio [W/C] - 0.8.

27.5.3 Cement: Sand - 1 : 1 Construction Methods

Prefabricated culverts shall be constructed under either:

a) "Trench conditions", where the units are laid in a trench excavated below existing ground level or in a trench excavated in previously constructed fill and, if necessary, subbase layers; or

b) "Embankment conditions", where the units are laid approximately on the existing ground surface and the fill is then constructed on either side and over the culvert.

Culverts shall be constructed by the method as shown on the Drawings or as instructed by the Engineer.

Small diameter concrete pipe and small portal culverts shall normally be constructed under trench conditions.

Large diameter concrete pipe and large portal culverts shall normally be constructed under embankment conditions.

27.5.4 Bedding and Laying of Prefabricated Culverts

27.5.4.1 Concrete Pipe Culverts

Concrete pipe culverts shall be laid on Class A or B bedding as shown on the Drawings or as directed by the Engineer. Spigot and socket or in-the-wall joint type pipes shall be laid with the spigot ends pointing downstream. The inside of the culverts shall be smooth with no displaced joints. All pipes shall be laid true to line and level.

(a) Class A Bedding

The pipe shall be laid so that the lowest part of the pipe rests on concrete of thickness 0.25D and the concrete extends upwards on either side of the pipe to a height of 0.25D, where D is the internal diameter of the pipe. The thickness of the concrete shall be a minimum of 100 mm and a maximum of 300 mm for trenches in soil and minimum 50 mm for trenches in hard rock.

The concrete shall be Class 20/19 F30 unless otherwise shown on the Drawings. During concreting, pipes shall be supported on suitably shaped temporary concrete cradles of the same class as the bedding concrete. Care shall be taken to prevent flotation or displacement of pipes during concreting.

A fill blanket of Type A material, Clause 15.3.2, shall extend upwards on either side of the pipe from the top of the bedding to 300mm above the top of the pipe.

(b) Class B Bedding

The pipe shall be bedded on a layer of compacted Type A bedding material, Clause 15.3.2, of thickness 0.25D not less than 100 mm and not exceeding 200 mm. The granular material shall extend to a height of 0.50D. Joint holes shall be formed in the trench bottom for pipe sockets and couplings. A fill blanket of Type A material, Clause 15.3.2, shall extend upwards on either side of the pipe from the top of the bedding to 300 mm above the top of the pipe.

(c) Rock Foundation

Where rock, or other hard material is encountered on the bottom of excavations, construction of pipes on Class B bedding shall proceed as follows:

- The loose material and rock pinnacles shall be removed and replaced with a levelling layer of sand or approved Type A bedding material compacted to 93% modified MODASSTO density. For payment purposes such material shall be classified as backfill; and
- Class B bedding shall then be prepared and placed.

(d) Concrete Encasing

Where directed by the Engineer, pipes shall be fully encased in Class 20/13 F30 concrete to the dimensions as shown on the Drawings or as ordered by the Engineer. Temporary supports shall be provided near the pipe ends to support the pipes during placing of the concrete. The concrete shall be placed in such a way that all spaces under the pipe are completely filled. Poker vibrators shall be used to ensure that all spaces under and around the pipes are properly filled with concrete.

Concrete casing shall have a flexible joint at each pipe joint formed using a joint filler in accordance with Clause 27.5.2.

27.5.4.2 Portal and Rectangular Culverts

(a) Cast In-situ Floor Slabs

Cast in-situ floor slabs shall be constructed to the dimensions and at the locations as shown on the Drawings or as directed by the Engineer. They shall be reinforced with steel reinforcement as detailed on the Drawings.

Joints as detailed on the Drawings shall be formed in the floor slabs, and between the floor slabs and the inlet and outlet structures.

(b) Placing the Portal Portion of Culverts

The upper portion of portal and rectangular culverts shall be placed accurately on the floor slabs, with a thin layer of 1 cement : 4 sand mortar between the contact surfaces to ensure a firm and uniform support.

