PPS 9

PARTICULAR SPECIFICATION

DRILLING AND GROUTING (DAMS)

PPS 9: DRILLING AND GROUTING (DAMS) SPECIFICATION

PPS 9.1 INTRODUCTION

PPS 9.1.1 Scope

This section deals with the requirements for exploratory drilling and pressure grouting required for the *works* including the following:

(a) Rotary core drilling into rock and concrete and SPT tests in soil for investigative purposes.
(b) Drilling of percussion and rotary holes for grouting.
(c) Water testing in grout and exploratory holes.
(d) Pressure grouting in grout curtain.
(e) Pressure grouting to control water ingress.
(f) Pressure grouting of rock/concrete interfaces.
(g) Pressure grouting of rock fissures and cavities.
(h) Pressure grouting of concrete/steel interfaces for built in parts and invert liners.
(i) Stemming of grout and exploratory holes.
(k) Cleaning up after grout operations.

PPS 9.1.2 Purpose and Function of drilling and grouting

The foundation of the dam is to be grouted to form a seepage control curtain as illustrated on the applicable drawings, while drainage holes are provided to relieve hydrostatic uplift pressures beneath the wall.

The grouting of joints between construction blocks will be required in order to form monolithic arches between the buttresses, and the recovery of cores from the body of concrete will be necessary to facilitate effective quality control during construction.

PPS 9.1.3 Supporting literature

The grouting methods and procedures described in the documents listed below are considered good practice:

(a) Foundation grouting for dams
Part 1: Investigation - Ancold Bulletin 47, April 1977
Part 2: Design - Ancold Bulletin 48, August 1977
Part 3: Construction - Ancold Bulletin 50, August 1978
(b) Grouting Manual
Fourth Edition 1981, Water Resources Commission, NSW Australia.

PPS 9.2 DEFINITIONS

The following terms whenever used in this section shall have the following meanings:

(a) **"Depth"** means the distance from the start of the hole regardless of direction.

(b) **"Stage"** means a partial or complete length of hole in which water testing and grouting is performed. The following grouting stages shall be applicable to the Works (unless otherwise specified in the Project Specifications or on the drawings):
Pre-stage: From collar to 1 metre into the foundation rock mass
Stage 1: From 1 m below collar to 5 metres into the foundation rock mass
Stage 2: From 6 m below collar to 10 metres into the foundation rock mass (or to the depth indicated on the drawings, if this is less than 10 metre)
Stage 3 & deeper: Similarly in increments of 5 m if depth exceeds 11 m below collar.

(c) **"Pressure grouting in descending stages"** means the procedure of drilling a hole to a limited depth, setting a packer and grouting the hole, permitting the grout injected into the rock

around the hole to set sufficiently to prevent its entering the hole when the hole is cleaned, washing out the hole, drilling the hole to a deeper stage, setting a packer at the bottom of the previously grouted stage or elsewhere as directed by the *Engineer*, grouting the new stage, and thus continuing in as many cycles of drilling and grouting as are required.

(d) **"Pressure grouting in ascending stages"** means the procedure of drilling a hole to full depth in one operation and grouting from the end of the hole towards the surface in successive stages by setting the packers at predetermined depths.

(e) **"Cavity grouting"** means grouting to fill any voids in rock/concrete or first stage/second stage concrete interfaces around structures.

(f) **"Consolidation grouting"** means the injection of grout into fissured and jointed rock beneath a grout cap, concrete plinth or other sealing element and around tunnel linings to consolidate the rock mass. Where a concrete plinth is provided, consolidation grouting includes grouting of the contact between the concrete and the rock mass.

(g) **"Cut-off grouting"** where used on the Drawings means consolidation grouting carried out in specific locations on the tunnel periphery to depths greater than the standard consolidation grouting fans.

(h) **"Contact grouting"** means grouting of embedded steel to fill any voids at steel/concrete interfaces.

(i) **"Curtain grouting"** means the injection of grout into a row or rows of holes to a specified depth and inclination below the dam, or into the abutments.

(j) **"Drain hole"** means the drilling of a hole in the rock to a specified depth and inclination for the purposes of draining water from the rock and preventing the build-up of water pressure in the rock.

(k) **"Lugeon"** is the measure of permeability of the rock. One lugeon unit signifies a leakage of one litre per minute per metre length of hole per 10 bars of pressure.

(l) **"Refusal"** is reached when the flow rate of grout pumped into a hole at the maximum specified pressure is equal to or less than one litre per minute per metre length of hole.

(m) **"Piezometer hole"** means a hole in the rock in which a piezometer standpipe or standpipes are installed to monitor groundwater levels.

(o) **"P_{max}"** is the maximum grouting pressure, as determined by the *Engineer*, for a particular hole or stage.

(h) "**Lugeon Unit"or "UL"** One Lugeon unit is defined as a water take of 1 l per minute per metre length of hole tested at a pressure of 1 MPa (10 Bars) and is very approximately equal in value to 1,3 x 10-5 cm/s.

For tests carried out at other pressures:

$$UL = \text{water taken in test (litres/metre/min)} \times \frac{1000\ (kPa)}{P\ (kPa)}$$

where P = gauge pressure in kPa + (10 x Sin Q x l)
Q = angle of hole from horizontal
l = half length of stage + length of previous stage(s).

(i) **"Cement"** All cementituous materials including pozzolans and pseudo-pozzolans.

(j) **"Drainage hole"** A drainage or pressure relief hole is a hole required to relieve hydrostatic pressure in the rock mass or concrete. It may be drilled from the surface or from a gallery, through concrete or through a pipe embedded in the concrete for this purpose.

(k) **"Exploratory hole"** A hole drilled to recover a cored sample of as much of the material drilled as is feasible.

(l) **"Grout take"** Grout take is the consumption of cement by weight (kilogram) per metre length of grouted holes.

(m) **"Instrumentation drill hole"** A hole drilled for the purpose of placing instruments in the structure or rock.

(l) **"Upstage grouting"** Upstage grouting shall mean the process of drilling a hole to full depth initially and grouting from the bottom of the hole upward at different depths by means of a packer set at different depths. Upstage grouting shall be performed by attaching a packer to the end of the group supply pipe, lowering the grout supply pipe into the hole to the top of the lowest section to be grouted, expanding the packer, grouting at the required pressure, allowing the packer to remain in place until there is no back pressure, withdrawing the grout supply pipe to the top of the next higher section to be grouted and thus successively grouting the hole in sections at the specified pressures until the entire hole is completely grouted.

(m) **"Downstage grouting"** shall mean the process of drilling a hole to a limited depth, grouting to that depth, either washing out the grout hole after the injected grout has attained its initial set or redrilling through holes that are not flushed out, drilling the hole to a further depth after at least 24 hours of grouting the previous portion and then grouting the next stage. Thus the hole is successively drilled and grouted until the required depth is completely grouted to the satisfaction of the Engineer.

Downstage grouting can further be sub-divided into:
(a) Grouting of all stages with the packer at the surface. This shall include any hole which is completely grouted from base to surface in a single operation.
(b) Grouting the stages with the packer at the bottom of the previous stage.

PPS 9.3 GENERAL

The general requirements for drilling and grouting of the *works* are shown on the Drawings. However, the final extent of the drilling and grouting will be determined by the conditions which are encountered during the progress of the work. The number, location, spacing, direction, inclination and depth of the drill holes, the order of drilling such holes, the pressure and mixtures to be used for grouting, the depths at which the grout will be injected, the sequence of grouting holes and the pressures for water testing shall all be as determined by the *Engineer*.

Decisions on these matters will depend upon the nature of the rock encountered in the exploratory drilling or in the excavations and the results of the drilling, washing, water testing and grouting trials which shall be carried out by the *Contractor* at the start of the drilling and grouting work. Modifications to the techniques specified in this Specification, the Project Specifications or on the drawings may be required as work proceeds and as knowledge and experience is gained of the natural rock and foundation conditions. The *Contractor* shall alter or vary his operations, if so instructed by the Engineer, to suit such modifications.

In general, the primary holes in the grout curtain will be spaced at 8 m intervals. With the method of split spacing of holes, secondary holes will bring the spacing down to 4 m, followed by tertiary holes bringing the spacing down to 2 m and, if required, quaternary holes bringing the spacing down to 1 m.

Four trial panels, each 16m long x 12 m deep and incorporating 3 primary holes each shall be carried out well in advance of the programmed dates for the consolidation and curtain grouting. The same equipment shall be used as for the permanent works. An area large enough to carry out the trial panels shall be designated by the *Engineer*.

Equipment and personnel shall be provided to meet the requirements of the programme with respect to grouting and exploratory work required, which is required to commence early in the

Contract period.

The *Contractor* shall not be permitted to proceed with the drilling and grouting of a section of the *works* until a grouting trial has been carried out and the results evaluated by the *Engineer*.

The *Contractor* shall employ an approved specialist Subcontractor to carry out drilling and grouting work unless he can satisfy the *Engineer* that he is experienced in this type of work and possesses the necessary staff and equipment for the proper execution of the work. Drilling shall be performed in a workmanlike manner by competent and experienced operators. The experience and qualifications of the supervisors and operators shall be subject to the prior approval of the Engineer. This information shall be submitted at least one month prior to the start of any drilling or grouting. The *Contractor* shall arrange at all times that the drilling and grouting operations are performed under the direct supervision of foremen thoroughly experienced in this type of work and who will be responsible for ensuring that good practice according to the current state of the art is observed.

At least two weeks before work commences, the *Contractor* shall submit to the *Engineer* for his approval full details of the equipment that he proposes to use and his proposed method of carrying out the work. The procedures approved or agreed shall be strictly followed and records shall be accurately kept. The failure of any operator to comply with these requirements shall be sufficient grounds to ban him from carrying out further work.

The *Contractor* shall, as far as practical, programme the work such that drilling of holes and grouting take place at different times or on different shifts to facilitate oral communication during grouting operations. Where this is not possible the *Contractor* shall install a sound absorbent partition between the drilling and grouting operations.

The *Contractor* shall provide for the adequate disposal of all wash water and waste grout resulting from all grouting operations. He shall not allow such water and grout to contaminate any fill, backfill or other Works, and such water or grout shall not be allowed to flow into any watercourse until it has passed through settlement ponds or tanks approved by the *Engineer*.

The *Contractor* shall take all steps necessary to ensure that no pollution is caused as a result of drilling and grouting work. Before work commences, the Contractor shall propose methods whereby grout spillage, which occurs as a result of defective equipment, burst pipes or any other reason, shall be handled. These methods shall be subject to the approval of the Engineer.

PPS 9.4 GROUT

PPS 9.4.1 Materials

Grout for injection shall consist of a mixture of cement and, where required by the *Engineer*, one or more of the following cement extenders: Fly Ash (FA) or Condensed Silica Fume (CSF). Sand or other additives, including bentonite, shall be used only where directed and in proportions as agreed by the *Engineer* as applicable for the relevant applications.

Where grout is required to fill large cavities the *Contractor* shall obtain the Engineer's instructions regarding the possible use of a filler such as sand (see Sub Clause 9.4.1.2). The *Engineer* may require or permit the use of admixtures to control the rate of settings of the grout. The proportions of cementitious material, water and sand and any admixtures used shall be as specified or as directed. No additional payment shall be made for additives unless they have been ordered by the Engineer.

Grout that has not been injected within two hours after mixing shall not be used for grouting, and shall be disposed of as directed, and no payment shall be made for any such wasted grout.

Materials for grouting shall comply with the requirements of Section 14 - Concrete and in addition, the following:

PPS 9.4.1.1 Cement (CEM), Fly Ash (FA) and Condensed Silica Fume (CSF)

Cement shall be type CEM I Class 42.5 N (OPC) or CEM I Class 52.5 N (RHC) or Class 42.5 R

(RHC) to SANS 50197-1 and passing a 0.090 mm sieve, and not more than 10% shall be retained on a 0.045 mm sieve. The Blaine fineness shall be greater than 440 m^2/kg and specific surface > 2500 cm/g. The total alkali content, expressed as the sodium oxide (Na_2O) equivalent, not exceeding 0,6%, where: % Na2O equivalent = % Na_2O + (0,658 x % K_2O)

Fly Ash and Condensed Silica Fume shall also conform to the requirements of SANS 50197-1.

All cementitious materials shall be obtained from approved sources. Bagged cementitious material shall not be stored for longer than 30 days and shall be delivered in 50 kg paper bags. One 50 kg bag of cementitious material shall be taken as being equivalent to 37,5 litres.

Separate storage facilities shall be provided on the Site for each type of cementitious material used. During transportation, storage and at the place of the grouting activity, all bagged cementitious materials shall be kept covered to provide proper protection against moisture and other factors that may promote deterioration of the materials. Sheds for the storage of bagged cementitious materials shall be dry, well ventilated, weatherproof and watertight. The bags shall not be stored or placed in contact with the floor or ground.

