**KERJA-KERJA PENYIASATAN TANAH BAGI REKABENTUK TERPERINCI BAGI SEBUAH KOLAM TAKUNGAN BANJIR DI ALMA DAERAH SEBERANG PERAI TENGAH, PULAU PINANG**

## 1. PRELIMINARIES

### 1.1 General

An online pond with vertical wall, inlet and outlet structures are proposed to be built near to Sungai Junjung Mati. Therefore, a soil investigation is needed for two locations which involve two boreholes at the proposed location.

### 1.2 The Site

*Attachment A* shows the BH location at the project site.

### 1.3 Scope of Works

The scope of works will involve the following:

(i) Boreholes
(ii) Standard Penetration Tests
(iii) Collection of Disturbed Samples
(iv) Laboratory test
(v) As per listed in Bill of Quantities
(vi) Following the instructions for in-situ testing as required in the technical specifications for collecting and storing samples.

***Note:*** Exact location of Boreholes shall be confirmed by the Engineer/S.O. at site.

### 1.4 Location of Sub Surface Investigation Positions

The location of investigation positions shall be as shown on the attached Drawing(s) or as varied by the Engineer by instruction in writing during the course of the execution of the Works.

### 1.5 Setting Out

The Contractor shall be responsible for all survey work necessary to locate these positions on the ground at his own cost. The exact locations at which the investigations are carried out shall be marked on the plan, property dimensioned with reference to a base line. The Contractor shall provide a method statement for setting out. All setting out shall be carried out by Licensed Surveyor.

## 1.6 Ground or Seabed Elevations at Investigation Positions

Reduced levels shall be taken for all investigation locations. The temporary bench marks used shall follow those given in the original site plan if such bench marks are given. Otherwise they shall be based on Bench marks established by the Authorities. Under no circumstances shall the reduced levels be assumed and interpolated from contour lines given on the site plan. The Contractor shall check all field data to ensure that the survey is correct before the survey team leaves the site.

## 1.7 Survey Datum

The datum to which all levels are referred throughout these Specifications and which shall be referred in the as-built plans, drawings, soil profiles and reports prepared in the performance of this Contract shall be the Admiralty Chart Datum and shall be related to the Local Land Survey Datum or standard bench mark(s) located at or near the site. The Contractor shall at the outset state in writing to the Engineer the relationships between all datums used, but this shall in no way relieve him of any responsibility for the correctness and reliability of his work, or any other contractual responsibility.

## 1.8 Tide Gauge

The Contractor shall set up a manual reading tide gauge and an automatic recording tide gauge at a location to be agreed by the Engineer, accurately levelled to zero at local Chart Datum. The manual reading gauge shall be read at intervals of not more than ½ hour at all times when boring or sounding tests are being carried out over water.

The readings shall be plotted on a graph with properly scaled time and level axes and shall be used to determine the reduced level of the borings being carried out at that time.

The automatic recording tide gauge shall be calibrated and zeroes to Local Chart Datum. The type and make of the automatic gauge shall be subject to acceptance by the Engineer.

## 1.9 Plant, Equipment, Materials and Labor

The Contractor shall keep on the site sufficient plant to meet the requirements of the work. The plant shall be in good operating conditions and capable of efficiently performing the work set forth.

The Contractor shall furnish jars, tubes, boxes and bags and crates, meeting the requirements as specified elsewhere in these Specifications.

The Contractor shall have at site at all time, only qualified, experienced, orderly and thoroughly competent persons including engineers/geologists who shall conduct and supervise drilling operations, sampling, logging and in-situ testing.

The boring/drilling, excavation, sampling and testing equipment selected by the Contractor shall be such as to be most suited to sub-surface strata likely to be encountered to enable the accurate determination of strata changes and to minimise the sample distribution.

## 1.10 Removal of Improper Equipment and Contractor's Personnel

The Engineer shall during the course of the Works have the power to order in writing from time to time:

(a) The removal from the site any equipment not conforming to the requirements of the Specification, and the replacement of such equipment at the Contractor's own cost.

(b) The dismissal from the site any personnel, technical, supervisor, equipment operator, or any workmen of the Contractor found incapable or refusing to follow the proper procedure of work as specified in the Specification and/or directed by the Engineer, and replacement of such workmen at the Contractor's own cost. The Contractor's attention is drawn particularly to the technician's or supervisor's capability to identify and describe correctly soil and rock samples in the field, and to do survey work including taking reduced levels and setting out.

## 1.11 Laboratory Testing Facilities

The Contractor shall carry out laboratory tests at his own testing laboratories. The contractor shall first obtain the written consent of the Engineer if the testing facilities of other laboratories are to be made use of.

## 1.12 Photographic Record of Soil Samples

The Contractor shall provide a camera of good quality and take sharp and clear colour photographs for all Standard Penetration Test samples with the split tube sampler split into its respective halves and placed side by side, together with a clear readable tag giving borehole and Standard Penetration Test number identification. Photographs for trial pits shall be taken in accordingly and shall be presented along with pit logs.

The Contractor shall provide the film and print six (6) copies of each exposure in 3R size and document the photographs in suitable sets of albums. The photographs shall be mounted in the Final Soil Investigation Report to be submitted by the Contractor.

The negatives and the photographs shall be the property of the Engineer and no prints from these negatives shall be supplied to any person or persons except with the approval of the Engineer.