The units shall be butted end to end with butt joints and the joints shall be sealed with two layers of waterproof adhesive tape, as per Clause 27.5.2.7, placed symmetrically over the joint. The strip of waterproof adhesive tape shall be at least 200 mm wide.

In the case where two or more culverts are placed side by side to form a multi-barrel culvert, the space between the culverts shall be filled with Class 20/19 F30 concrete up to the level of the top of the culverts.

27.5.4.3 General

Construction of culverts shall begin at the lower end, the position of which shall be fixed as shown on the Drawings or as directed by the Engineer. The position of the other end of the culvert shall normally be determined by the end of the last whole unit, the top of which breaks through the fill slope. However, in the case of skew culverts, or culverts with a cover of less than 0.5 m at the shoulder, the Engineer may order that the end unit be cut to the length and skew required.

Any units which deform or crack or which are not constructed to the required lines, levels and grades, or which become displaced during the duration of the Contract, shall be removed and replaced by the Contractor without additional payment.

Precast units shall be lifted and handled by means of approved lifting devices only. Lifting holes shall be caulked with a suitable mortar after the units have been installed. The Contractor shall exercise due care not to damage, overstress or displace any prefabricated culverts with his own traffic or compaction equipment.

Where loads in excess of those prescribed for Class 100D culverts are likely to pass over completed culverts, the Contractor shall provide additional cover over the culverts so as to ensure that the design stresses of the culverts are not exceeded. If the Contractor is required to supply and install culverts at a slope of more than 1:4, the work shall be carried out as specified in Clause 27.5.5.

27.5.5 Culverts on Steep Gradients

Where culverts are constructed on gradients exceeding 1 in 4, they shall be referred to as “inclined culverts”. Particular care shall be taken to protect excavations against stormwater damage and the trenches shall be excavated to firm ground. The trenches shall be backfilled with selected gravel or concrete if it is necessary to over-excavate in order to obtain a firm floor.

After first completing the outlet structure, the culvert units shall be laid in the normal manner, starting from the lower end and placing successive units firmly against each other to prevent subsequent movement. The lower unit shall be securely cast into the outlet structure.

Thrust and anchor blocks shall be constructed according to the Drawings supplemented by details furnished by the Engineer to suit the site conditions.

Backfilling of trenches shall be undertaken in horizontal layers, starting at the lower end.

27.5.6 Stormwater Pipes, and other Closed Conduits

The requirements set out for culverts in this Section, including the method of measurement and payment, shall apply mutatis mutandis to the construction of stormwater pipes or any other closed conduits intended for drainage.

27.6 DRAINAGE STRUCTURES

27.6.1 General

Drainage collecting structures such as manholes, catch-pits and other inlet structures and dispersion structures such as chutes, down pipes and other outlet structures shall be constructed at the locations and to the sizes, shapes and dimensions shown on the Drawings or as directed by the Engineer.

27.6.2 Materials

27.6.2.1 Concrete and Reinforcement

All formwork, reinforcement and concrete shall comply with the provisions of Section 20 – Concrete Works (Structural).

27.6.2.2 Precast Concrete Blocks in Outlet Structures

Where shown on the Drawings or instructed by the Engineer, the Contractor shall supply and install in drainage outlet structures, precast reinforced concrete flow dissipater blocks of Class 30/19 F50 concrete of and sizes shown on the Drawings or listed in the Bill of Quantities.

27.6.3 Construction

27.6.3.1 General

The methods, procedures, etc., to be used shall be strictly in accordance with the requirements of Section 20 - Concrete Works (Structural).

The form of manhole construction to be adopted is to be compatible with the finished depth of the manhole, the size of the largest pipe in the invert and the location of the manhole.

27.6.3.2 Concrete Cast In-situ Manholes

Concrete cast in-situ manholes shall be constructed in reinforced concrete in accordance with the Drawings or as directed by the Engineer. The inlet and outlet pipes shall be cast into the manhole walls but shall not protrude into the manhole by more than 150 mm. Where necessary the pipes shall be bevelled to suit the entrance and exit angles.