PPS 9.4.1.2 Sand

The sand shall comply with the requirements of the Section 14 - Concrete; except that all sand shall pass a 2.36 mm sieve and not more than 10 % shall pass a 0.075 mm sieve.

PPS 9.4.1.3 Water

In addition to the requirements of the Section 14 - Concrete, water for grouting shall not contain organic matter in suspension or solution, and shall contain no particles larger than 80 microns. The temperature of the water immediately prior to the preparation of grout shall be in the range of 5˚ to 35˚C.

PPS 9.4.1.4 Bentonite

Bentonite used in bentonite/cement grout shall have a Plasticity Index greater than 400. It shall be supplied from an approved source. Test certificates of the properties of the bentonite supplied shall be made available to the *Engineer* on request. When mixed with water the bentonite shall not contain any particle larger than 75 microns and shall not contain any substance detrimental to the setting and hardening of the bentonite/cement.

The *Contractor*'s arrangement for delivery and storage of bentonite shall comply with the requirements of SANS 1200, as amended for the delivery and storage of cement.

The *Contractor* shall store at the site of the *works* sufficient bentonite to satisfy grouting requirements for at least ten days.

The bentonite/water slurry base shall be prepared in advance using cement-free water in a high turbulence (colloidal) mixer and kept agitated in a large container for at least 24 hours. Mixers used for grout shall not be permitted to mix the bentonite/water slurry.

PPS 9.4.1.5 Admixtures

Admixtures used shall comply with ASTM C-494, AASHO M-154 or BS 5075. Admixtures, such as plasticisers, accelerators and retarders, may be used only with the approval of the *Engineer*. In support of the request for the use of an additive the *Contractor* shall submit the results of relevant laboratory tests demonstrating the effectiveness and advantages of the product. Products whose chemical composition is not made known to the *Engineer* will not be approved for use in grout.

PPS 9.4.2 Testing

The *Contractor* shall provide acceptable Marsh flow cones, thermometers, mud balance and measuring cylinders (60 mm diameter) to enable the *Engineer* to check the consistency of the grout at any time. The applicable limits shall be jointly established by laboratory and field tests prior to work commencing.

PPS 9.4.2.1 Density (Mud Balance)

Determination of the relative density of freshly mixed grout shall be with a mud-balance. Readings of relative density taken directly from the calibrated beam shall be converted to a water cement ratio by means of an agreed curve or table.

PPS 9.4.2.2 Viscosity (Marsh Cone)

The fluidity of grout shall be measured with a flow cone, immersion apparatus or viscometer. The instrument shall be accurately calibrated in a laboratory so that the specified viscosity of the grout can be controlled satisfactorily.

The procedure for conducting the flow-cone test for measuring the fluidity of grout shall be as follows: The type of flow cone shall be subject to the approval of the *Engineer*.

Immediately after the grout has been mixed, the pre-wetted flow cone, which is held firmly with its top rim in a level position, shall be filled with grout to the level indicated by the pre-set pointer, whilst the bottom orifice is held closed with a finger.

As soon as the required volume of grout, (± 1 750 mℓ), is reached, the finger shall be released to allow the grout to flow out freely through the bottom orifice. A stop watch shall be used to determine the flow time for emptying the cone, to the nearest second.

The readings obtained during grouting shall be compared with the times determined in the laboratory for grouts of the specified viscosities.

PPS 9.4.2.3 Bleeding

The bleeding of grout shall be measured in a metal or glass container with an internal diameter of approximately 100 mm and a height of approximately 120 mm. The grout and water levels in the container shall be controlled with a metal bridge into which two adjustable studs A and B are secured. The procedure for determining the bleeding of grout shall be as follows:

Studs A and B in the metal bridge shall be adjusted and locked so that the distance from the lower tips of the studs to the bottom of the container will be approximately 100 mm and 107 mm respectively. The volumes V_A and V_B for the container at the respective levels of the stud settings shall then be determined to the nearest millilitre.

The container shall be filled with freshly mixed grout to a level where the grout will just touch the tip of stud A which points downwards. The bridge shall then be removed and the container tightly sealed to prevent evaporation. The container shall then be stored at 20°C and kept free from vibrations for the entire duration of the test.

Three hours after the grout has been mixed, the container shall be opened and the free (bleed) water poured off. The bridge shall be placed over the container with the tip of stud B pointing downwards and water poured onto the grout with a measuring apparatus until the water level touches the tip of stud B. The volume of water added shall be determined to the nearest millilitre and designated as ΔV.

The percentage of bleeding shall be calculated from the formula.

$$100 - \left\{ \frac{(V_B - \Delta V)}{V_A} \right\} \times 100$$

PPS 9.4.2.4 Test Cubes

For grout in production at each grout mixing station for use in the Works, samples of grout shall be taken by the *Contractor* at the point of mixing or of deposition as instructed by the *Engineer* and in the presence of a representative of the *Engineer*, all in accordance with the sampling procedures described in SANS 5862.

Samples shall be taken on the basis of one for each 20 m^3 of grout pumped but in any case not less than one sample per day per mixing station.

The *Contractor* shall cast from each sample, cure and test six test cubes as set out in SANS 5863. Three cubes shall be tested at 7 days and 3 at 28 days.

The average strength of the 3 cubes crushed shall be referred to as one test result.

Grout shall be deemed to comply with the strength specified if the average strength of any 4 consecutive test results exceeds the agreed characteristic strength by 2 MPa and the strength of any test result is not less than the specified characteristic strength minus 3 MPa.

The quantity of grout represented by any group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. When a test result fails to comply only the particular batch from which the sample was taken shall be deemed to fail to comply.

The *Contractor*'s methods of sampling, making of cubes and testing shall not be considered as a valid reason for rejecting the results of such tests on grout placed in the Works. Should test results fail the remedial measures referred to in SC 14.14.3 shall apply.

PPS 9.4.3 Mix

The grout mix is specified as the ratio of water to cementitious material by mass. In principle a single grout mix shall be used for the grout curtain irrespective of depth of hole and location. However, the *Engineer* may require a thicker mix for use in zones of high take and a thinner mix for special cases. In case of major absorptions a cement mortar mix shall be used. The *Contractor* may, however, propose an admixture to render the grout thixotropic instead of using sand.

The appropriate grout mix shall be determined on the basis of grout tests prior to the commencement of the trial panels.

In carrying out the laboratory tests the mixing equipment to be used on the grouting *works* shall be used. Bentonite slurry shall be prepared in accordance with Sub Clause 9.4.1.4.

Any grout which does not contain a retarder and has not been used within one hour of the time of mixing shall be discarded and disposed of in a manner approved by the *Engineer*.

Initially, grout tests shall be carried out on mixes with water/cement (W:C) ratios of 0.8:1, 1:1, 0.6:1 and 0.4:1, aiming to provide stable mixes with less than 5% settlement at 2 hours and Marsh Cone values of about 35 seconds. Admixtures may be used to reduce Marsh Cone values and compressive strengths at 28 days shall be greater than 25 MPa on 50 x 50 x 50 mm cubes cured under water. One set of cubes shall be tested per day until consistency of results allows testing intervals to be increased.

All grout shall be mixed in a high speed colloidal mixer for at least 1½ minutes from the time the last constituent is added to the mixer.

During grouting operations the following routine tests shall be performed at the collar of the hole as directed by the *Engineer*.

Density	-	Mud balance test
Viscosity	-	Marsh Cone
Bleeding	-	60 mm diameter measuring cylinder

The *Contractor* shall make arrangements for a location close to the hole being grouted where the bleeding test will not be disturbed.

PPS 9.5 EQUIPMENT

PPS 9.5.1 General

The *Contractor* shall provide sufficient drilling and grouting equipment and all necessary ancillary equipment, scaffolding and other accessories to complete the various types of drilling and grouting required. Such equipment shall be of types and capacities approved by the *Engineer* and shall be maintained in first class operating condition at all times.

Where equipment is air driven the *Contractor* shall provide sufficient compressors such that all equipment in use can operate together at the necessary pressure. The use of internal combustion engines for grouting in tunnels and galleries will not be permitted.

Equipment shall be suitable for operation on surface as well as in underground locations and galleries.

Equipment and other items required for drilling and grouting shall be transported along the tunnels or galleries in such a manner to ensure no damage is caused to the finished surfaces of concrete.

The *Contractor* shall not use any drilling and grouting equipment of which full details have not been submitted to the Engineer and approved before any drilling or grouting is started. Details shall be submitted at least one month prior to the start of the drilling and grouting activities.

PPS 9.5.2 Drilling Equipment

PPS 9.5.2.1 General

Drilling of grout holes shall be undertaken with water flushed through hollow drill rods. Either pneumatic percussion drilling or rotary type diamond drilling may be used. Tungsten carbide tips or other types may be used with the approval of the Engineer. The hole diameter shall be 40 mm at the point of maximum penetration.

The *Contractor* shall provide equipment capable of accurately measuring (to within one degree) the slope and direction of holes and where required the orientation of the core.

If necessary, a stable platform from which to drill shall be provided as part of the temporary works.

PPS 9.5.2.2 Percussion Drills

Percussion drills shall be capable of drilling 50 mm diameter holes for curtain (if authorised by the *Engineer* after test drilling in the grouting trial panels referred to in Sub Clause 9.3) and consolidation grout holes in the dam foundations and to depths of up to 30 m in the case of curtain grouting or such greater depth as shown on the Drawings. For other types of grouting, holes at least 38 mm diameter up to 10 m in length will be required. Such drills shall be provided with a water supply at a minimum pressure of 8 bar at the drill, when all equipment on the same supply is operating together.

PPS 9.5.2.3 Rotary Core Drills

Rotary core drills and associated equipment shall be capable of producing minimum diameter NX series cores from holes drilled in any direction. Drills shall be equipped with hydraulic feed control and double tube core barrels. The equipment shall be capable of drilling and recovering cores to a depth of 50 m.

Rotary core drilling with diamond crowns and swivel type bottom discharge triple tube core barrels for exploratory holes where core recovery will be the primary requirement. The use of split inner barrels or plastic liners for inner barrels shall be adopted where suitable to aid sample recovery.

The rigs shall be equipped with measuring devices capable of automatically measuring and recording drilling parameters such as drilling speed, bit pressure and fluid flow.

PPS 9.5.2.4 Rotary Drills for Cutting Steel

Rotary drills with diamond tipped coring bits of the same diameters as the grout holes shall be available to penetrate any reinforcement which cannot be avoided by sleeved holes.

PPS 9.5.2.5 Standpipes and Casings

Standpipes and casings shall have an internal diameter suitable for the use of packers and the required drill bits.

Casings shall be either solid or perforated and of mild steel, or suitable plastic material. Casings used to support the sides of holes in caving ground shall be mild steel flush screw jointed tubes complying with BS 1387. Plastic casings shall be of a quality and thickness sufficient to resist collapse by earth pressure or self-weight and shall not be subject to cold flow. A minimum pressure class of 1000kPa is required.

Where perforated casing pipes are used they shall have 10 mm diameter drain holes or slots (10 mm x 25 mm), constituting about 10% of the area of the pipe walls.

PPS 9.5.2.6 Storage of Cores and Core Boxes

All core recovered from all boreholes shall be retained and carefully, neatly and securely packed in the correct sequence in approved core boxes, the design of which is given in Figure 9.1 in Appendix D, so as to produce a faithful record of the formation drilled. No core box shall contain core of more than one hole. The borehole number, depths of core and the box shall be marked clearly, neatly and indelibly on boxes as specified in Figure 9.3 in Appendix D.

Core boxes shall be of robust wooden or steel construction to withstand the weight of core and any full boxes which may subsequently be placed upon them and also sufficiently watertight to protect the core from rain on Site or in transit. They shall be made to hold the particular size of core tightly in place in rows separated by securely fitted partitions. Core box lids shall be kept securely fastened to the boxes at all times except when inspected. A sample core box shall be submitted to the *Engineer* for approval prior to manufacture or placing of orders.

Where instructed by the *Engineer*, cores shall be sealed to retain the natural moisture content, by wrapping tightly in thin self-adhesive polythene film (cling wrap) immediately on removal of the sample from the core barrel, followed by wrapping in aluminium foil and completely coating the sample in a layer of wax at least 5 mm thick. The application of the wax shall take place as soon as possible after initial wrapping. During the intervening period the core shall be kept covered with damp sacking and protected from damage.

Core shall be laid in the boxes in correct sequence clearly marked with wooden spacers, giving the depth at any points of interest and marking all points of core loss.

Each sample shall be clearly labelled and an identification sheet shall be wrapped around the sample under the aluminium foil.

The samples and boxes shall be carefully handled to prevent damage and shall be delivered to the *Employer*'s core shed.

PPS 9.5.2.7 Photographs of Cores

Before the cores are sampled and as soon as possible after cores have been correctly packed in the core boxes and marked up, the *Contractor* shall photograph the core boxes in colour.