A suitably typed caption shall be affixed to the reverse side of each photograph describing the subject and the time at which it was taken. One copy of each photograph shall be signed by the contractor and the Engineer.

## 1.13 Programme to be Furnished

As soon as practicable and within two (2) weeks after acceptance of his Tender, the Contractor shall submit to the Engineer for his approval a programme showing the sequence, order of procedure and method in which he proposes to carry out the Works and particulars of Plant and Temporary Works which the Contractor intends to supply, use or construct as the case may be. The submission and approval by the Engineer of such programme or particulars shall not relieve the Contractor of any of his duties or responsibilities under the Contract.

## 1.14 Sequence of Work

The Engineer will, subject to and depending on the results of the initial investigation completed, determine with the Contractor the sequence in which the remaining boreholes and sounding tests are to be carried out.

## 1.15 Standards

All field/site work shall be in accordance with the latest Revision of BS 5930 and all laboratory testing shall be in accordance with the BS 1377:1990.

## 1.16 Method of Measurement

Except where any description of the work in the Specification, Drawing, Preamble to Bill of Quantities or the Bill of Quantities expressly shows or state to the contrary, measurement shall be made in accordance to the procedure set forth in the latest Revision of the Standard Method of Measurement of Civil Engineering Quantities published by the Institution of Civil Engineers, UK.

## 1.17 Damage to Overhead and Underground Mains and Services

The Contractor's attention is specially drawn to his responsibilities in ensuring that all utilities in and around the site are preserved in good condition. Particular care shall be taken to avoid damages to electricity mains, water mains, telephone lines, sewage mains and the like.

The Contractor shall be fully responsible for ascertaining the position of all mains or services at the site, particularly in the vicinity of boreholes, and all tests to determine their location. He shall be fully responsible for any damage and for all claims for consequential damages.

The engineer shall be immediately informed if any of the original locations of the boreholes or other tests coincides with the positions of the mains or services. It will be the Engineers responsibility to change the locations of the affected boreholes or other tests.

## 1.18 Watching and Lighting

The Contractor, shall in connection with the Works provide and maintain at his own cost all lights, guards, fencing and watching when and where necessary, or required by the Engineer, or by any competent statutory, or other authority for the protection of the Works, or for the safety and convenience of the public or others.

## 1.19 Interference with Traffic

All operations necessary for the execution of the Works and for the construction of any temporary works shall so far as compliance with the requirements of the Contract permits, be carried out so as not to interfere unnecessarily or improperly with the public convenience or the access to use.

## 1.20 Temporary Access

The Contractor shall provide all temporary roads and gangways required for the execution of the Works. He shall provide all times during the progress of the works, proper means of access and the necessary attendance for the inspection of the works by the Engineer or his representative as directed.

## 1.21 Workmen's Accommodation

The Contractor shall be responsible for the proper housing at site or elsewhere, of his labor force to the satisfaction of the relevant health authorities.

## 1.22 Water Supply

The Contractor shall provide all water required in connection with the Works, including the supply and fixing of all fittings, maintenance of the supply, payment of all fees, removal of all fittings and making good all disturbances after completion of the Works.

## 1.23 Electrical Power Supply

Should the Contractor require any electricity supply, he shall make his own arrangement with the authority concerned, comply with all safety regulations and pay all fees in connection with the installation and supply.

## 1.24 Storage Facilities

The Contractor shall provide proper facilities for the storage and protection of soil, rock and water samples.

### 1.25 Clearance of Site on Completion

As soon as the investigation work is completed, all test pits, boreholes, etc. shall be backfilled to the satisfaction of the Engineer. On completion, the Contractor shall remove from site all plant, surplus materials, condemned equipment, temporary works and rubbish of any kind and leave the site and Works clean and tidy to the satisfaction of the Engineer.

### 1.26 Inspection of Site

The Contractor shall inspect and examine the site and its surrounding and shall satisfy himself before submitting his tender as to the nature of the site, the scope and nature of the Works, equipment, plant and materials necessary for the completion of the Works and in general shall himself obtain all necessary information (subject as above mentioned) as to risks, contingencies and other circumstances which may affect his tender.

### 1.27 Documents Mutually Explanatory

The several documents forming the Contract are to be taken as mutually explanatory of one another and in case of ambiguities or discrepancies the provisions of the Conditions of Contract shall prevail over those of any other document forming part of the Contract. Provided always that any ambiguities or discrepancies shall be referred as soon as possible to the Engineer who shall issue to the Contractor instructions directing in what manner the work is to be carried out in accordance with the provisions of this Clause.

## 2. DEEP BORING

### 2.1 Boring Plant and Mobilisation

Mobilisation shall consist of delivery at the site of all plant, equipment, material and supplies to be furnished by the Contractor including the drilling rigs, sampling and test equipment and all things necessary to carry out and complete the Works. The Contractor shall make assemble completely in satisfactory working order of all such plant and equipment on the job and satisfactorily store at the site of all such materials and supplies. The contractor shall mobilise all equipment and supplies necessary to perform the work in a satisfactory manner under existing site conditions.

The plant used shall be capable of boring/drilling to the maximum depth indicated in the Bill of Quantities and Drawings etc.

The plant shall be suitable for advancing the bore, sampling in-situ testing and rock drilling in accordance with relevant specification for each of these operations.

## 2.2 Method of Advancing Boreholes

The method used shall be such that an accurate observation of the soils encountered is possible throughout the process. No mingling of soils from different levels shall be allowed to occur.