Where manholes are deeper than 1.0 m, galvanised step-irons shall be cast into the walls at 300 mm staggered vertical intervals. Manhole covers shall be of the type shown on the Drawings.

27.6.3.3 Inlet and Outlet Structures

Concrete cast in-situ inlet and outlet structures shall be cast in accordance with the Drawings or as directed by the Engineer. Where specified, a reinforced concrete apron with flow dissipaters shall be constructed at the outlets of culverts, stormwater sewers and pipe chutes as shown on the Drawings or as directed by the Engineer.

The Contractor shall be responsible for stormwater dissipation to sheet flow / plate flow conditions downstream of scour valve chamber wet wells, wingwall outlet structures and any other temporary or permanent outlet structures. The objective shall be to mimic stormwater sheet flow conditions during normal rain conditions, by means of rip-rap, or similar type of energy dissipaters in order to dissipate the energy of the water and spread the water out to sheet flow conditions. The maximum velocity of the sheet flow are to be kept below 0.5 m/s in order to prevent erosion immediately downstream of the structure.

27.6.3.4 Screeding to Fall

Where shown on the Drawings screeding shall be placed to fall to the invert of drainage structures. The screed shall be of the pre-scribed mix in accordance with Clause 20.4.7.6 and shall have a wood-floated finish in accordance with Clause 20.4.7.13.

27.7 DOWNPIPES

27.7.1 Materials

Concrete, formwork and reinforcement shall comply with the requirements of Section 20 - Concrete Works (Structural).

The materials to be used shall be as shown on the Drawings or as directed by the Engineer. The Contractor shall confirm and submit to the Engineer at least 28 days prior to the commencement of the specific Section of the Works, samples, specification and performance data, as applicable of all the products he intends to use.

27.7.2 Construction

27.7.2.1 Installing Down Pipe Units

The installation of the down pipes and discharge of these pipes into the surface or sub-surface stormwater drainage shall be as indicated on the Drawings or as instructed by the Engineer.

27.8 STONEWORK AND EROSION PROTECTION

27.8.1 General

Stonework and other erosion protection measures shall be used to prevent scour and erosion of watercourses, cuts, fills, drains and culvert inlet and outlet areas as shown on the Drawings or as directed by the Engineer.

The construction of, and the materials used in the construction of reno mattresses, as shown on the Drawings or as directed by the Engineer, shall comply with all the relevant requirements of Section 21 - Gabions and Reno Mattress Structures.

27.8.2 Materials

27.8.2.1 Stone

a) Stone for pitching shall be clean, hard, durable, unweathered boulders or rock fragments with no stone less than 150 mm in minimum dimension except that smaller pieces or spalls may be used for filling spaces between the larger stones. Rocks or stone shall be of such a shape that a stable protection structure of the required thickness is formed. Rounded boulders or cobbles shall not be used on slopes steeper than 2:1 unless grouted. The specific gravity of the stone shall not be less than 2.5.

b) Stone for rip-rap shall be uniformly graded, approved, dense, hard rock fragments or stone, not susceptible to disintegration or excessive weathering (which includes loss of mass, strength or the development of cracks) on exposure to the atmosphere or water. Rip-rap shall be abrasion resistant and shall withstand the stresses involved in supplying, dumping, spreading and compaction in place. It shall be free from soft material such as sand, clay, shale or organic material and shall not contain an excessive amount of elongated stone. Rip-rap material shall contain no deleterious matter such as oil, grease, chemicals or cement.

   The stone shall be obtained from essential excavations or commercial sources.

   The grading of rip-rap stone shall fall within the grading limits given in Table 27/3.