Each photograph will usually show two consecutive core boxes (1-2, 3-4, etc.,), both from the same borehole. The core boxes shall be arranged so that all details of the core and markings inside the core box will be clearly visible and easily readable in the photograph, which shall also include colour charts, a linear scale and a title board (Figure 9.2 in Appendix D). To facilitate the clarity, the cores shall be wetted just before being photographed. The *Contractor* shall submit the photographs in digital format with the information being provided on CD as well as the two colour prints to the *Engineer*.

PPS 9.5.3 Grouting Equipment

PPS 9.5.3.1 General

Grouting equipment shall be capable of effectively batching (with an accuracy of better than 2% for batching by volume or mass), and producing a colloidal mix as specified, and of delivering and pumping grout into the grout holes through grout connections in a continuous uninterrupted flow at any constant pressure up to the limiting pressure specified. Where required, equipment shall be protected against direct sunlight.

The arrangement of the grouting equipment shall be such as to provide a continuous circulation of grout of uniform consistency throughout the grouting system and to permit accurate pressure control at the collar of the hole being grouted at all rates of grout approval. Pressure gauges and valves shall be supplied at the pump, at each hole being grouted, and elsewhere as required to ensure the necessary control of grouting operations. In the case of all grouting activities automatic pressure/time and flow/time and total volume chart recorders shall be connected at the collar of each hole being grouted unless otherwise agreed by the *Engineer.* A new chart shall be used for each hole injected. All grouting circuits shall be so designed as to provide a return line from the site of injection to the holding tank such that a continuous flow of grout is maintained in the delivery line between the grout pump and the collar of the hole being injected.

Computerised systems (Lutin supplied by Lutz or similar approved) may be used for measurements, but these shall be of a robust design capable of operating under all conditions that will exist during grouting operations. One such system is required per injection point with one spare.

All equipment shall be satisfactorily maintained to ensure continuous and efficient performance during all grouting and water testing operations.

Grouting equipment shall be to the following minimum requirements and shall include all associated valves, water flow meters, pressure hoses, pipes, sleeves, casings, packers, fittings and small tools necessary to complete the grouting as specified.

PPS 9.5.3.2 Pumps

Grouting pumps shall be double acting reciprocating, with pressure damping cylinder, positive displacement screw-feed or other type of pump approved by the *Engineer.* Grout pumps for fissure, curtain, cover, cut-off and consolidation grouting shall be capable of injecting grout continuously at a rate of up to 100 litres per minute at pressures between 100 kPa and 1000 kPa (both maxima to be achievable simultaneously). The grout pumps for grouting construction joints and underneath equipment shall be capable of grouting at pressures between 1 kPa and 50 kPa.

The rate of pumping shall be readily and accurately adjustable from zero flow to the maximum capacity. Equipment shall be such that grout consistency can be adjusted without causing an interruption that could result in setting of grout before pumping is resumed.

Pumps shall be equipped with quick acting lubricating plug valves and accurate pressure gauges, reading in bars. Pumps shall be fitted with automatic pressure relief valves unless otherwise agreed by the *Engineer*.

Grout pumps shall be capable of pumping grout at a water:cement ratio of up to 1:3 as well as grout containing other materials such as bentonite, sand or other chemicals.

PPS 9.5.3.3 Mixers

Grout mixers shall be of the high speed colloidal type, with a minimum of 1200 rpm, designed primarily for mixing grout materials, including grout to which sand or additives have been added if required, and of sufficient capacity to ensure that the pumps are supplied with a continuous flow of thoroughly mixed grout.

PPS 9.5.3.4 Tanks

Tanks for holding grout between mixing and grout injections shall be of the double drum type

equipped with mechanical agitators capable of maintaining the solids of the grout in suspension. The feed into the tanks shall be equipped with adequately sized screens to remove any hardened grout or foreign material larger than 1 mm from grout entering the tanks from the mixers and from the grout return lines. The capacity of the holding tanks shall not be less than that of the grout mixer and the tanks shall be fitted with a graduated dip-stick or gauge glass which is capable of recording the volume of grout contained in the tank to within 1 litres.

Constituent materials of the grout shall not segregate during transportation.

PPS 9.5.3.5 Water Meters

Meters for the measurement of water to be used in grout mixes shall be large faced with adjustable volume markers graduated to read to an accuracy of one tenth of a litre at all rates of flow.

PPS 9.5.3.6 Flow Meters

Refer to Sub Clause 9.5.3.1.

PPS 9.5.3.7 Pressure Gauges

Pressure gauges shall be calibrated to read in kPa and have minimum divisions of 10kPa. They shall be equipped with devices which will protect the mechanism of the gauge from being damaged by grout. The gauges shall have a range of approximately twice the expected maximum pressure for the particular hole and shall have an accuracy of ±3%.

Gauges shall be provided at the grout pump and at the point of injection.

The *Contractor* shall have an accurately calibrated high-precision master pressure gauge for checking the accuracy of all pressure gauges used in the grouting system. A pressure gauge certified by an approved certification body for calibration of working gauges and a 100% replacement stock of working gauges shall be on hand at all times. Working gauges shall not be used for longer than two shifts, hereafter they shall be cleaned and calibrated. All working gauges shall be marked with a number for identification.

Packers shall be suitable for all pressures and rock conditions, and shall be subject to approval. Mechanically expanded packers may be used at the top of the hole (for downstage grouting) but pneumatic or hydraulic packers shall be used where the hole has to be sealed at depth.

PPS 9.5.3.8 Chart Recorders

Refer to Sub Clause 9.5.3.1.

PPS 9.5.3.9 Packers

Packers shall consist of pneumatic or hydraulic expandable tubes which can be set singly in a grout hole at any depth required. Packers shall be so designed that they can be expanded to seal the holes at the specified depths and that when expanded they shall be capable of withstanding without leakage, water pressures equal to the maximum grout pressures which they will have to withstand.

The *Contractor* shall also have double packers of the pneumatic or hydraulic type at least 1 m in length available for use when required by the *Engineer*.

PPS 9.5.3.10 Connections to Embedded Steel

In areas where concrete is faced with steel and contact grouting is to be carried out, sleeves will be required to screw into the grout holes provided in the steel into which packers can be installed or to which grout connections can be attached. The length of thread on the sleeves shall be limited to prevent the sleeves being excessively screwed into the holes and blocking the steel/concrete interface. An adequate stock of sleeves shall be made available to enable grout to be injected behind the steel plate, the valves closed off and the pressure maintained in the grout until the initial set has taken place.

PPS 9.5.3.11 Sleeve Pipes

In areas where grouting is to be carried out through concrete, PVC sleeves will be required through which drilling can be undertaken and into which packers can be installed or to which grout connections can be made.

PPS 9.5.3.12 Grouting Delivery Lines

All grout pipes, hoses and fittings shall be capable of withstanding a pressure of 1000kPa and shall be protected from damage or breakage by vehicles, plant, blasting operations, freezing and the like. A return line shall be provided for flushing hoses, to control the rate of pumping and for emergency pressure relief. These shall be connected to the pump side of the recorder gauges at the collar of the grout hole and shall discharge into the holding tanks or to waste containers only. The *Contractor* will not be permitted to discharge grout without such collectors.

The length of grouting hose from the grout pumps to the hole to be grouted shall not exceed 100 m.

PPS 9.5.3.13 Water pressure testing equipment

The *Contractor* shall provide suitable pumps for water pressure testing which shall be capable of delivering at least 100 litres of water per minute against the specified maximum pressure. The pump shall be provided with equipment that allows for the measurement of the rate of flow into the hole to an accuracy of ± 2 % for flows exceeding 0,5 litres/min. The rate of pumping shall be readily and accurately adjustable from zero flow to the maximum capacity. Pumps shall be equipped with quick acting lubricating plug valves and accurate pressure gauges, reading in bars. Pumps shall be fitted with automatic pressure relief valves unless otherwise agreed by the *Engineer*.

PPS 9.5.3.14 Standby Equipment

During all grouting operations, the *Contractor* shall have available at all times 100% standby equipment of all types to ensure that grouting operations can be continued without significant interruptions caused by breakdowns of equipment. Circuits shall be provided such that standby pumps can be brought into operation within 10 minutes.

PPS 9.5.4 Flushing Equipment

Flushing equipment shall comprise separate pumps, gauges, hoses, nozzels, etc other than that used for flushing and water pressure testing at grout holes. The equipment shall be suitable to pump water into designated locations in structures which require a continuous flow of water to intercept and prevent injected grout from solidifying in unwanted locations.

Pumps shall be capable of delivering at least 300 litres of water per minute against a maximum pressure of 3 bar at the location of injection. The pumps shall be provided with equipment that allows for the measurement of the rate of flow into the hole to an accuracy of ± 3 % for flows exceeding 10 litres/min. The rate of pumping shall be readily and accurately adjustable from zero flow to the maximum capacity. Pumps shall be equipped with quick acting lubricating plug valves and accurate pressure gauges, reading in bars. Pumps shall be fitted with automatic pressure relief valves unless otherwise agreed by the *Engineer*. Unless suitable storage with intermediate pumping is provided above the crest level of the dam, pumps will be located on barges on the impoundment.

Hoses, nozzles, couplings, etc shall be connected to holes in the concrete faces of structures and shall be capable of withstanding the maximum pressures listed above without dislodgement.

PPS 9.5.5 Displacement gauges

Displacement gauges shall be provided to enable any rock movement during grouting to be measured. A displacement gauge may consist of a screw-adjusted spirit level on a steel straight edge 2 m long, or other approved device. Displacement gauges shall be required to monitor movement of adjacent blocks during grouting of joints in a concrete wall.

PPS 9.5.6 Communication during Grouting Operations

Where the various individual elements of the plant are located in such positions that communication by normal voice between the hole being injected and the plant is not satisfactory the *Contractor* shall install an effective means of clear oral communication such as a telephone or radio system to the satisfaction of the *Engineer*. If approved communication systems are not available the *Engineer* will stop the work until such system of communication is effected.

PPS 9.6 DRILLING PROCEDURES

PPS 9.6.1 General

The position, direction, inclination, spacing, depth, order and timing of drilling holes for exploratory drilling, drain holes or grouting, shall be as shown on the Drawings or as directed by the *Engineer*. The holes shall be drilled straight in the required direction and inclination, and the length of holes shall be established by reference to the collar level and profiles recorded by the *Contractor* or *Engineer*.

Unless otherwise required, holes shall be started within 250 mm of the specified position or plan or section and shall be drilled in the direction specified within a tolerance of 2% of the length of the hole. The holes shall be drilled to within 0.3m of the specified depth. No hole shall be deepened or drilled within 5 m of freshly grouted holes until the *Engineer* is satisfied that the grout in the rock adjacent to the hole has set sufficiently to prevent it being washed into the hole.

Holes shall be drilled wet and a constant flow of return water, sufficient to ensure that all drill grindings and sludge are completely washed out, shall be maintained at all times. Except where approved by the *Engineer*, the *Contractor* will not be permitted to use rod lubricants or other additives to the drilling water as an aid to drilling or stabilising the holes.

Where packers are to be used in any hole for grouting or water testing, the *Contractor* shall take every precaution to maintain a smooth wall in the hole in order that packers can be set at any location required by the *Engineer*.

No blasting shall be permitted within a radius of 100 metres from completed grout holes.

PPS 9.6.2 Holes through Concrete

Where holes are required through concrete, the *Contractor* will be permitted either to drill the holes or where indicated on Drawings or as instructed by the *Engineer* shall embed PVC sleeves in the concrete through which the rock behind can be drilled.

No drilling shall be carried out in concrete less than 7 days old.

In the case of reinforced linings, the formwork shall be marked by means of plugs or in some other way approved by the *Engineer* to indicate positions where drilling may be carried out without obstruction by reinforcement.

Should steel reinforcement be encountered during the drilling of any hole in concrete, where required by the *Engineer*, drilling shall be discontinued immediately and a new hole shall be drilled alongside. Such discontinued holes shall be stemmed as specified in Sub Clause 9.11. Where it is approved to drill holes through reinforcement, (such as quaternary curtain grout holes and inclined check holes), rates for drilling through concrete shall include the possibility of drilling through reinforcement. Sleeves left in the structure not used for drilling holes shall be stemmed.

PPS 9.6.3 Rotary Core Drilling for Grout Curtain, Piezometers and Exploratory Work

Rotary core drilling is a hole drilled by means of a diamond or a tungsten tipped bit using a double tube or triple tube core barrel from which 100% core recovery is expected. The hole diameter shall be 76 mm (N size) for curtain grouting and exploration work and not less than 102 mm for piezometer holes.

Unless otherwise instructed by the *Engineer*, every 4th primary hole in the grout curtain shall be

cored and comprehensively water tested. All other grout curtain holes shall be rotary drilled (non-cored) holes unless percussion drilling of these holes is permitted in terms of Sub Clause 9.6.5. Grout curtain holes shall be 50 mm diameter or other similar diameter to suit the diameter of the packer to be used.