Acceptable method shall be continuous augering, continuous sampling and rotary, drilling or a combination of these methods. Percussion boring shall not normally be permitted unless otherwise specified. Wash boring in which the borehole is advanced by chopping action where the casing is withdrawn and lowered in a continuous and successive series of steps shall not be permitted. Wash boring when it is allowed will be clearly stated in the Bill of Quantities/Drawings etc.

Drilling techniques adopted shall be such that little disturbance is caused to the soil in the boreholes where undisturbed samples are required. Water shall not be added to the holes in cohesive or silts unless specially approved by the Consultants.

Deep boring casing sizes shall be selected such that telescoping of casing shall not prevent the carrying out of undisturbed sampling and in-situ testing. Casing shall not be driven in advance in the borehole, except when specially by the Consultants.

Should alternating layers or rock and soil be encountered the full depth of boreholes shall be achieved by a combination of boring and rock coring techniques.

The Contractor shall take good care to ensure the boreholes are vertical.

## 2.3 Uncased and Cased Boreholes

Unless otherwise stated boring without casing may be permitted provided that there is no collapse of the borehole. A collapse is considered to have occurred when, in the opinion of the Engineer there is a mingling of soil or rock from different depths inside the borehole.

Casing shall be provided to stabilise the borehole as soon as there are signs that the walls of the boreholes are collapsing.

## 2.4 Other Methods of Stabilisation of the Boreholes

Other methods of stabilistion of the boreholes against collapse may be carried out subject to the prior approval of the Engineer on the procedure used. Nevertheless, casing shall be used when, in the opinion of the Engineer there is considerable doubt on the effectiveness of the method of stabilisation proposed or practised.

## 2.5 Drilling Fluid

Type, density and use of drilling fluid as such shall be approved by the engineer in each case. Such drilling fluid should be sufficient density to pavement caving in and to remove the cuttings from the boreholes.

## 2.6 Heaving of the Bottom of Boreholes

To prevent heave and disturbance of the soil at the bottom of the borehole, the level of drilling fluid in the hole must at all time be equal to or higher than the elevation of the ground water. This condition shall be strictly observed in formations of fine sand or silt or in operations involving undisturbed sampling and in-situ testing.

## 2.7 Size and Depth of Borehole

The size of the boreholes shall be such that the requirements of size in sampling, in-situ testing, etc. are satisfied.

**Depth of Borehole**

**(a) Cut Area**

In cut areas, the boreholes shall be terminated at the depth 3m below the proposed formation level and/or at a maximum depth of 10m or after 3 consecutive SPT exceeding 50, or after 3m rock curing, whichever comes first.

**(b) Fill Area**

***i. Alluvial Soils***

The boreholes shall be terminated after reaching very stiff/dense strata where three (3) consecutive SPT (N) values taken after interval of 1.5m depth exceeds 30b/300mm.

*ii. Residual Soils*

The borehole shall be extended until very hard/dense strata where SPT N, value exceed 50.

**(c) Bridges and Structures**

Boring shall be terminated after 7 consecutive SPT taken at 1.5m intervals encounter N valves which exceeds 50, or 5 consecutive SPT exceeds 30 if the borehole depth also exceeds 60m. Boring shall be terminated if rock is encountered. Rock corings shall be carried out in accordance with Table 2.7.

Table 2.7

| Rock Type | Min. Core Length |
|---|---|
| Igneous rock (granite) and bore depth < 24m or recovery ration R/r < 50% | 4.5m |
| Igneous rocks, bore depth > 24m | 3.0m |
| Shale/schist/slate/sand stone, Recovery ration R/r < 50% | 6.0m |
| Shale/schist/slate/sand stone, Recovery ration R/r > 50% | 3.0m |
| Lime stone R/r > 50% and no cavity | 6.0m |
| Lime stone R/r < 50% and no cavity | 9m – 21m |
| Other rocks R/r > 50% | 4.5m |
| Other rocks R/r < 50% | 6.0m |

## 2.8 Rock Drilling

The procedure for rock drilling shall be in accordance with ASTHMA D2113-70 (1976) "Diamond Core Drilling for Site Investigation" or its latest Revision.

The minimum diameter of cores acceptable shall be 54.0mm diameter (NWX, NWM core barrels). However, when directed by the Engineer, core of 30.2mm (AWX, AWM core barrels) may be taken at the lower end of the coring runs.

The core Recovery Ratio (CRR) and the Rock Quality Designation (RQD) as described below shall be reported for each core run.

## 2.9 Core Recovery Ratio (CRR) and Rock Quality Designation (RQD)

Good quality core is defined as intact core having a fully circular circumference or in the case of broken rock fragments assembled to form cores with a fully circular circumference. The CRR shall mean the ratio of the total length of the good quality cores over the drilling run, expressed in percent (%) rounded to the nearest digit. The RQD is the ratio of the sum total of the individual length of good quality cores each exceeding 100mm in

length, over the drilling run, expressed in percent (%) rounded to the nearest digit.

### 2.10 Unnatural Obstructions and Abandoned Boring

Should unnatural obstructions to boring be encountered, the Engineer shall be informed immediately so that a decision may be made regarding the use of any special technique, including chiselling or diamond drilling, or termination of the borehole. Borehole terminated with the consent of the Engineer shall be measured.

Under no circumstances shall the Contractor abandon or terminate a borehole without the approval of the Engineer. Boreholes so abandoned or terminated will not be measured and will not be considered for payment.