TABLE 27/3
GRADING LIMITS FOR RIP-RAP

RANGE OF STONE SIZE (IN TERMS OF D_{50} STONE SIZE)	FRACTION OF TOTAL WEIGHT SMALLER THAN THE GIVEN SIZE (%)
1.50 – 2.00 D_{50}	100
1.30 – 1.80 D_{50}	85
1.00 – 1.50 D_{50}	50
0.30 – 0.50 D_{50}	15

The D_{50} stone size for rip-rap in various sections of the Works shall be as specified on the Drawings.

c) Only stone that has received the prior approval of the Engineer shall be used on any particular part of the Works.

27.8.3 Construction

27.8.3.1 Stone Pitching

(a) Plain Stone Pitching

The area shall be prepared by excavating, shaping and trimming to accommodate the stonework and shall be thoroughly compacted by hand ramming to minimise subsequent settlement. A trench shall be excavated, as directed by the Engineer, along the toe of any slope to be pitched or along the unprotected edge of the pitching in the beds of streams. Two methods for the laying of stone follow, and the method to be adopted shall be decided by the Engineer.

(i) Method 1

Commencing at the bottom of the trench, the stone shall be laid and firmly bedded into the slope and against adjoining stones. The stones shall be laid with their longitudinal axes at right angles to the slope and with their surfaces in contact. The stones shall be rammed well into the bank and surface to be protected and the spaces between the larger stones shall be filled with fragments of approved pitching stone securely rammed into place. Placing of rock by dumping shall not be allowed.

(ii) Method 2

The technique and requirements laid down in Method 1 shall apply to Method 2 except for the following aspects:

a) No small stones or spalls shall be used to fill in spaces between larger stones.

b) Simultaneously with placing of stones, topsoil shall be introduced between individual stones and shall be sufficiently rammed so as to provide a firm bonded construction. The topsoil shall be provided to the full depth of the stone pitching at any point.

c) Rooted grass or grass tufts shall then be planted in the topsoil between the stones and be given copious initial watering. Thereafter it shall be watered at regular intervals until the grass is established.

Whichever of the above two methods is adopted, the finished surface of the pitching shall present an even, tight and neat appearance with no stones varying by more than 25 mm from specified surface grades or lines. The thickness of the pitching, measured at right angles to the surface, shall not be less than 150 mm.

(b) Grouted Stone Pitching

This work shall be undertaken in accordance with all the requirements specified for plain pitching in Clause 27.8.3.1 (a) above, except that the stones shall be individually set in a bed of cement mortar composed of 1 part cement and 3 parts sand. Before the mortar is applied, the surfaces of the stones shall be thoroughly cleaned of adhering dirt and clay and then moistened. The mortar shall be placed in a continuous operation for any day's run at any one location. The mortar shall penetrate to immediately below the top of the pitching surface to ensure that each stone is completely surrounded, other than the surface, by a layer of mortar.

After the mortar has been placed, the stones shall be thoroughly brushed so that their top surfaces are exposed. The grouted pitching shall be cured with wet sacking or other approved wet cover for a period of not less than 4 days after grouting and shall not be subjected to loading until adequate strength has developed. Where required, weep holes shall be formed in the pitching.

(c) Grouted Rockfill

This work shall be undertaken in accordance with the requirements of Clause 27.8.3.1 b) when rockfill is to be fully embedded in cement mortar.

27.8.3.2 Rip-rap

(a) General

Rip-rap shall consist of a course or courses of selected rock placed on bank slopes and toes, river and streambeds and other localities where protection of this type may be required. The grading, minimum dimensions and mass of the rock shall be as specified on the Drawings.

The surface of areas to receive rip-rap shall be neatly trimmed to line and level and all loose material compacted. The perimeters of rip-rap shall be protected by the construction of either rock toes, rock-filled trenches, gabions, reno mattresses, walls or other structures, as may be required.

Perimeter trenches shall normally be backfilled with rock of the same size and quality as used in the construction of the rip-rap it adjoins, but any cavities shall be filled with smaller material and the whole backfill shall be well compacted.