Drilling for grout curtain holes shall be carried out with water circulation. If water loss is experienced, drilling shall cease and the hole shall be grouted to refusal, irrespective of depth reached, before resuming the drilling operation.

Where support to the sides of the hole is necessary the *Contractor* shall supply and install drillhole casing to a depth approved by the *Engineer*. The casing shall be of sufficient diameter to permit a drillhole of the specified size to be drilled within it.

Unless otherwise directed, drilling fluids other than water may be used, with the approval of the *Engineer*, to improve core recovery and/or to prevent caving-in of drillholes. The additives mixed with water shall be degradable with time. The consistency and properties of the drilling fluid shall be such that it does not effect the samples of cores recovered, render them unacceptable for testing, prevent the accurate description of the profile of the material and does not adversely affect any tests carried out in the drillhole. Bentonite mud shall not be used.

Where approved by the *Engineer* a weak or caving hole may be stabilized by grouting up the hole with cement grout. Stabilisation of a hole by means of inserting reduced size casing, and thereafter continuing the drilling in a reduced size, will only be permitted in exceptional cases where the *Engineer* considers that no other means of stabilisation is practical.

Where required by the *Engineer*, drilled holes shall be protected from being clogged or otherwise damaged by fitting a cap, plug or other suitable device to the collar of the hole.

All curtain grout holes shall be drilled in stages as specified up to a depth as shown on the Drawings or directed by the *Engineer*.

Curtain holes shall be tested for deviation from the vertical or from the direction otherwise specified as directed by the *Engineer*. The *Contractor* shall propose the method for doing this.

Inclined check holes (cored if necessary) will be required to be drilled on the grout curtain, water tested and grouted as directed by the *Engineer*.

Piezometer holes shall be rotary core drilled from the surface for the installation of piezometers in locations as shown on the Drawings or directed by the *Engineer*. The holes shall be vertical, up to 40 m deep and shall be a minimum diameter of 102 mm unless otherwise instructed. Casing will be required for some of these holes.

PPS 9.6.4 Core Recovery and Storage

Where core recovery is ordered or scheduled, the drill string shall be pulled and the core removed as often as necessary to secure the maximum possible length of intact core. The core shall be removed from the core barrel by a method designed to produce minimal disturbance to the core. Extraction under steady carefully applied pressure, the use of split inner barrels or other method approved by the *Engineer* shall be used. The cores shall not be extracted by hammering the barrel or by extrusion under high air or water pressure.

On removal of the core barrel, the cores shall be placed directly into core boxes in correct sequence. Very broken core shall be contained in a transparent plastic sheath, if ordered by the *Engineer*.

Each core box shall be clearly marked with the site name, the borehole number and numbered in sequence for each borehole. No core box shall contain the cores of more than one hole. Wooden spacers shall be provided giving the depth at the end of evert "draw". The length of the core recovered will not be taken as a measure of the depth of the borehole, but this shall be determined by measuring the total length of equipment (core barrel and drill rods) in the hole and subtracting the length of drill rod protruding from the borehole.

Special care shall be taken during the course of drilling to locate geological contacts, zones of weakness, open fissures, cavities and loss of drilling fluid, and the depth at which they occur shall be clearly marked.

The cores shall be kept at the hole during drilling, and the *Contractor* shall ensure that they are protected from the weather and not disturbed. On completion of the drilling of the holes, the *Engineer* may require the cores in their core boxes to be transported to the designated storage shed and stored in an overlay sequence.

Before the core boxes are stacked, they shall be made available to be photographed.

PPS 9.6.5 Percussion Drilling

Percussion drilling may be used for consolidation grout holes and anchor bars, dowels and rock bolts as and where directed by the *Engineer*.

Percussion drilling of grout curtain holes will only be permitted by the *Engineer* if it is proved in trial panels that such drilling produces clean circular holes where packers can be effectively used and it is economical to do so.

Percussion holes shall be flushed clean in terms of Sub Clause 9.6.7.

All holes shall be drilled within the specified tolerances.

PPS 9.6.6 Drainage Holes

Unless otherwise directed, drain or pressure relief holes shall be drilled by percussion drilling and flushed clean. The holes shall be drilled to the diameter and in the direction, inclination and location as indicated in the Drawings or directed by the *Engineer*.

Drainage holes shall not be drilled until all grouting required within the vicinity i.e. within a radius of 50 m of such a drainage hole has been completed to the satisfaction of the *Engineer*.

Drainage holes through concrete and rock shall be lined with an approved slotted PVC sleeve where shown on the Drawings or directed by the *Engineer*. Where drainage holes pass through materials of such a nature that there is a possibility of the holes caving in, the *Contractor* shall obtain the *Engineer's* instructions regarding casing the hole.

On completion of the hole, it shall be suitably sealed off to prevent the ingress of any undesirable material. All threads shall be suitably greased before the fitting of hollow plugs or caps.

PPS 9.6.7 Washing, Protection and Identification

When drilling of a grout, check, drain or exploratory hole has been completed to its final depth or to the bottom of a stage, the hole shall be washed with high pressure water to remove all drill cuttings, sediments, sludge and other loose or foreign materials until the return water is clear, and all downward holes shall be left filled with water to the surface, or to such level as the water will stand.

Each grout, check and exploratory hole shall be protected from becoming clogged or obstructed until it is grouted and, where a grout pipe or standpipe is permanently embedded in rock or concrete, the *Contractor* shall provide a suitable cap to keep the hole sealed. Whether or not a grout pipe or standpipe is used, any hole which becomes obstructed before being grouted shall be cleared or re-drilled to the satisfaction of the *Engineer* without any additional payment.

Each grout, check and exploratory hole shall be numbered as required by the *Engineer* to permit identification of each hole at all times until grouting and checking has been completed in the area.

Drain holes shall be protected against the ingress of dirt until a piezometer or other suitable protective device has been installed.

PPS 9.6.8 Standpipes

Where required by the *Engineer* or where conditions dictate, grout holes shall be provided with standpipes or grout nipples at the head of the hole which shall project approximately 150 mm above the rock or concrete surface and shall be bonded firmly into the surface for a length of not less than 500 mm. The bore of the standpipes shall be adequate to accommodate the size of drilling bits required.

All standpipes shall be cleaned thoroughly of all dirt, grease, grout and mortar before being embedded in the concrete or rock.

PPS 9.6.9 Casings

Where the rock surface is buried beneath an embankment or other materials requiring support, grout casings shall be provided, as directed or approved by the *Engineer*, for the full depth of embankment material penetrated.

On completion of drilling of the hole and with the *Engineer*'s permission, the *Contractor* may salvage the casing, provided that the capping gives proper protection to the hole. The *Engineer* may, however, order the casing to remain and the hole to be capped. The *Contractor* shall ensure that casings are of a suitable size and are inserted in such a manner that they can be removed.

PPS 9.6.10 Grout caps

Concrete grout caps shall be used when the surface from which the hole is started comprises soft and weathered material which, in the opinion of the *Engineer*, is unsuitable for the standpipe to be bonded into. Except in the case of holes under water, immediately on completion of the drilling and, where required, water pressure testing of the hole, the hole shall be fitted with a casing of length at least 1 metre and extending 200 mm out of the hole. The casing shall be fitted with a screwed cap, and embedded in a 500 mm x 500 mm x 100 mm deep concrete block marked with the borehole number (or as otherwise ordered).

PPS 9.6.11 Loss of Holes

If jamming of a hole or other cause makes continuation of the drilling impossible the *Contractor* shall immediately inform the *Engineer* and request instructions for siting of a substitute hole or otherwise. If the *Engineer* considers the desired purpose of the hole has been achieved no substitute hole will be necessary.

Should any hole become clogged before its intended purpose has been fulfilled and cannot be cleared to the satisfaction of the *Engineer*, it shall be replaced at the *Contractor*'s expense.

Lost holes shall be washed out and grouted.

PPS 9.7 WATER PRESSURE TESTING

PPS 9.7.1 General

Water pressure testing of holes for all types of grouting shall be carried out by using the grouting equipment or alternatively, water may be connected directly to the holes provided that suitable water meters, pressure gauges and equipment are provided to control the pressure.

In conjunction with the drilling and grouting operations, the *Contractor* shall make water tests in grout holes and check holes at any time and at such depths as are required by the *Engineer* to determine the permeability of the rock and the effectiveness of the grouting operations. The *Contractor* shall set packers in the drill holes at locations determined by the *Engineer*, supply all necessary equipment, gauges etc., inject water at pressures determined by the *Engineer* and record the rate of water acceptance.

Unless otherwise directed by the *Engineer* abbreviated water tests shall be conducted in designated holes immediately before grouting. Abbreviated water tests shall be conducted in grout holes in each stage above the water table to wet up the surrounding rock.

Similarly, all cored grout holes shall have a comprehensive water test per stage drilled. The *Engineer* may, at his discretion, instruct comprehensive water tests on other types of holes.

The duration and number of tests may be varied by the *Engineer* to suit particular ground conditions.

PPS 9.7.2 Abbreviated Water Pressure Test

Water shall be pumped into the hole until the pressure rises to the water test pressure specified by the *Engineer*. The pressure shall be maintained constant for five minutes and the rate of flow shall be measured and recorded at 1 minute intervals. If the leakage is too great to enable the required pressure to be attained then the discharge of the pump shall be maintained constant and the pressure recorded at 1 minute intervals.

PPS 9.7.3 Comprehensive Water Pressure Test

Water shall be pumped into the hole in 5 incremental stages up to the pressure specified by the *Engineer* and then reduced in the same stages to zero pressure. The pressure shall be maintained constant for 5 minutes at the end of each pressure increment or decrement and the rate of flow shall be measured and recorded at 1 minute intervals. The pressure at which flow commences on the incremental stage and the pressure at which flow stops on the decremental stage are to be carefully observed and recorded.

PPS 9.8 GROUTING METHODS

PPS 9.8.1 Grouting Procedures

PPS 9.8.1.1 General

The *Contractor* shall continuously supervise grouting operations and measure and regulate the pressures so that they are at all times in accordance with the *Engineer*'s requirements. The *Contractor* shall be entirely responsible for any damage resulting from errors that he may make in performing grouting operations. All blanket grouting operations shall be performed in the presence of the *Engineer* or his duly authorised representative.

Grouting will generally be undertaken with a stable mix to be determined in the laboratory. (See Sub Clause 9.4.1).

Careful control of pressures will be required during grouting and water pressure testing as excessive local pressures could crack or buckle the concrete or steel liners or hydrofracture the rock. Pressure chart recorders shall be used during all such injections. Pressures shall be limited to those shown on the Drawings or agreed with the *Engineer* for individual sections of the Permanent *works* and different grouting procedures. At no time shall grout from any one pump be injected into more than one hole at a time.

Equipment for mixing, holding and pumping the grout shall be maintained as close as possible to the area being grouted and all pipelines and hoses between such equipment and the area being grouted shall be protected wherever necessary to reduce temperature build-up in the lines and the grout.

Grouting of any drill hole within 20 m of a concrete structure or which extends through concrete shall not start until the foundation concrete in the structure is a least 14 days old.

Stage lengths shall be as directed or approved by the *Engineer* and generally not greater than 5 m. Lesser stage lengths may be required near concrete structures.

In the event of drilling water ceasing to return (total or partial water loss), drilling shall be interrupted, the packer placed one metre above the leak and the hole grouted irrespective of depth reached, and drilling resumed.

During grouting the *Contractor* shall take every precaution to prevent the grouting equipment and

lines from becoming blocked. He shall accordingly continuously circulate the grout and periodically flush the system with water.

After grouting each stage, the hole shall be cleared of grout by washing or re-drilling as soon as the grout in the rock adjacent to the hole has set sufficiently to prevent it being washed into the hole. Any re-drilling required to clear the grout in a stage of the hole completed prior to testing or re-grouting shall be performed by the *Contractor* to the satisfaction of the *Engineer* without any additional payment, except where grout has been allowed to set in a stage by direction of the *Engineer*.

If a hole absorbs an abnormal amount of grout, generally more than 250 kg/m of cement or as specified on the Drawings, the *Contractor* shall inform the *Engineer* immediately and the rate of injection shall then be reduced or injection shall be carried out intermittently or such other procedure as may be agreed with the *Engineer* shall be adopted.

When water pressure testing and grouting other than contact grouting is carried out adjacent to embedded steel all ports in the steel shall be kept open to prevent the build up of pressure against the liners.

While grouting is proceeding the *Contractor* shall watch for leakage of grout or other untoward happenings. Grout leaks shall be caulked but if this cannot be achieved and the leaks are excessive, grouting shall be stopped and resumed later when the grout already injected into the leaking fissures has hardened. The *Engineer* may order the establishment of level reference points, upheaval gauges, etc., to be observed as a check against uplift. Any appreciable movement shall be taken as an indication that the grout pressures being used are excessive and they shall be immediately relieved.