However, should the Contractor be unable to complete any borehole due to encountering underground services or structures which cannot be reasonably foreseen after all reasonable precautions in Clause 1.17 "Damage to Overhead and Underground Mains and Services" have been complied with, the completed borehole may be allowed to be measured.

## 3. SAMPLING

### 3.1 Disturbed Samples

Disturbed samples may be obtained by any appropriate means as long as the soil sample obtained is representative and unchanged in the constituent contents. Samples with flap retainer or basket retainer or other attachment may be necessary for cohesionless soils.

Disturbed samples shall be taken from cutting shoe of thin wall tube sampler or from split spoon sampler. Samples with flap retainer or basket retainer or other attachment may be necessary for cohesionless soils. Where solids cone is used instead of split spoon sampler for the Standard Penetration Test or where undisturbed sample is lost on extraction, a disturbed sample shall be taken when cleaning out the borehole at the depth of the test or sampler penetration.

The minimum amount of soil sample required shall be that quantity which is sufficient for the soils to be tested in the various classification tests, such as moisture content, Atterberg limits and particle size distribution.

When sufficient quantity of soil is not obtained in the first instance, the sampling operation shall be repeated at no extra cost. It is the contractor's responsibility to choose appropriate samplers so that enough sample will be

obtained in the least number of sampling operations. However, when the operation has been properly repeated for a total of 3 times and a sampler with a retaining device has been used at least once, the operation need not be continued. The operation shall be measured.

### 3.2 Undisturbed Samples with the Thin-Walled Tube Sampler

Undisturbed samples shall be taken with the thin-walled tube sampler described in ASTM D 1587-74, "Thin-walled tube sampling of soils" or its latest revision. The minimum outside diameter of the tube used shall be 63.5mm (2 ½ inches) and the minimum length of the tube 610mm (24 inches).

In soft to stiff cohesive soils, the thickness of the wall of the tube shall not be greater than 1.59mm (one-sixteenth of an inch). The tube shall be pushed into the ground at a rate of 100 to 200mm per minute, without impact or twisting. Under no circumstances should driving of the sampler by a hammer be permitted. To ensure successful sampling without driving of the sampler, the boring plant used shall be weighed down and/or anchored adequately to the ground to exert hydraulically a jacking force of up to 25KN without uplifting of the plant. Should the plant be unable to exert such a force, it shall be considered as an improper plant and be replaced under the clause of the preliminaries "Removal of Improper Plant".

When sampling in soft to stiff cohesive soils, the last 0.30m of soil in a borehole left overnight shall be removed before attempting to take the undisturbed sample.

When sampling is required in cohesionless soils and very stiff to hard cohesive soils as directed by the Engineer, light driving of the sampler may be allowed. Samplers for such purpose may have a wall thickness up to 3.18mm (one-eighth of a inch). The weight of the hammer, height of drop and the number of blows per 75mm penetration of the tube shall be recorded until the full length of the sampling tube has been driven into the soil to be sampled.

### 3.3 Handling of the Samplers

All soil samples and rock cores shall become the property of the employer and the Contractor shall be responsible for their storage and safe keeping.

Tubes containing undisturbed samples shall be sealed with at least 5 millimetres of non-shrinkable sealing wax at each end to avoid changes in moisture content.

Sample shall be sheltered from weather and protected from extremes of temperature and from solar radiation.

### 3.4 Preservation of Disturbed Samples

Immediately after being recovered, disturbed samples shall be preserved in a wide-mouth, air-tight, screw-top, clear glass jar or metal container sealed with a non-shrinking microcrystalline wax for determination of natural moisture content at the laboratory.

### 3.5 Preservation of Undisturbed Samplers

About 40mm of soil shall be removed from the top and bottom of the sample tube and preserved as a disturbed sample for visual identification. The ends of the sample tube shall then be immediately sealed by filling with anon-shrinking microcrystalline wax in suitable layers to a thickness of about 40mm. The voids at the ends shall then be completely filled with moist sand or other suitable fillers. Sealing of the tube shall be completed by capping the tube with suitable tight-fitting caps and the caps sealed with wax.

### 3.6 Labelling of Soil Samples

For disturbed samples, a label clearly and indelibly marked with the name of the project, borehole number, depth of sampling, date taken and the type of sample (e.g. split-barrel tube samples, auger samples or from the ends of undisturbed samples) shall be placed inside the jar or polyethylene bag. The outside of the jar or bag shall also be marked with the sample number, borehole number and project number with the same legend used in the borelog. A suggested format is Dx(Ux)/y/z where x is the sample number, y the borehole number, z the project number, D for disturbed samples and U for undisturbed samples.

For undisturbed samples, additional information required in the label includes the recovery ration and the maximum hydraulic force/dynamic force used to secure the sample. The label shall be placed just below the cap at the top of the sample. The marking on the outside of the tube shall be similar to that for the disturbed samples. In addition, the top and the bottom of the sample shall be indicated.

### 3.7 Storage and Transportation of Soil Samples

All soil samples shall be stored orderly at site in protective boxes in a dry place and under cover until they are dispatched to the designated laboratories. The undisturbed samples shall be placed in wooden boxes, preferably with partitions and packed with saw-dust, paper, etc. to prevent damage during transit.

Under no circumstances should the undisturbed samples be transported without proper packing.

### 3.8 Preservation, Storage and Transportation of Rock Cores

The procedure of preservation and storage of rock cores shall be in accordance with ASTM D2113-70(1976) "diamond core drilling for site investigation" or its latest revision. The core box to be provided shall be of a type approved by the Engineer.