(b) Dumped Rip-rap

Dumped rip-rap shall be constructed by dumping the stone on the prepared surfaces, spreading it by means of bulldozers or other suitable earth-moving equipment and trimming it to the required lines and levels. Rip-rap shall be placed in a manner to ensure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock

fragments in such a manner as will result in well keyed, densely placed, uniform layers of rip-rap of the specified thickness. The critical mass of stone used shall be as specified on the Drawings.

(c) Rip-rap Slope Protection

Where rip-rap protection is required on slopes which are too steep to allow the dumped method b) above to be used, the rip-rap shall be placed in layers concurrently with the construction of the fill. The rip-rap shall be placed in a manner to ensure that the larger fragments are uniformly distributed and the smaller fragments fill the spaces between the larger fragments forming well keyed densely placed, uniform layers of rip-rap of the specified thickness. Hand trimming will be required only to the extent necessary to achieve a well keyed surface. Where shown on the Drawings or instructed by the Engineer synthetic-fibre filter fabric (Grade 1) shall be placed between the rip-rap and the fill to prevent the migration of fine material.

(d) Filter Fabric for Rip-rap

When the use of synthetic-fibre filter fabric is required, the material shall be placed on the prepared surface. The overlap between adjacent sheets shall be 500 mm, unless otherwise specified. Care shall be taken not to damage the filter fabric when placing subsequent layers, nor to expose the filter fabric to the sun for periods longer than necessary before covering up.

(e) Graded Natural Filter for Rip-rap

When the use of a graded natural filter is required, the material shall be placed on the prepared surface to the thickness specified on the Drawings or instructed by the Engineer. Care shall be taken not to disturb this layer when placing the rip-rap. The grading of the natural filter, which shall be a natural gravel or crushed stone, shall be given on the Drawings.

27.8.3.3 Masonry Walls for Drainage and Road Works

Masonry walls shall be constructed with stones set in cement mortar, as indicated on the Drawings, specified or ordered. The minimum mass of stone shall be 10 kg. The minimum dimension of stone shall be 75 mm. A foundation trench shall be excavated down to rock or to material of adequate bearing capacity and the minimum depth shall be 300 mm below ground level. Large selected stones shall be used in the foundation layer. Flat and stratified stones shall be laid with the flat surface in the horizontal plane. Stones shall be individually placed to break joints and to provide a minimum of voids.

The stones shall be wetted and set in 3 sand to 1 cement mortar. Exposed stones on the wall faces shall be cleaned of mortar by washing or wire brushing. The mortar shall be flush pointed to the approval of the Engineer, who may require a capping and end treatment in the same mortar. The top and ends of the wall shall be neatly finished with selected coping stones.

Weep holes shall be provided as instructed and shall be cleaned of mortar and any other clogging material that may have entered during construction. The walling shall be protected from the elements and be kept moist for a minimum period of 4 days after completion.

27.9 TRIMMING AND CLEARING UP ON COMPLETION

After completion of construction all areas affected by the Contractor's operations shall be finished off and cleaned up, and all rock larger than 75 mm in maximum dimension, shall be removed and disposed of as directed by the Engineer.

All intersecting earthwork slopes shall be neatly rounded. Drains shall be cleared of debris and obstructions, and any excess earth, debris or other waste material shall be removed to spoil or shaped and trimmed as directed by the Engineer.

All loose stones, dead vegetation, or other waste matter exposed on fill or excavation slopes which are liable to become loosened and fall into drains shall be removed.

All parts of the work and adjacent ground shall be left in a neat and presentable condition to the satisfaction of the Engineer.

The rehabilitation of all disturbed areas shall be in accordance with Section 47 – Landscaping and Rehabilitation.

27.10 MAINTENANCE OF DRAINAGE WORKS

The Contractor shall regularly inspect and clear in all drainage works the rubbish, sediment run-off, waste, weed growth or any other material liable to interfere with the correct operation of the system.

27.11 MEASUREMENT AND PAYMENT

The rates tendered under this section shall not include for the general obligations and work deemed to be covered by the items provided in Section 1 - General.