During grouting any slight movement of the rockmass or the structure is to be recorded. If any movement should occur, the grouting pressure is to be relieved immediately and the *Engineer* alerted.

The *Contractor*'s grouting programme shall be such that there is no risk of permanent drains such as pipe drains, or pressure relief drains being blocked by grout. All grouting works shall be completed in any area before permanent drains or drain holes are constructed.

If the pipework or any other part of a drainage system becomes blocked by grout the whole system shall immediately be flushed out with clean water and all grout removed before injection is recommenced.

The temperature of the grout during mixing and grouting shall not exceed 30ºC or be lower than 10ºC.

In general no holes shall be left open whilst other holes in the vicinity are being grouted. The number of holes to be drilled at any time shall therefore be limited to the number which can be grouted simultaneously with the plant provided. When drilling is interrupted or completed, holes shall be fitted with removable plugs or caps to prevent the ingress of foreign matter. When ordered by the *Engineer* a steel pipe shall be securely grouted or caulked into the hole and shall be protected by a screw cap.

In the event of caving ground being encountered and where, as a result, drilling cannot proceed, the *Engineer* may decide that, as an alternative to the use of casing, such holes shall be grouted with a thick grout to seal and support the hole. The grout shall be left to set and then the hole shall be re-drilled as directed by the *Engineer*. The *Contractor* shall take all measures to ensure that re-drilled holes in set grout do not deviate.

Completed grout holes shall be filled with thick grout as directed by the *Engineer*.

Upon completion of the grouting all concrete, steel or foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition.

Comprehensive records detailing the grouting process and testing are to be maintained throughout. A copy of these records shall be forwarded to the *Engineer* at regular intervals and the *Engineer* is to be kept informed of of any changes to the grouting programme and its general progress at all times.

PPS 9.8.1.2 Requirements for Grouting

All grouting operations shall be performed in the presence of the *Engineer*.

Foundation grouting shall not start until the excavations for the foundations at the location of the grouting have been completed as specified nor until the excavation of all foundations within 20 m of the hole have been completed. If for any reason it is necessary to excavate further within 20 m of a hole after the grouting of the hole has started, explosives shall not be used, and the *Engineer* will determine whether or not the hole should be re-grouted and if so, to what extent. The additional grouting will be paid for at scheduled rates, provided that the further excavation was not needed because of the fault or negligence of the *Contractor*.

Grouting shall be undertaken, irrespective of water test results. Repeating a water test after curtain grouting will be unnecessary (unless otherwise directed by the *Engineer*) because water tests undertaken in the inclined check holes across the panels will suffice.

PPS 9.8.1.3 Protection of Embedded Steel

During all grouting around areas of embedded steel, the *Contractor* shall control the grouting pressures with particular care and continuously monitor the internal surface of the steel so that grouting can be stopped at once if any localised pressure causes the steel to deflect.

The *Contractor* shall brush down the steel face to prevent grout spilt on the steel from drying and adhering.

PPS 9.8.1.4 Surface Leaks and Inter-hole Connections

If, during the grouting of any stage, grout is found to flow from nearby grout holes the holes shall be left open until the grout emerging is of the same consistency as the grout being injected whereupon the holes shall be closed and injection continued to completion, provided the pressure in the interconnected holes does not exceed the maximum pressure specified for those holes. Interconnected holes shall also be flushed and water pressure tested to confirm they have been satisfactorily injected.

If, during the grouting of any stage, grout is found to flow from cracks and fissures in the rock surface, such flows or leaks shall be plugged or caulked by the *Contractor* as directed by the *Engineer*. The *Contractor* shall have available on Site at all times sufficient wooden wedges, sacking, lead wool and other materials which can be used to seal surface leaks.

PPS 9.8.2 Curtain Grouting

A grout curtain is to be formed in the foundation rock below the dam and extended beyond the dam extremities as shown on the Drawings. The spacing, diameter and depth of the primary holes shall be as specified on the drawings.

The general method to be adopted will commence with the drilling of one row of primary holes over the full foundation length, as indicated on the Drawings. Every stage of each primary hole shall be grouted regardless of the Lugeon value recorded during water pressure testing of that stage. Secondary holes are to be drilled equidistant between the primary holes and grouted for the pre-stage and each subsequent stage for which the Lugeon value is greater than 3. Should Lugeon values and grout-takes be recorded at any particular location, tertiary grouting shall be required in this area, at points equidistant between the secondary holes, under the direction of the *Engineer*. Zones where tertiary, quaternary or further series of holes may be necessary will be confirmed by the *Engineer* during the grouting operations on the basis of the preceding grouting records, and as such timeous submission of pressure testing and grouting results is imperative. Holes shall be drilled and grouted only after the adjacent holes of the previous series have been grouted to their full depth.

Grouting of the foundation rockmass will generally be required where water pressure testing reflects a Lugeon value in excess of 3, although all primary holes shall be grouted to full depth, regardless of the Lugeon values recorded.

Drilling of a stage of a subsequent series of holes shall not commence until grouting has been completed one stage ahead of the proposed drilling stage on the previous series of holes. For example, drilling of Stage 2 of a secondary hole shall not commence until grouting of Stage 3 of the primary holes has been completed. This is not applicable when the final stage of a hole of a subsequent series is drilled.

Grout holes shall be flushed to the bottom of the hole with clean water before commencing water pressure testing or grout injection. Flushing shall continue until clean water emerges at the top of the hole. Each stage of each grout hole shall be grouted only after being satisfactorily cleaned and water-tested in accordance with Sub Clause 9.7.

All drill holes for curtain grouting shall be rotary drilled holes as per Sub Clause 9.6.3 unless otherwise directed by the *Engineer* or indicated on the Drawings. Where shown on the drawings, sleeves will be provided in the concrete for such grout holes.

In general, surface packers, seated into solid rock or concrete, shall be used. However, where it is found that grout from lower stages "breaks back" through a previously grouted stage or where there is excessive leakage of grout or where it is found impossible to build up a grout pressure, the *Engineer* may order the *Contractor* to use packers so that only a portion or stage of any hole is grouted separately.

(a) Starting mix and thickening
Grouting shall commence with a cement grout mix of thin consistency (e.g 1.32:1 water:cement) as defined on the drawings, and confirmed in the trial section.

The grout consistency shall be gradually thickened and the injection pressure gradually built up to the required maximum. Should it prove impossible to attain the required pressure with the grout consistency approved, the grout shall be gradually thickened up by adding cement while injection continues at a constant rate until the required maximum pressure is attained.

(b) Completion of grouting
After it has become evident that no further grout take into the hole has occurred during a 15 minute interval, the pressure shall be held for another 15 minutes after which time the packer shall be closed off and left in the hole until wash-out time or for 6 hours from last application of grout in the hole.

Grouting of any hole or stage of a hole shall not be considered complete until the hole or stage refuses to take any grout at the specified maximum pressure for the particular hole or stage of the hole, or until approved by the *Engineer*.

When curtain grouting of a stage is complete, and the grout has taken its initial set, the grout in the hole shall be washed out with a high pressure air and water jet until the wash water runs clear. No further drilling of a hole or stage shall be permitted until at least 24 hours after grouting the previous stage or portion of the stage. Alternatively, the *Engineer* may direct that the grout be left undisturbed for 24 hours and then the hole be re-drilled and washed out. After washing out, the hole shall be drilled a further stage, tested and grouted successively until the specified depth is reached.

(c) Pressures
The injection pressure shall be measured and controlled at the collar of each hole with the return line being used for temporary flushing of hoses and for pressure control.

The actual pressures used for grout injection will vary with the conditions encountered and will be determined during grouting trials as directed by the *Engineer*. Where not

indicated on the drawings, a maximum pressure of (27.d) kPa at the top of the hole, where d is the depth of the hole in metres, may be taken as a guide. The pressures shall be as high as practicable but shall be limited so that grout is not wasted by leakage through the rock surface and so as not to cause displacement of rock (hydrofracturing) or concrete and not to cause excessive grout travel. The *Contractor* shall regulate, measure and supervise the grouting operations continuously so that the pressures and volumes of grout injected remain within the limits set and the *Contractor* shall be entirely responsible for any damage which may occur due to errors he may make in grouting operations. Should any movement of the rock or structure be observed during grouting operations, the pressure in the hole shall immediately be released.

The *Contractor* shall, during grouting operations at pressure intervals of at least 50 kPa, take levels from check points to the grouting area to monitor the displacement of rock. Should any uplift be noted the *Contractor* shall immediately reduce the grouting pressure and report the matter to the *Engineer*. The costs of providing uplift check points and reference level points shall be deemed to be covered by the other rates for grouting operations. The *Engineer* shall specify the holes or positions to be monitored.

So as to avoid premature plugging in the event that a rapid build-up of pressure takes place during the thickening process, the grout consistency shall be thinned as may be required or, if necessary, clear water shall be injected.

To achieve the maximum effectiveness of the grouting consistent with economy of materials, the pressure at which grouting is carried out shall generally build up to the maximum permissible pressure and the greater the rate of absorption of grout the lower shall be the grouting pressure. The pressure shall not be permitted to rise towards the maximum until the rate of absorption is reduced.

Automatic pressure relief valves shall be installed in the grouting circuits adjacent to the injection point wherever there is a risk that the grouting pressures used may cause displacement.

(d) Grouting Direction

Curtain grouting shall generally be undertaken with testing done in descending stages and grouting done in ascending stages, except when otherwise instructed by the *Engineer*.

The ascending stage method of grouting shall be performed in successive operations consisting in each case of:

(a) Where water tests are required:

1) Drill the hole to the bottom of the first stage to depth, in general, of 5 m or as shown on the drawings, or as directed by the *Engineer*
2) Wash out the hole.
3) Install the packer into the hole at the top of the stage drilled.
4) Carry out a comprehensive or abbreviated water test as applicable, or as directed by the *Engineer*.
5) Drill the hole to the bottom of next stage.
6) Repeat operations (2) to (5) (generally in stages of 5 m or as directed by the *Engineer*).
7) On reaching the bottom of the hole, wash out the hole and place a packer 5 m from the bottom of the hole and grout the stage to refusal at the designated maximum pressure.
8) Repeat operation (7) until the packer reaches the collar of the hole.

(b) Where no water tests are required.

1) Drill the hole from collar to the bottom of the hole, stopping when any water loss occurs to grout and stop the water loss before continuing to the bottom.
2) Flush out the hole.

3) Place packer 5 m from the bottom of the hole.
4) Grout the stage to refusal at the designated maximum pressure.
5) Raise the packer to the next stage.
6) Repeat operations (4) to (5) until the packer reaches the collar of the hole.
7) Should the Engineer so direct, water pressure testing (abbreviated or comprehensive) may be done in ascending stages after operation 3.

Should the *Engineer* so direct, the descending methods of grouting and testing shall be performed in successive operations consisting in each case of:

1) Drill the hole to the bottom of the first stage to depth, in general, of 5 m, or as shown on the drawings, or as directed by the Engineer.
2) Wash out the hole.
3) Install a packer into the hole at the top of the stage drilled.
4) Carry out an abbreviated or comprehensive water pressure test as applicable, or as directed by the Engineer.
5) Grout the hole to refusal at the designated maximum pressure.
6) Redrill or flush out the hole once the grout in the rock has stiffened sufficiently not to flow back into the hole and drill the next stage to the same length as under (1)
7) Repeat operations (2) to (6) until the hole has reached its final depth and been pressure tested to its final depth if required.
8) Backfill the hole with thick grout in accordance with Sub Clause 9.11.
9) Where grouting is undertaken below concrete, grout cap or concrete lining, the packer shall be placed in the concrete on the top stage to ensure that the concrete/rock contact is properly sealed.

When grouting any stage, care shall be taken to ensure that grout does not by-pass the packer, either through the rock or past the packer due to poor sealing in the hole. This could result in loss of the packer and the hole. The *Contractor*'s Method Statement shall include techniques to ensure that grout bypass does not occur such as filling the hole with water above the packer and monitoring water losses during grouting or keeping the hole flushed by passing water through a small diameter pipe to the top of the packer - (Discoloured flushing water would indicate packer by-pass). As a safety precaution, the *Contractor* shall attach a steel cable to the packer to assist in its removal should it get stuck down the hole.

When grouting holes near the surface of the rock the *Contractor* shall, if any substantial leaks in grout occur through cracks and fissures in the rock, take whatever measures (eg: caulking) that may be necessary to stem the grout flow and prevent the loss of grout. The measures taken shall be at the *Contractor's* expense. The pressure used for grout injection will vary according to the conditions encountered and shall be as directed or approved. In general the upper stages shall be grouted at a low pressure and the deeper stages at a high pressure. The pressure shall generally be as high as possible but shall be limited so as not to cause displacement of rock or concrete.

If during injection of a hole, connection is established with a neighbouring hole, the hole or holes shall be left open until the grout emerging is of the same consistency as the grout being injected. The hole or holes shall then be closed and injection continued to completion. Interconnected holes shall also be flushed after the grout has set and water tested to confirm that they have been satisfactorily injected.