The name of the project and borehole number or numbers shall be printed on the cover. The labelling inside the box shall follow that recommended in the above ASTM standard. Each box shall contain cores from the same project.

All rock cores shall be delivered to the Engineer's office unless otherwise directed and the core box shall remain the property of the employer.

### 3.9 Provision of "Record Samples"

About 250gm of representative soil sample shall be taken from the disturbed/undisturbed samples and sealed inside a plastic tube type container. These samples shall be known as "record samples" and shall be delivered to the Engineer's office. The borehole number and the depth of sample shall be marked on a label glued to the container. All the "record samples" from the same borehole shall be stored in an appropriate durable box of appropriate dimension and size, with the name of the project and the year and the month of investigation clearly and indelibly marked on the top and sides of the box.

These samples shall be delivered to the Engineer's office at the time of submitting the final reports.

It can be expected that only non-cohesive or residual soil samples need be preserved as "record samples". The cost of provision of these samples shall be deemed to be included in the rates of obtaining disturbed/undisturbed samples if not separately billed as a pay item in the Bills of Quantities.

## 4. FIELD TESTING

### 4.1 Standard Penetration Test (SPT)

SPT shall be carried out in accordance with Test No 19, BS 1377:1975, "Determination of the Penetration Resistance Using the Split Barrel Sampler" or its latest revision, using a self tripping hammer of an approved design. It shall be carried out at 1.5m intervals unless otherwise directed by Engineer.

When drilling in granular soils the water table in borehole shall be maintained at sufficient height to prevent disturbances of boiling occur due to unforeseen piezometric conditions no testing shall be carried out until the boiling is stopped and the disturbed material removed.

The value of N as defined in the Test Method shall be reported together with number of below counts for each 75mm penetration of sampling tube in bracket. The blow counts for first 150mm penetration (the seating drive) which do not contribute to value of N shall be included in the bracket. Two examples appropriate recording are N = 42 (2, 3, 6, 7, 10, 19) and N = 50/100mm (28, 30, 35, 15/25mm).

When a penetration resistance of 50 blows for 25mm penetration is encountered in the seating drive, the test may be stopped and the standard penetration test value reported as N = 50/25mm.

## 4.2 In-situ California Bearing Ratio Test (CBR)

The in-situ CBR test shall be carried out in the field and in accordance to BS 1377: Part 9: 1990 Section 4 Sub-section 4.3.

## 4.3 In-situ Density

The in-situ density test shall be carried out in accordance to BS 1377: Part 9: 1990 Section 2 Sub-section 2.2.

### 4.3.1 Water Table

Before a permeability test is conducted, it is essential to determine the level of the natural ground water table. To measure ground water pressures accurately, it is generally necessary to install special measuring devices called piezometers. The ground water pressure may vary with time owing to seasonal, tidal or other causes. The standpipe piezometer is a device consisting of a tube or pipe with a porous element on the end or with a perforated end section surrounded by or wrapped with a filter, which is sealed into the ground at the appropriate level. It is normally installed in a borehole. The tube should be of at least 12mm diameter to allow air bubbles to rise freely. Access to the top of the standpipe is generally required for plumbing the water level, although this can be determined remotely using an air-bubbling system. In any case, standpipes need an air vent to allow the water level to come to equilibrium.

The main advantage of a standpipe is its simplicity. The main disadvantage of the standpipe is the length of time taken to reach equilibrium or to respond to changes in pre-water pressure in soils of relatively low permeability.

### 4.3.2 Constant Head Test

The period required for constant head tests is decreased and the interpretation simplified if short lengths of borehole are used for the test. Pore pressures should be in equilibrium before the test is performed and with clays of low permeability, it can take several months for the pore pressures set up by the drilling of the borehole to equalise.

A constant head test is conducted as an inflow test in which arrangements are made for water to flow into the ground under a sensibly constant head. It is essential to use clean water. It will not be possible to achieve a constant head if the ground water level is not constant or the head lost by friction in the pipes is significant. Where a high flow rate is anticipated and where the installation comprises a piezometer tip surrounded by a filter material, two standpipes should be installed, one to supply the water and the other to measure the head in the filter material surrounding the piezometer tip. The rate of flow of water is adjusted until a constant head is achieved and in the simplest form of test, flow is allowed to continue until a steady rate of flow is achieved. In some ground, this may take a long period of time and the actual rate of flow is measured and recorded at intervals from the commencement of the test.

## 5. LABORATORY TESTING

### 5.1 Scope of Laboratory Testing

The scope of laboratory testing shall be as instructed in writing by the Engineer after studying the preliminary borelogs and field or in-situ tests results submitted by the Contractor. In order that the Engineer can issue timely test instructions, the Contractor shall ensure that copies of all preliminary boring logs, field and in-situ test results in their raw data form are submitted to the Engineer not more than one day after such boring and/or test had been completed. Laboratory tests identified and allowed for in the Bill of Quantities/Drawings, etc. are strictly provisional.

The instruction for laboratory testing, whenever applicable, shall be issued by the Engineer only after receipt by the Engineer of such preliminary field log and/or record for perusal. It is thus the responsibility of the Contractor to ensure timely submission of field logs, records and data. As a guide to Contractors in their estimates of the Time of Completion for the contract, it

may be assumed that the first instruction on laboratory testing shall be issued within one week after receiving the preliminary field logs of half of the total number of boreholes to be completed under the Works in the Contract. Subsequent instructions on laboratory testing shall be issued one week after receipt of preliminary field logs of each remaining borehole. The last instruction shall be issued within one week after receiving the preliminary field log of the last borehole.