Except as itemised below, the measurement of all work for earthworks, reinforcement, formwork and concrete included in this Section will be made in terms of the applicable Clauses in Section 9 – Bulk Surface Excavations and Trenching, Section 15 – Trench Backfilling and Bedding, Section 16 – Embankment Construction and Section 20 – Concrete Works (Structural).

27.001 Catchwater drains

a)	**Natural open earth drain**	**Unit: cubic metre (m^3)**
b)	**Concrete lined drain**	**Unit: metre (m)**
c)	**Gabion and reno mattress lined drain**	**Unit: metre (m)**
d)	**Grouted stone pitched drain**	**Unit: metre (m)**
e)	**ACB lined drain**	**Unit: square metre (m^2)**

Measurement of natural open earth drains shall be the in-situ volume of material excavated to form the drains to the dimensions given on the Drawings. The rate tendered shall include full compensation for excavating in soft material and forming and compacting the bank with the excavated material to the dimensions shown on the Drawings.

In the instance of a lined open drain the rate shall include all labour, equipment and materials to construct the drain as per the Drawings. The rate shall include for all earthworks, shaping and surface preparation, disposal of surplus material and bed preparation as well as for the lining systems in the following instances:

- Supply, deliver and construct concrete, mesh, formwork, jointing material and finishing in the case of a concrete lined drain;

- Supply, deliver and construct geotextile, wire baskets, binding wire and stone in the case of a gabion and reno mattress lined drain;
- Supply, deliver and construct stones and grout in the case of a grouted stone pitched drain; and
- Supply, deliver and construct geotextile, concrete blocks, in-situ concrete beams to either side of the lined drain and in-situ concrete beams to the full width of the lined drain at intervals as prescribed by the manufacturer, galvanized wiring and Y- fencing standard, topsoil backfilling and grassing in the case of an ACB lined drain.

The rates shall include for the maintenance of the drains for the duration of the Contract.

27.002 Permeable material in subsurface drains

a)	**Natural permeable sand**	**Unit: cubic metre (m^3)**
b)	**13.2 mm crushed stone**	**Unit: cubic metre (m^3)**
c)	**19.0 mm crushed stone**	**Unit: cubic metre (m^3)**

Measurement will be the volume of approved permeable material in place in the drains, calculated from the dimensions given on the Drawings for the different classes of permeable material.

The rate tendered shall include full compensation for procuring, furnishing, transporting and placing the material as specified.

Only material placed within the specified widths, lengths and depths shall be measured for payment. If excavations are carried out in excess of the dimensions authorised by the Engineer, the quantity of material will nevertheless be based on the dimensions on the Drawings.

27.003 Bedding for prefabricated culverts

a)	**Class A bedding**	**Unit: cubic metre (m^3)**
b)	**Class B bedding**	**Unit: cubic metre (m^3)**
c)	**Extra over Class B bedding for construction on rock foundation**	**Unit: cubic metre (m^3)**
d)	**Concrete encasing**	**Unit: cubic metre (m^3)**
e)	**Cast in-situ concrete floor slabs for portal culverts (including blinding, reinforcement, formwork, joints, etc)**	**Unit: cubic metre (m^3)**

Measurement of bedding will be the volume of material placed, calculated from the dimensions given on the Drawings.

The rate tendered shall include full compensation for procuring, furnishing and placing the material including for trimming and compacting the material to the densities specified.

27.004 Prefabricated concrete culverts

a) Concrete pipe (diameter and class indicated) Unit: metre (m)

b) Portal culvert (size and type indicated) Unit: metre (m)

Measurement of prefabricated culverts will be the length measured along the soffit centre line of the culvert. The concrete work, formwork and reinforcement will be measured under Section 20 – Concrete Works (Structural) according to the dimensions on the Drawings or as instructed by the Engineer.

The rate tendered for prefabricated culverts shall include full compensation for supplying, testing, loading, transporting and off-loading of all culverts, for the provision and placing of mortar where required for bedding of culverts, for the installation, laying and jointing of culverts, including cutting on Site and waste.