If any grout hole becomes blocked and cannot be flushed out, it shall be reamed out or re-drilled and, should the *Engineer* require, it shall be subjected to a water test before grouting continues. If such action cannot be carried out or is not successful, a new hole shall be drilled alongside the blocked hole.

If the grouting of any hole is interrupted for any reason, the *Contractor* shall immediately wash out the hole being grouted and any adjacent holes into which grout has entered.

PPS 9.8.3 Cavity Grouting

Cavity grouting will only be required at the contact between first and second stage concrete.

Cavity grouting shall be carried out before any other grouting, except fissure grouting, which may be required, but not before the concrete is at least 28 days old unless otherwise agreed by the *Engineer*.

For first stage concrete and steel linings holes of not less than 38 mm diameter shall be drilled through the concrete and continued until penetration into the rock for 300 mm has been proved. The spacing of holes shall be as shown on the Drawings or instructed by the *Engineer* to ensure a full and complete filling of cavities. For grouting of second stage concrete, the *Contractor* shall carry out such grouting through pre-placed manchette pipes. The *Contractor* shall in any case submit a Method Statement to the *Engineer* for approval 7 days prior to commencing work.

Any voids which are detected during drilling shall be noted in the grouting record. In the case of large voids, the *Engineer* will require air release holes to be drilled and a bleed-pipe inserted reaching to the highest point of the void.

Cavity grouting shall be carried out in the sequence and using mix proportions and pressures agreed by the *Engineer*. Generally, injection of grout shall be commenced at the lowest holes to allow air and water to be displaced. When interconnections occur the holes shall be kept open until emerging grout is of the same consistency as the grout being injected, after which the holes shall be closed. Injection shall continue until the hole refuses to accept grout at the specified maximum pressure.

Where large voids have been detected a 1 cement : 2 sand mixture at a water/cement ratio of 0.60 or other mix as approved by the *Engineer* shall be injected.

If the *Engineer* considers that cavity grouting is not complete at the hole spacing adopted, he may instruct additional holes to be drilled and grouted.

Unless directed otherwise by the *Engineer* holes in which cavity grouting is complete shall be left undisturbed for a minimum period of 24 hours before any redrilling is done for the stemming of holes or for the continuation of consolidation grouting.

Unless the holes are subsequently required for other grouting they shall be completely filled in accordance with Sub Clause 9.11.

PPS 9.8.4 Consolidation Grouting

The extent of consolidation grouting required for rock below the footprint of the dam is detailed on the Drawings and/or is set out in the Bill of Quantities.

Grouting pressure will be as shown on the Drawings or as determined by the *Engineer* from the grouting trials.

Unless otherwise directed by the *Engineer*, consolidation grouting in prepared areas below the foot print of Dam shall take place before curtain grouting in those areas. This grouting shall be accomplished using the methods as outlined in Sub Clause 9.8.2. Unless otherwise directed by the *Engineer*, consolidation grouting shall be done in stages not more than 5 m, which will include grouting of the contact between the concrete and the foundation rock. Consolidation grouting depths may vary significantly across the dam footprint and will be taken to a maximum of 12m, or as otherwise directed by the *Engineer*.

Grouting operations for any stage of grouting in a hole shall be preceded by an abbreviated water pressure test, except as otherwise directed by the *Engineer*. Immediately following the injection of water, grout shall be injected at pressures and rates as agreed with the *Engineer*.

Under no circumstances shall the pressure or rate of pumping be increased suddenly or the pressure in the hole being grouted exceed the maximum grouting pressure specified. In the event that rock is disturbed due to negligence on the part of the *Contractor*, remedial measures to repair the damage as directed by the *Engineer* shall be carried out by the *Contractor* without additional payment.

The grouting of each stage shall be continued in accordance with the agreed procedures until the hole refuses to accept grout at the consistency and pressure agreed with the *Engineer* or until the *Engineer* directs that the injection should be terminated.

After grouting is completed in any hole the back pressure shall be maintained by closing the inlet valve at the collar until the grout has set sufficiently.

PPS 9.8.5 Contact Grouting

Contact grouting of embedded steelwork shall be carried out after all other grouting has been completed, holes have been stemmed as described in Sub Clause 9.11**,** and in any case not before the concrete surround is at least 28 days old.

The grouting of embedded steelwork shall be appropriate for the design. Detailed procedures shall be agreed with the *Engineer* prior to the start of grouting.

The success of the grouting shall be tested by tapping the embedded steelwork with a copper hammer. Any areas sounding hollow shall be re-grouted where necessary to suit the design requirements. The *Contractor* shall, if necessary drill, tap and subsequently grout additional grout holes at any point in order to fill voids detected. These holes shall be not less than 15 mm diameter and shall be threaded and fitted with screwed plugs, welded into position and finished flush on completion of grouting.

When all grouting has been completed, the threads in all holes shall be cleaned out and greased and all plugs screwed flush into place.

PPS 9.8.6 Contraction joints in a concrete dam

The timing of operations for grouting contraction joints will be determined by the *Engineer* in the light of conditions during construction. This may necessitate the re-establishment on site of the *Contractor* at a later stage specifically for the purpose of joint grouting.

The compartments shall be as defined on the drawings. If a secondary grouting system is required, this shall be as shown on the drawings. The necessary grout pipes shall be cast in place, or cavities and grooves shall be formed, during the construction of the appropriate portions of the Works. The pipe materials shall be as specified on the drawings, Project Specifications or Schedule of Quantities.

In order to distribute the horizontal forces on the concrete blocks arising from pressure testing and grouting operations in any joint, the grouting systems of the corresponding compartments in the joints on each side of the joint being tested or grouted shall, unless they have already been grouted, be pressurised. Measured at the highest point of the compartment, this pressure shall be approximately half that being applied at the joint in question.

Immediately before grouting of a joint compartment commences, the grouting system shall be washed out until the effluent from the outlet of the collecting groove runs clear. The outlet valve shall then be closed and the pressure raised to the pressure specified by the *Engineer* for grouting. If it is not found possible to reach this pressure or if there is an excessive loss of water the *Contractor* shall immediately inform the *Engineer* and obtain his approval regarding the remedial action he proposes to staunch the leak and complete the grouting.

If the pressure test is successfully passed, the outlet valve from the compartment shall be opened and grout shall be introduced into the grouting system. Initially the grout shall be composed of 2 parts of water to 1 part of cement by volume and it shall be thickened gradually to 1 part of water to 2 parts of cement. When the grout emerging from the outlet pipe is of a consistency equal to that being pumped in, the grouting shall be stopped and the upper collecting groove shall be washed out and filled with water. The outlet valve shall then be closed, and the grouting pressure raised to 1 MPa, measured at the highest point of the compartment. This pressure shall be maintained for 15 minutes after grout ceases to be absorbed, and the inlet valve shall then be closed.

The *Contractor* shall provide suitable means for collecting and disposing of grout emanating from the joint. Such grout shall not be reused in the Works. Any grout spilled shall be washed off immediately.

PPS 9.8.7 Flushing of features intersected by grouting holes

Where grout holes intersect, either directly or indirectly, features such as joints, conduits, pipes, drains, etc, in which grout may not harden, these facilities shall be flushed by pumping clean water through such features. Flow volumes and water pressures shall be determined on site by the *Engineer* on the basis of the extent of the features affected.

Generally clean water will be introduced at one accessible end and to exit at another location from where the flushing water shall drain away. Depending on the configuration, water may be recirculated back to the injection point, but in all cases the contractor shall manage the safe disposal of the water in line with Particular Specifications PPS1 and PPS 2.

The *Contractor* shall monitor the water emanating at the exit point for contamination by grout at all time during grouting operations where flushing facilities are required. Where such contamination should be detected the Contractor shall immediately refer the matter to the Engineer for further instructions as to the required further grouting regime. To this end the *Contractor* shall supply suitably personnel and communication systems.

PPS 9.9 CHECK HOLES

In order to check the effectiveness of grouting the *Contractor* may be required to drill additional percussion or cored holes at any location, angle and depth within the range of the adjacent grout holes not less than 14 days after completing grouting in an area to enable water tests and possible supplementary grouting to be carried out. The number of holes required will be approximately 10% of the holes detailed on the Drawings and shall be spread over the grouted area as directed by the *Engineer*.

Except as otherwise required by the *Engineer*, check holes shall be grouted to the same requirements as the original holes.

PPS 9.10 RECORDS

The *Contractor* shall provide to the *Engineer* each day, an accurate record, in duplicate hard copy and electronically on an approved form of all drilling and grouting operations carried out the previous day.

All costs in connection with the records required will be deemed to be covered by the rates for the various items of work concerned.

PPS 9.10.1 Drilling and Grouting Records

The information provided shall include:

(a) The location, reference number and stage of the holes drilled and grouted;
(b) The depth of concrete drilled and total depth of hole drilled with measurements of any voids encountered;
(c) Details of comprehensive and abbreviated water pressure tests giving pressures, pumping times, and water takes;
(d) Details of grout injections giving pressures, grout consistencies, volumes of grout injected, quantities of other material injected, and injecting times throughout the period of injection;
(e) Charts from the recording pressure gauges and flow metres;
(f) Results of mix control tests, times of sampling and location where samples were taken; and
(g) Remarks on grouting incidents, delays, surface leaks, interconnections, refusals and any other factors which might influence the effectiveness of the grouting.

A typical form is bound in at the back of this Specification under Appendix A describing the majority of the above. A separate form is required for each stage of a hole.

On completion of the grouting of a hole, within 24 hours, the *Contractor* shall provide the *Engineer* with a fresh and complete log, produced on the spreadsheet, printed in duplicate of the grouting work in that hole.

The *Contractor* shall be responsible for completing the summary drawing(s) of the curtain grouting results. The drawing(s) shall be submitted to the *Engineer*. An example of how the drawing shall be filled in and of the information required, is given in Appendix C at the back of this Specification. This drawing shall be updated daily and be available to the *Engineer* in electronic format at all times. The *Engineer* shall be provided with a hard copy of the updated drawing once a week, or as ordered.

PPS 9.10.2 Exploratory Drilling Records

The information provided shall where applicable include:

(a) Borehole number and coordinates, angle from vertical and direction if not vertical;
(b) Name of driller and type of machine;
(c) Dates of setting up and removal;
(d) Weather (including cloud cover, degree of sunshine, direction and speed of wind) on each day, including time of weather changes;
(e) Depth of water in hole before drilling commences each day;
(f) Date of each advance;
(g) Calculation of depth for each advance/run;
(h) Type and number of bit for each advance/run;
(i) Bit pressure and rotational speed;
(j) Times of start and finish of each advance/run (to nearest 5 sec), duration of any delays and number of times chuck was raised if applicable;
(k) Reasons for any core loss;
(l) Note of any core left behind in borehole;
(m) Note of any drops of rods due to cavities;
(n) Location of any exceptionally hard or exceptionally soft layers;
(o) Use of drill mud and type of drill mud;
(p) Estimated water or drilling fluid losses or inflow, with location of occurrences;
(q) Amount and size of casing inserted into borehole;
(r) Amount and size of casing drilled into borehole;
(s) Amount and size of casing left in borehole;
(t) Amount of cement grout poured or pumped into borehole;
(u) Depth of top of grout after grouting operation;
(v) Length of grout that required drilling;
(w) Time of and reason for delays e.g. mechanical, pumps, rods stuck, etc.;
(x) Details and records of tests or surveys conducted or samples taken;
(y) Records of core photographs; and
(z) Any other item that may be of relevance to the interpretation of the core.

PPS 9.11 STEMMING OF HOLES

Upon completion of the grouting and checking of any area, the holes shall be washed using a flushing pipe to remove all loose materials and laitance from grout which has not hardened. The *Contractor* shall then backfill all grout holes with a thick grout mix or dry pack mortar as directed by the *Engineer*.

Filling of upward inclined holes shall be by pressure injection unless a thixotropic grout is used. Filling of downward inclined holes shall be through tremie pipes pushed down to the bottom of the holes and withdrawn slowly as filling proceeds after first blowing all water out of the holes.

The end of each hole shall be filled to a depth equal to the lining thickness with dry pack mortar which is well rammed in and finished flush with the face of the concrete, or in the case of

embedded steel, not more than 5 mm below the steel/concrete interface.

If any hole shows signs of weeping water after being stemmed the hole shall be drilled out, re-grouted and re-stemmed without any additional payment.

PPS 9.12 PLUGGING EXPLORATORY HOLES

Existing exploratory holes on the Site shall be plugged. The *Contractor* shall locate these holes, if necessary by land surveying methods. The work of plugging shall be carried out at an early stage in the Contract, as directed by the *Engineer*, before the standpipes or identification marks are damaged during Site activities. The standpipes or casings shall be removed as specified in Sub Clause 9.6.12

The plugging of existing exploratory holes and holes drilled for the recovery of cores shall be carried out as specified below.