## 5.2 Testing Standards

All preparation of test samples and specimens for laboratory testing shall be carried out in accordance with methods and procedures stated in the latest revision of BS 1377: "Methods of Testing for Soils for Civil Engineering Purposes", unless otherwise stated or instructed by the Engineer. The test reference numbers indicated in the Bill of Quantities/Schedule of Rates refer to the same test number in BS 1377: 1985. It should be noted that the Test Reference No. of the same test may differ from the above, when reference is made to other editions of BS 1377.

The permeability test for granular soils shall be carried out in accordance with method and procedures stated ASTM D 2434-68 (1974) "Permeability of Granular Soils (Constant Head)" or its latest up-date.

The unconfined compression test shall be in accordance with ASTM D 2166-66 (1972) "Unconfined Compressive Strength of Cohesive Soils" or its latest up-date.

For the three types of special consolidated triaxial compression test, namely undrained with or without pore water pressure measurement and drained with a suitable back pressure, the methods and procedures shall be in accordance with those described in the "the Measurement of Soil Properties in the Triaxial Test" by A.W. Bishop and D.J. Henkel, E.L.B.S. 1969 Edition.

## 5.3 Soil Classification System

Soil samples shall be classified according to the unified soil classification system in ASTM D 2487-69 (1975) "Classification of Soils for Civil Engineering Purposes".

The visual manual description of soils shall be in accordance with ASTM D 2488-69 (1975) "Description of Soils (Visual Manual Procedure)".

## 5.4 Units to be Used

The units to be used in this Work shall be S.I. units and those as given in the relevant testing standards. The accuracies of measurements shall also be in accordance with those stated in the relevant testing standards.

## 5.5 Chemical Composition Analysis

Samples collected from boreholes shall be tested in an accredited laboratory to assess levels of various chemical constituents or contaminants. Chemical analyses shall be conducted in accordance with the relevant standards. The sediment quality will be tested for the parameters as listed in *Table 1.*

Table 1 Sediment quality parameters and methods

| Test Parameter | Unit | Method Used |
|---|---|---|
| Nitrate | mg/kg | Leaching, APHA 4500 NO3-H |
| Total Phosphorus | mg/kg | USEPA 3050 B, 6010 B |
| Oil & Grease | mg/kg | APHA 5520 E |
| Sulphide | mg/kg | Leaching, APHA 4500 S2-D |
| Organic Matter | % | APHA 2540 G |
| Total Organic Carbon (TOC) | % | USEPA 9060 |
| Nickel | mg/kg | USEPA 3050 B, 6010 B |
| Copper | mg/kg | USEPA 3050 B, 6010 B |
| Chromium | mg/kg | USEPA 3050 B, 6010 B |
| Lead | mg/kg | USEPA 3050 B, 6010 B |
| Arsenic | mg/kg | USEPA 3050 B, 6010 B |
| Cadmium | mg/kg | USEPA 3050 B, 6010 B |
| Zinc | mg/kg | USEPA 3050 B, 6010 B |
| Manganese | mg/kg | USEPA 3050 B, 6010 B |
| Iron | mg/kg | USEPA 3050 B, 6010 B |

Baseline data obtained for sediment quality shall be compared with the US EPA Standard (*Table 2*).

Table 2 US EPA Standard for sediment quality

| Parameter | Unit | US EPA Standard | | |
|---|---|---|---|---|
| | | Non-Polluted | Moderately Polluted | Heavily Polluted |
| Zinc as Zn | mg/kg | <90 | 90 – 200 | >200 |
| Nickel as Ni | mg/kg | <20 | 20 – 50 | >50 |
| Lead as Pb | mg/kg | <40 | 40 – 60 | >60 |
| Arsenic as As | mg/kg | <3 | 3 – 8 | >8 |
| Cadmium as Cd | mg/kg | - | - | >6 |
| Copper as Cu | mg/kg | <25 | 25 – 50 | >50 |
| Chromium as Cr | mg/kg | <25 | 25 – 75 | >75 |
| Nitrate | mg/kg | N/A | N/A | N/A |
| Total Phosphorus | mg/kg | N/A | N/A | N/A |
| Oil and Grease | mg/kg | <1,000 | 1,000-2,000 | >2,000 |

## 6. REPORTING OF RESULTS

### 6.1 Submission of Preliminary Field Log

The preliminary field log shall include information listed below, wherever applicable:

- Type make and model of deep sounding/boring machine
- Type and size of casing and rods
- Details of cones and rods use in deep sounding
- Names of supervisor and operator
- Dates and times of work
- Depth of casing
- Reduced level of borehole, sounding and field test position and other remarks

A copy of the preliminary field log and the site plan/location plan showing the actual surveyed position of the investigation carried out shall be formally submitted to the Engineer at the later's office by the contractor as soon as the field work is completed at that particular position.

## 6.2 Submission of Final Report

Six copies of the final report shall be submitted. Prints of all drawings as described in Clause 8.4 and 8.5 of this Specification shall be included in all six copies. The original tracing of the drawing shall be submitted to the Engineer and shall remain the property of the Employer. The report and all associated drawings shall also be submitted in the form of computer files and disks. Two sets of disks containing the report and drawing files shall be submitted. The software used in the preparation of the report an drawings shall be such that files can be translated by and into commonly used word processing, drawing and plotting software.