The tendered rate for cast in-situ concrete floors shall include full compensation for procuring and furnishing all the materials, storing the materials, providing all Plant, mixing, transporting, placing and compacting the concrete, reinforcement, formwork, forming the inserts, construction joints and contraction joints, curing and protecting the concrete, repairing defective surfaces and finishing the concrete surfaces as specified.

27.005 Stormwater pipes and other closed conduits

a) Size and type indicated Unit: metre (m)

Measurement for pipes will be the length of pipe for the various types and diameters indicated, measured in place along the centre line, including the joints and fittings. Joints and fittings shall not be separately measured.

The rate tendered for pipes shall include full compensation for procuring, furnishing, transporting and installing the pipe work and shall also include for all fittings.

In the case of pipes to be encased in concrete, the rates shall also include for the provision of supporting devices as well as all measures to prevent flotation or displacement of the pipes / ducts during concreting.

27.006 Concrete structures for drainage systems

a) Outlet structures – sub-soil drains Unit: number (No)

b) Junction boxes – sub-soil drains Unit: number (No)

c) Cleaning eyes – sub soil drains Unit: number (No)

d) Concrete caps – sub soil drains Unit: number (No)

e) Culvert drop inlets (including grid) Unit: number (No)

f) Standard service manholes (including covers) Unit: number (No)

g) Headwall and Wingwall structures for pipes and culverts Unit: number (No)

h) Outlet storm water structures as per detail Unit: number (No)

The unit of measurement shall be the number of items constructed in accordance with the details on the Drawings, in the Specification or the Engineer’s instructions.

The tendered rate shall include full compensation for all excavation, backfilling, compacting to 90% of modified AASHTO density, disposing of surplus excavated material, keeping the excavations safe, dealing with any surface or sub surface water, building in the storm water conduit, procuring and furnishing all materials including reinforcement steel, providing, erecting and removing formwork, mixing, transporting, placing and curing the concrete and all labour, construction Plant and any other work required for constructing the concrete structures as specified.

27.007 Screeding to falls **Unit: square metre (m²)**

Measurement will be the net area of screed laid as calculated from the dimensions given on the Drawings.

The rate tendered shall include full compensation for supplying, placing, finishing and curing the screed in accordance with Section 20 – Concrete Works (Structural).

27.008 Stone pitching

a) Plain pitching

i) Method 1 **Unit: square metre (m²)**

ii) Method 2 **Unit: square metre (m²)**

b) Grouted stone pitching **Unit: square metre (m²)**

c) Grouted stone pitching on a concrete bed (total thickness indicated) **Unit: square metre (m²)**

Measurement will be the area in place of each type of pitching.

The rate tendered for each type of stone pitching shall include full compensation for furnishing all materials, compaction and trimming of excavated areas, forming and cleaning of weepholes, placing of stones, grouting, grassing and watering (applicable to Method 2) and for all other work necessary to complete the pitching as specified.

The tendered rate for the reinforcement mat shall be the mat installed as indicated on the Drawings or as authorised by the Engineer on Site. The rate shall include full compensation for the procuring and furnishing all materials required, fixing the mat to the ground and all pegs, labour, equipment and incidentals required.

27.009 Rip-rap **Unit: cubic metre (m³)**

Measurement for rip-rap will be the net volume of rip-rap in place calculated from the lines and levels on the Drawings for the different D_{50} stone size specified.

The rate tendered shall include full compensation for the preparation of surfaces, and for furnishing, transporting, handling and placing the filter material and rip-rap. The rates shall also include full compensation for all other incidentals necessary for completing the work as specified.

27.010 Masonry walls **Unit: cubic metre (m^3)**

Measurement for masonry walls will be the volume of actual walling constructed to the dimensions given on the Drawings.

The rate tendered shall include full compensation for furnishing all materials, trimming of areas, compaction of foundation, placing of stones, cement-mortar and for all other work necessary to complete the walls as specified.