(a) Where the hole, or portion thereof, is in rock, one-stage grouting using a fairly stiff grout shall be carried out. No water pressure test will be required.

(b) Where the hole, or portion thereof, is in overburden, which may or may not have a casing, it shall be backfilled with a 1:2 mixture (by volume) of cement and water. If the hole is dry the grout may be poured from the top but, if the hole contains standing water, the grout shall be fed through a tremie pipe, the outlet of the tremie pipe being kept submerged in the grout at all times. If running water is encountered in the hole, the *Engineer* shall direct what procedure is to be followed.

(c) Where the hole, or portion thereof is in a concrete structure, it shall be backfilled with a 1:1 mixture of cement and water.

PPS 9.13 REPAIR AND CLEAN-UP

Concrete surfaces and foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition.

Upon completion of the grouting, the *Contractor* shall remove all removable grout nipples from grout pipes embedded in concrete or embedded steel. Generally any standpipes shall be cut off 75 mm back from the surface. The curtain grout holes shall be cut off flush with the concrete surface, and the holes shall be filled with grout under the direction of the *Engineer*. Holes in concrete for such connections shall be cleaned of grout spillage and filled with dry pack mortar well rammed in and finished as required by the *Engineer* to restore and match the general surface of the concrete.

On completion of grouting in areas of concrete with a steel liner, the steel surface shall be cleaned of all grout contamination. Only methods of cleaning which will not indent or score the lining shall be used.

PPS 9.14 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 SANS 1200 A

The rates shall be deemed to include full compensation for all direct resources and delay or disruption not covered by the relevant time related charges in SANS 1200A.

Measurement and payment for all work involved for drilling and grouting shall be made against the following items:

PPS9.14.1 Setting up equipment for drilling grout and drainage holes **Unit : number (No)**

a) Percussion drilling rigs
b) Rotary core drilling rigs
c) Rotary drilling rigs

Setting up drilling equipment for drilling grout or drainage holes in surface work will be measured by the number of set ups at positions indicated on the Drawings or instructed by the *Engineer* irrespective of the number of stages drilled.

Separate measurement shall be made for consolidation grout holes, curtain grout holes and drainage holes.

The rate tendered shall include full compensation for all work required to set up for drilling and subsequent removal. The rate shall also include for provision of all services to the rig and for taking all precautions against pollution.

PPS9.14.2 Drilling of grout and drainage holes **Unit : metre (m)**

Measurement shall be the length of hole drilled as detailed on the Drawings or as instructed by the *Engineer*. Distinction shall be made between percussion drilled holes, rotary core drilled holes (N series) and rotary drilled holes (50 mm).

Separate items will be provided for:
i) 0 – 25 m depth
ii) 25 – 50 m depth
iii) over 50 m depth

and for drilling at inclinations to the vertical

i) 0° - 30°
ii) 31° - 60°
iii) 61° - 90°

The rate tendered shall cover all variations in strata encountered and the direction and inclination of the hole and include full compensation for all work required to drill the holes to the required depth.

PPS9.14.3 Re-drilling of grouted holes **Unit : metre (m)**

Measurement shall be the length of hole re-drilled where grout has been allowed to set on instruction of the *Engineer*. Grouted holes re-drilled on account of the *Contractor*'s failure to flush out grout before it has set, shall not be measured.

Separate items will be provided for drilling at inclination to the vertical:
i) 0° - 30°
ii) 31° - 60°
iii) 61° - 90°

The rate shall include full compensation for all work required to redrill grouted holes, irrespective of the depth of grouted hole.

PPS9.14.4 Water pressure tests

a) Abbreviated water pressure tests **Unit : number (No)**
b) Comprehensive water pressure tests **Unit : number (No)**

Measurement shall be by the number of water tests completed on instruction of the *Engineer*.

The rate tendered shall include full compensation for setting up equipment, conducting the tests over the full range of pressures and for all delays to other work occasioned by the tests.

PPS9.14.5 Cavity grouting **Unit : square metre (m^2)**

Measurement will be the area of concrete over which cavity grouting is carried out, irrespective of the method used. Materials will not be measured separately.

The rate tendered shall include full compensation for all work required to effect the cavity grouting including stemming of holes and for cleaning up on completion. The rate shall also include for all materials required to fill any voids left by incomplete filling of the concrete lining.

PPS9.14.6 Contact grouting **Unit : square metre (m^2)**

Measurement will be the area of embedded steelwork grouted. Materials will not be measured separately.

The rate tendered shall include full compensation for contact grouting the embedded steelwork in accordance with the design submitted by the *Contractor* and approved by the *Engineer*. The rate shall include for the removal and subsequent replacement of steel plug caps, setting up equipment, freeing the steel from the concrete encasement by water pressure, grouting including all materials, checking the grouting and re-grouting as necessary including drilling, grouting and repair of extra injection points, cleaning up and all necessary other work for grouting the embedded steelwork.

PPS9.14.7 Curtain and consolidation grouting for the dam (Stage Specified) **Unit : Number (No)**

Measurement will be the number of stages successfully grouted as schedules or as directed by the *Engineer*. The rates tendered shall include full compensation for all work required to move to, set up and grout each hole, flushing out after each stage, for stemming of holes and for cleaning up on completion, and for all precautions against pollution by waste grout. The rate shall cover the cost of grouting and redrilling through set grout where holes are not flushed out and for making-good drill holes in concrete

Materials will be measured separately as detailed in item 9.008.

PPS9.14.8 Grouting materials

Fissure, cover, curtain, consolidation and cut-off grouting operation

i)	**Type I (Normal)**	**Unit : tonne (t) or kilogram (kg)**
ii)	**Type III (High Early Strength)**	**Unit : tonne (t) or kilogram (kg)**
iii)	**Fly Ash**	**Unit : tonne (t) or kilogram (kg)**
iv)	**CSF**	**Unit : tonne (t) or kilogram (kg)**
v)	**Bentonite**	**Unit : tonne (t) or kilogram (kg)**
vi)	**Sand**	**Unit : tonne (t) or kilogram (kg)**

Cementitious materials, CSF, Bentonite and sand used will be measured separately on the basis of the quantity actually injected in grouting operations. No payment will be made in the case of any grout which was lost on account of the *Contractor*'s failure to comply with the requirements of the Specification or which was rejected by the *Engineer* as being unsuitable for use in grouting operations or for losses from mixes, pumps and lines. Measurement will be the mass injected as calculated from the mix proportions and volumes injected. The mass of water shall not be measured. If sand-cement grout is used the dry mass of sand used in the grouting operation will be measured separately. The rate tendered shall include full compensation for the materials and the work required for mixing and delivery of grout including mixing.

PPS9.14.9 Grouting additives **Unit : Provisional Sum (PS)**

Where ordered by the *Engineer* additives used in grouting operation shall be measured separately. Payment shall be made against a Provisional Sum.

PPS9.14.10 Casings **Unit : metre (m)**

(a) Casing for rotary core drill holes
(b) Extra over (a) for permanent casing
(c) Casing for rotary drill holes
(d) Extra over (a) for permanent casing
(e) Casing for percussion drill holes
(f) Extra over (c) for permanent casing

Measurement will be by length of temporary casing excluding that length comprising the standpipe. An extra-over rate will be paid for permanent casing ordered by the *Engineer* to remain in the hole. The rates tendered shall include full compensation for the supply and installation of temporary casing and removal on completion. The extra over rate shall include for all costs involved in installing the casing permanently.

Where grout caps are required, these shall be measured under SANS 1200G.

PPS9.14.11 Recovery of cores

(a) Core recovery **Unit : metre (m)**

Measurement of core recovery in all types of material will be the length of core recovered from the core barrel and placed in core boxes. The rates tendered for core recovery shall include full compensation for special methods adopted during core drilling and core extraction to ensure recovery of the greatest possible length of complete core and for placing in core boxes, including orientation to facilitate joint mapping.

(b) Core boxes **Unit : number (No)**

Measurement will be by the number of core boxes required. The rate tendered shall include full compensation for the supply to Site of core boxes, the temporary waterproof storage (if required) on Site of boxes and cores, the photography of boxes and transport to permanent storage on site.

PPS9.14.12 Check holes

Drilling and grouting of check holes as directed by the *Engineer* will be reimbursed under the relevant items 9.002 to 9.009 for the type of grouting being checked. Cored holes will be reimbursed against the relevant items 9.003 and 9.013.

PPS9.14.13 Loss of hole

No payment will be made for a "lost" hole, either for drilling, grouting or in any other respect unless the *Engineer* considers the desired purpose of the hole has been achieved in which case applicable work falling under the measurement Clauses above will be paid for.

PPS9.14.14 Sleeve pipes **Unit : metre (m)**

a) Steel sleeve pipe (diameter specified)
b) PVC sleeve pipe (diameter specified)

Measurement will be by the length of sleeve pipe installed in concrete as detailed on the Drawings or as ordered by the *Engineer*. The rate tendered shall include full compensation for the supply and installation of sleeve pipe, together with any fittings required, and securing during casting of concrete.

PPS9.14.1 Records

No separate payment will be made for providing the records required in terms of Sub Clause 9.10 and the rates for the items of work concerned shall include full compensation for this work.

PPS9.14.16 Backfilling of exploratory boreholes **Unit : number (No)**

Measurement will be the number of boreholes successfully backfilled.

The tendered rate shall include full compensation for all work required to locate the existing borehole, flush the hole with either compressed air or water jet to undo blockages and to pressure grout the hole using a mixture of CEM I (OPC) and water. The end of each hole shall be treated as per Sub Clause 9.11.

The rate shall include all materials and clearing up after grouting each hole. No separate payment will be made for moving and setting up at each hole.

PPS9.14.17 Establishment of flushing systems **Unit : Sum**

(Designate feature to be flushed)

The sum shall cover all costs related to the establishment, erection, commissioning, dismantling and removal from site of all pumps, pipes (including all fittings and couplings) nozzles, drains, power or fuel supplies, etc necessary to flush the relevant feature designated.

Payment shall be made in two instalments; 80% on completion of installation and commissioning of the flushing facilities to the approval of the Engineer and 20% following satisfactory dismantling and removal thereof.

PPS9.14.18 Flushing of features **Unit : number (No)**

(Designate feature to be flushed)

The unit of measurement will be the number of associated grouting stages during which grouting is undertaken while the designated feature is flushed, as directed by the Engineer.

The rates tendered shall include full compensation for all work required to move to, set up and flush each facility, the flushing of the facility as required by the Engineer, the monitoring of the emanating water, managing the emanating water, etc

PPS9.14.19 Pipes and channels for grouting systems **Unit : metre (m)**

The unit of measurement shall be the metre length of pipe or channel required for the grouting system to be used for joint grouting.

The tendered rate shall include full compensation for the supply of all pipes (including all fittings and couplings) and for the installation of the pipe system in the structure including any modification needed to formwork to accommodate the pipe system.

PPS9.14.20 Re-establishment on site for joint grouting **Unit : number (No)**

The unit of measurement shall be the number of times for which the *Contractor* must re-establish on Site for joint grouting. The quantity in the Schedule of Quantities shall be regarded as a provisional quantity.

The tendered rate shall cover the costs of materials, transportation and labour.

PPS9.14.21 Grouting joints **Unit : number (No)**

The unit of measurement shall be the number of compartments that are satisfactorily grouted.

Separate items shall be scheduled for compartments in the various sections of the Works.

The tendered rate shall include full compensation for all work involved in the grouting of the joints according to the requirements specified in the applicable sub-clause of this specification, including pressurising adjacent compartments (where applicable).

The cost of pipes for the grouting system shall be paid for under Item 9.017. Materials will be measured separately as detailed in item 9.008.

DRILLING AND GROUTING RECORDS

CONTRACT NO. : .... PAGE.....A

LOCATION IN WORKS : .... CHAINAGE: .... TYPE OF GROUTING:.....

OPERATOR ....: ....

HOLE REFERENCE NO. : .... HOLE SEQUENCE: ..... STAGE: .... STAGE DEPTH: ....m TO .....m

R.L. AT COLLAR : .... INCLINATION (TO VERTICAL): ..... degrees ORIENTATION: .....degrees

DRILLING

Bit Size ....Type of drilling . ...

Date	Depth of hole (m)	

WATER PRESSURE TEST

Gauge number ....

Date	Collar pressure (kPa)	Time			Water Take			Lugeon (UL)	REMARKS (level(s) of packer(s), length of test section, level of water in hole before testing, any loss of pressure, etc.)
		From	To	Run time (5 min)	Begin (litres)	End (litres)	Injected (litres)		
		1st Run							
		2nd Run							
		3rd Run							
		4th Run							
		5th Run							

ENGINEER: .... DATE: .....

DRILLING AND GROUTING RECORDS (CONT.)