The hard copies of the final report shall be in A4 size with suitable cover and spiral ring binding. Stapled binding is not acceptable. The tile on the cover shall be in stencil lettering of 5mm nominal size and in capital letters. The title shall contain the following information:

- Name of Employer
- Project Title
- Title of the Contract
- Contract Number (if any)
- Period (Start Month – End Month) and year during which investigation was carried out
- Name of Contractor
- Name of Employer's Supervising Consultants

The Final Report, its contents, detail and form of presentation shall be prepared in accordance and in compliance with Clause 8.3 of this Section of the Specifications.

The Contractor shall submit a draft of his investigation report including the drawings to the Engineer for his perusal and approval. It may be expected that the Engineer shall give comments within two weeks after receiving the draft.

If only minor corrections are necessary, the Contractor shall be allowed to take back the draft report, correct it and immediately reproduce the required 6 copies. If the corrections required are major and numerous the Contractor shall be required to resubmit the amended draft for approval.

The Date of Completion shall be taken as the date the Final Reports and their respective computer disks have been submitted and accepted by the Engineer.

## 6.3 Presentation of the Final Report

The Final Report on the works completed shall include the factual presentation of the results of the investigation and the conceptual engineering interpretations made of the field and laboratory test result.

The following format shall be followed:

### 6.3.1 GENERAL

#### 6.3.1.1 Introduction

This should include the objective of the subsurface soil investigation and general description of the site and it surroundings.

#### 6.3.1.2 Site Conditions

A general appraisal on the topography and geology of the area should be presented.

#### 6.3.1.3 Scope of Work

A detailed list and extent of works carried out.

### 6.3.2 SITE INVESTIGATION

#### 6.3.2.1 General

A site plan indicating the exact surveyed positions of all investigation points identifying the type of investigation carried out and its reference number, should be presented. A table showing the co-ordinates of these positions and their respective reference number shall be included.

#### 6.3.2.2 Field Investigation

A summary of the type of plant and machinery and methods employed in the field work should be presented.

### 6.3.3 LABORATORY TESTING

#### 6.3.3.1 Type of Tests

A summary of the types of laboratory tests conducted as specified by the Engineer should be presented.

### 6.3.4 SUBSOIL CONDITIONS

#### 6.3.4.1 General

This should include a summary on the soil properties and soil profiles.

#### 6.3.4.2 Interpolated Soil Profiles

The interpolated soil profiles shall be simplified and the following parameters are to be included:

(a) The standard Penetration Blow Counts of the soft and hard strata.
(b) Field Vane Shear Results of the various soil layers.
(c) Physical identification of the subsoil based on the Unified Classification System.

The interpolated soil profile shall be presented on standard A2 size paper.

### 6.3.5 THE CONCEPTUAL ENGINEERING INTERPRETATIONS BASED ON THE FIELD AND LABORATORY TEST RESULTS

Emphasis should be based on the Engineering Properties of the subsoils as obtained from the field and laboratory result. Recommendations should be made as to any likely problems to be encountered in the design and in the construction process.

### 6.3.6 SUMMARY

This should summarise the main points of the report.

### 6.3.7 ILLUSTRATIONS

| | |
|---|---|
| Appendix A | Summary of Geotechnical Investigation Data and Soil Strength Parameters |
| Appendix B | Borelogs |
| Appendix C | Laboratory Test Results |
| Appendix D | Photographs of Rock Coring Samples, SPT Split Tube Samples and Undisturbed Soil Samples |

## 6.4 Details on the Drawings

Summarised test results and the location of testing shall be presented on the Drawing. The site plan/location plan shall be traced form the plan supplied by the Engineer with suitable extraction of relevant data. Each drawing shall have a separate drawing number with the drawing number of the original drawing from which it had been traced noted. The site plan and location plan shall show the position of all investigations/tests carried out at that particular site, identifying both the type of investigation/test and its reference number. The temporary bench mark used for the reduced levels shall be marked and described on the site plan/location plan. Reference points used in the setting out of the locations of investigation shall also be indicated.

For deep boring or hand augering, the final borelog shall be presented on the drawings with a suitable summary of the field and laboratory test results such as SPT, vane shear, Atterberg Limit, soil moisture content, soil classification grouping, sieving results in terms of gravel/sand/silt/clay content, cohesion/friction angle and ground water level. The preferred order of plotting is depth (including ground water level), legend, soil description, soil group classified according to ASTM D 3282-73 (1978) or ASTM D 2487 (1975), field test result and laboratory test result. The recommended scale for depth is 1:100 for deep boring.

## 6.5 Standard Tracing/Drawing Size

The original tracing shall be in standard A1 size of an approved gauge with a title block of proper dimension at the lower right-hand corner. The arrangement of the title block shall follow that given in the sketch.

The use of suitable translucent graph paper to facilitate drawing work may be permitted. However, such paper must be of a suitable gauge approved by the

Engineer. The use of small sheets of translucent graph paper pasted onto ordinary tracing paper shall not be allowed.

Stencil lettering shall be used for the title block, sub-titles or any of the drawings, site plan/location plan and the key words in a table of results. Freehand lettering may be used in other parts of the drawing, if its legibly and expertly written. However, the Engineer may insist that all drawings to be carried out with stencil lettering.