PAGE . . . . . .B

HOLE REFERENCE NO.: .... HOLE SEQUENCE: ..... STAGE: .... STAGE DEPTH: ....m TO .. ..m

GROUTING RECORDS ..... 1 x 50 kg cementitious material = 37,5 litres

Gauge number ..... Type of grouting: .... Length of state: ....m

Date	Time			W/C by Volume	Pockets added to mixer			Grout			Grout take (cement + PFA/ CSF) (pockets)	Stand-pipe pressure (kPa)	Remarks (leaks, inter-connections, uplift, waste details, plant difficulties, refusals additives, etc.)
								In Tank		Injected (litres)			
	From	To	Time (mins)		Cement	PFA or CSF	Total	Start (litres)	Finish (litres)				
	:	:											
	:	:											
	:	:											
	:	:											
	:	:											
	:	:											
	:	:											
	:	:											
				Totals				pockets				pockets	= _____ kg/m

ENGINEER: .... DATE: .....

DRILLER'S LOG **PAGE . . . . . .**

HOLE REFERENCE NO. : ....OPERATOR: ... .MACHINE: ....

Date												
Start depth		(m)										
Time	From		:		:		:		:		:	
	To		:		:		:		:		:	
	Delays/Drilling	(mins)										
Drill string	Total length of rods	1,50 m (No)/(m)										
		3,00 m (No)/(m)										
		, m (No)/(m)										
		, m (No)/(m)										
	Total length of adaptor	, m (No)/(m)										
		, m (No)/(m)										
	Length of quill	, m (No)/(m)	1		1		1		1		1	
	Total drill string	(m)										
	Stick up	(m)										
Hole depth		(m)										
Run length		(m)										

Recovery	(m)					
Core left in hole*	(m)					
Water return (estimate)	(%)					
Water colour						
Bit No.						
Bit pressure	(kPa)					
Rotation speed	(RPM)					
Formation						

* Indicate if recovered in next run

Add other records and remarks on separate sheet or on back

CORE DRILLING AND RECOVERY RECORDS **PAGE . . . . . .**

CONTRACT NO.....: ....

LOCATION IN WORKS: .... CHAINAGE: .... TYPE OF DRILL: .....

OPERATOR ....: ....

HOLE REFERENCE NO.: .... CO-ORDINATES: X..... ..... Y .....

R.L. AT COLLAR : .... INCLINATION (TO VERTICAL): .....degrees ORIENTATION: ..... degrees

DRILLING

Bit Size ....Type of drilling . ...

Core drilling data (from Driller's log)							Hydrological data						
Date	Depth of hole	Depth		Depth drilled (m)	Core recovered (m)	Formation	Section tested		Water loss		Duration of test (mins)	Pressure applied (kPa)	Water R.L.
		From (m)	To (m)				From (m)	To (m)	(litre)	(mins)			

ENGINEER: .... DATE: .....

APPENDIX C
GUIDELINES FOR COMPLETING THE SUMMARY DRAWING
METHOD FOR PRESENTATION OF GROUT RECORDS

1. At the top of the hole indicate the hole sequence:
   - P = Primary hole
   - S = Secondary hole
   - T = Tertiary hole
   - K = Quaternary hole
   - Q = Quinary hole

2. Indicate the end of a stage with a stage number "N" (i.e. 1, 2, 3, etc.) and the cumulative vertical depth of the hole in the rock foundation "V" at either end of the short line transverse to the grout hole line.

3. Draw in the grout hole where, for each stage, the thickness of the line represents the grout take as shown in the table below:

Grout take in stage (kg cementitious material/m)	Required line thickness for grout hole stage (mm)
0 - 50	0,35
50 - 100	1,0
100 - 200	2,0
200 plus	3,0

4. Write grout record "X:Y:Z:R" on grout line for the specific stage, where:
   - X = Lugeon value for stage (l/min/m/MPa)
   - Y = Grout take of stage expressed in kilogram of cementitious material per metre run of stage
   - Z = Drilled length of stage in metres (i.e. actual length along the incline)
   - R = Remarks on the validity of the results or of the problems encountered during the operation

   Three major incidents shall be recorded as follows:
   - A = Normal grouting with normal readings
   - B = Suspect readings
   - C = Hole not grouted under required specifications for foundation grouting;

   which shall be followed by one of the following:
   - 1 = No specific problems encountered
   - 2 = Surface leaks experienced
   - 3 = Leaks through to other holes experienced
   - 4 = Fissures encountered
   - 5 = Cavities encountered
   - 6 = Problems experienced with grouting equipment

5. Letter sizes shall be limited to a height of 2,5 mm and using a pen thickness in all cases of least 0,25 mm.

6. The *Contractor* shall be responsible to provide the "As Built" rock line on the drawing. The *Engineer* shall provide the necessary data on the proposed excavation line.

Appendix D Figures

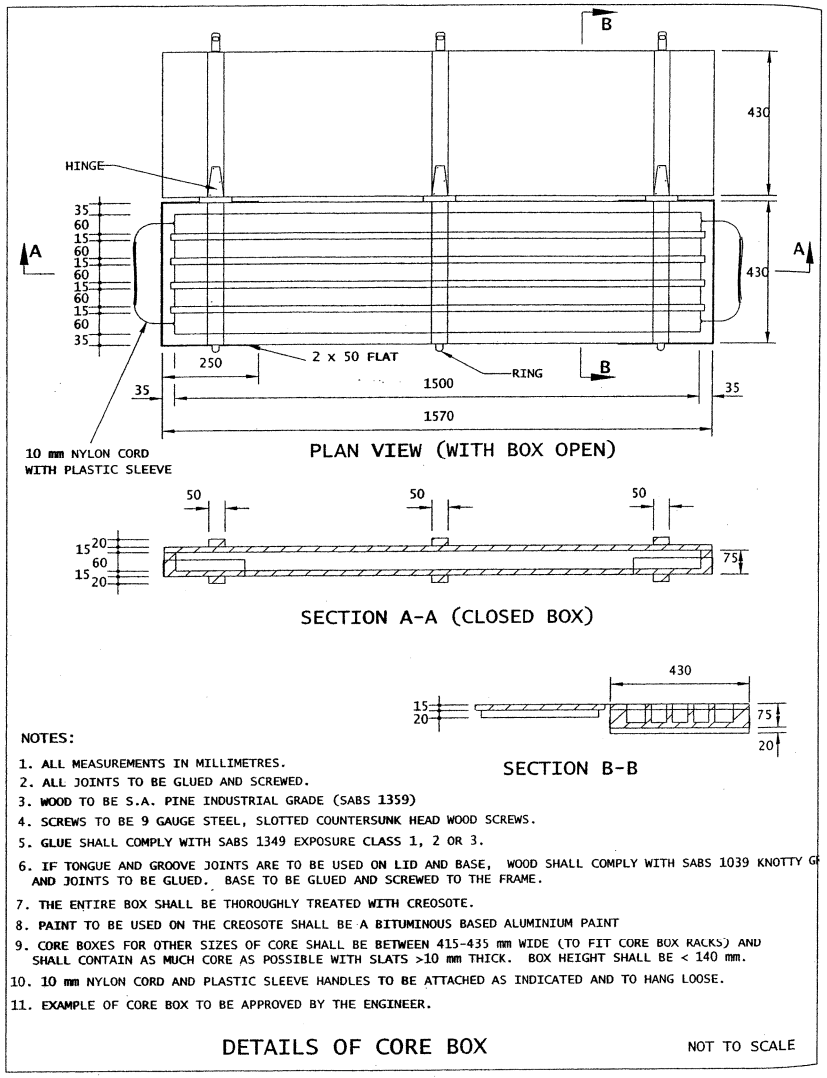

Figure 9.1 Details of Core Box

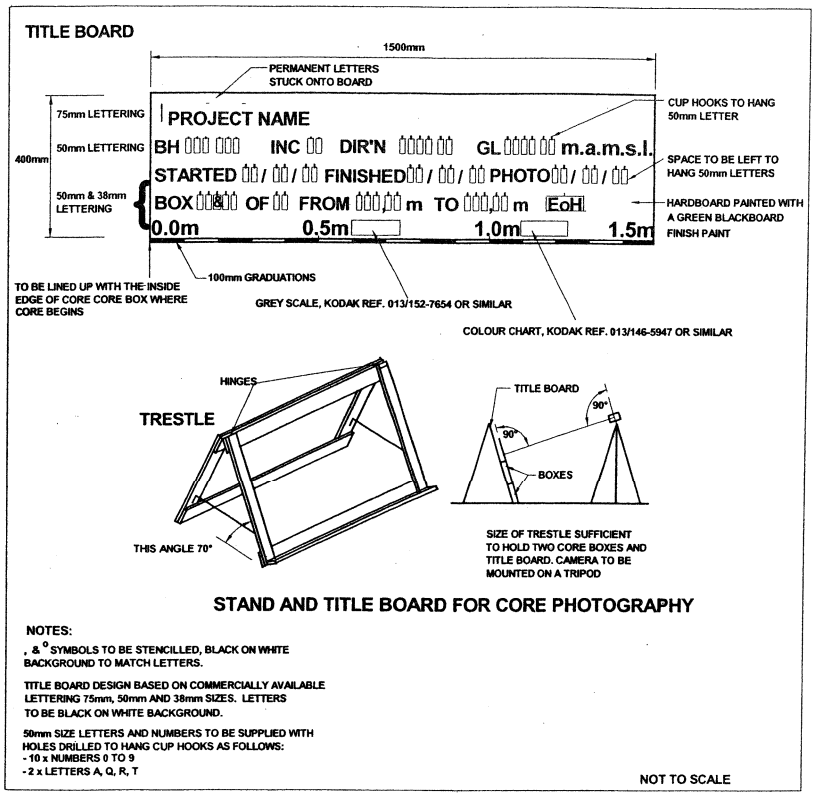

Figure 9.2 Stand and Title Board for Core Photography

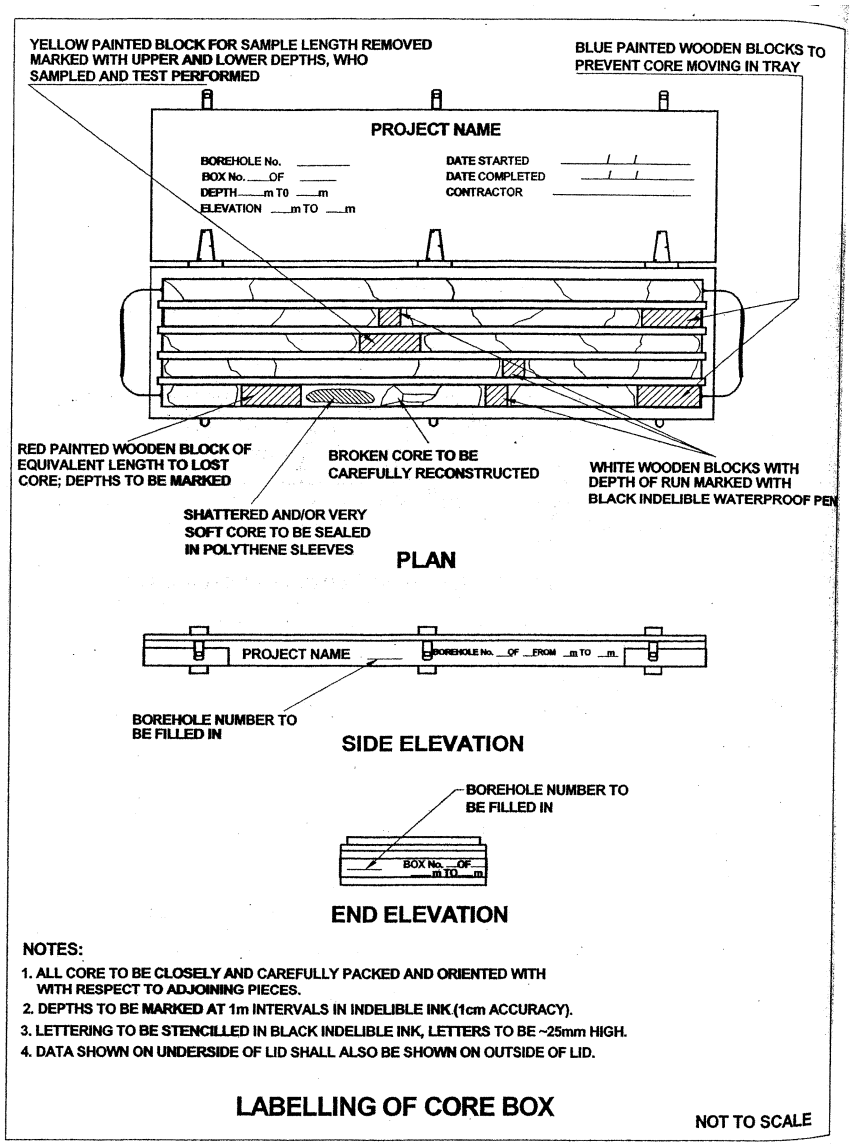

Figure 9.3 Labelling of Core Box