Though the tracing is in A1 size, the drawings to be included in the final report shall be reduced to A2 size with a reduction printer.

The Contractor shall ensure that details on the A1 size tracing are still legible in the A2 size drawing. These drawings shall be properly folded, trimmed of unwanted margins if necessary and bound in the final reports in such a manner that the whole sheet can be flatly laid out in the bound condition. Alternatively, the drawings shall be properly folded and placed in paper or plastic envelope bound in the final reports. Each envelope may contain up to a maximum of 3 drawings.

## 6.6 Details Required in the Final Report

For deep boring, the final field log to be included in the ordinary reports shall contain all information listed for the preliminary field log in Clause 8.1. However, the soil description presented in the preliminary field log shall be revised according to the laboratory test result and the amended description presented in the final field log.

Details of laboratory test results required to be included in the report are given below:

(a) Moisture content: value only
(b) Atterberg limits: value only
(c) Linear shrinkage: value only
(d) Specific gravity: values of the tests
(e) Particle size distribution: semi-logarithmic chart of the type shown in Fig. 10, BS 1377: 1975. A maximum of 3 individually distinguished curves (3 samples) of the borehole are allowed on single chart.

(f) Compaction test (single moisture content): compaction energy, dry density and moisture content.

(g) Detailed compaction test (5 of more moisture contents): plot of dry density against moisture content, maximum dry density, optimum moisture, classification result and items in (f).

(h) Unconfined compression test: unconfined compressive strength, strain at failure, moisture content, bulk density. Dimension of specimen, strain at failure and the load against deflection test chart as shown in Fig. 49, BS 1377: 1975 if a portable apparatus is used or the proper plot of stress against strain if a proper compression machine is used.

(i) Unconsolidated undrained triaxial compressive test without pore-water pressure measurement (single specimen): bulk density, moisture content, cell pressure, maximum principal stress difference and mode of failure, dimensions of specimen and plot of stress against strain.

(j) Unconsolidated undrained triaxial compression test without pore-water pressure measurement (3 or more specimen): plot of Mohr circles and the failure envelope, cohesion, angle of seharing resistance and items (i).

(k) Consolidated triaxial compression test of various types: items in (j) and others as directed by the Engineer

(l) One-dimensional consolidation test: specific gravity initial and final bulk densities and moisture contents, plot of void ration against the logarithm of applied pressure, tables of coefficient of consolidation, initial compression ratios, primary compression ratios and secondary compression ratios against pressure increment, table of coefficient of volume compressibility against pressure increment, completed Form T (pages 137 – 141, BS 1377: 1975 or its latest revision). The laboratory curves used in square root of time fitting method or the logarithm of time fitting method to determine the coefficient of consolidation shall be included.

(m) Organic matter content: value only

(n) Total sulphate content: value only

(o) Sulphate content of ground water: value only

(p) pH value: value only

(q) Constant head permeability test: completed test data sheet as in Fig. 3, ASTM D 2434-68 (1974) and plots of velocity against hydraulic gradient.

(r) Chemical Composition: value only

# 7 SPECIAL INSTRUCTIONS

## 7.1 Boring Plant

The Contractor shall deploy to site during the execution of the Works a minimum of two (2) boring/drilling rigs and their work teams and a minimum of two (2) sounding plants and their work teams to simultaneously carry out the Works.

## 7.2 Supports for Plant

The form of support for all investigation work over water with water depth equal or greater than 1.5m shall be fixed stagings or jacked-up platforms above water level. Floating pontoons or platforms shall not be used.

A scaled diagram of the proposed type of support(s) shall be submitted together with the tender. Detailed, dimensioned and scaled drawing(s) of the support(s) shall be submitted to the Engineer for record and acceptance of the proposed support(s) within two (2) weeks of possession of site by the Contractor.

## 7.3 Contractor's Professional Attendant on Site

The Contractor shall assign experienced geotechnical engineers to supervise and control the field operations, examine the samples, describe and prepare field logs.

## 7.4 Interim Reports

The Contractor shall forward to the Engineer at the beginning of each working day, copies of field logs of work done on the previous day and properly prepared interim reports at the completion of every five (5) boreholes.

## 7.5 Submission of Final Reports

The final report shall be prepared in accordance with Clause 8 of the Specification. The report shall also provide information regarding geotechnical parameters, plots of cross-section and preliminary analysis of the ground condition.

The final reports shall be endorsed by an experienced professional Geotechnical Engineer. The curriculum vitae of the professional Geotechnical Engineer shall be submitted for approval.

## 7.6 Raw Data of Laboratory Tests

One copy of all raw data, readings, records, etc. taken in the process of each and every laboratory test, properly bound and identified shall be submitted together with the Report.

All raw data, readings, records etc. shall also be entered into 1.44Mb computer diskettes useable on IBM personal computers or compatibles in spread sheet format and one set of such diskettes shall be provided with the bound copy of such data, readings and records. Where such data are recorded in dedicated laboratory test equipment data loggers, such data shall be translated in the spread sheet format, useable in common spread sheet or database programmes for personnel computers.

Unless otherwise itimised in the Bill of Quantities, costs of preparation and supply of such data, readings, records etc. diskettes shall be deemed to be included in the price/rate for laboratory testing and preparation of this Report.

## 7.7 Precedence

Insofar as any of the clauses or specification in this section may conflict with any of the clauses or specifications in other sections of the Specifications, the above clauses or specifications in this Section shall prevail.