SPECIFICATION FOR INSTRUMENTATION AND MONITORING OF RECLAMATION WORKS

1.0 GENERAL

Instrumentation shall be installed to measure horizontal and vertical displacement or structures and water pressures in the soil. Instrumentation is part of the permanent works and shall remain in good condition and operational both during and after the construction contract, unless as agreed by the Engineer.

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

2.0 PROTECTION AND MAINTENENCE OF INSTRUMENTS

The Contractor shall take all necessary precautions to protect the instruments and maintain the instruments in good working order after commissioning. For all instruments which project through and above the ground, special precautions shall be taken to provide protection from vehicles and plant including substantial and readily visible barriers at a distance of 750mm around each instrument. Heavy compaction equipment shall not approach within 1.5m of projecting instruments. Damaged instruments shall be replaced or repaired by the Contractor at his own expense within seven days unless otherwise agreed by the Engineer.

3.0 STABILISING ELECTRONIC READOUT DEVICES

All electronic readout devices and transducers shall be shaded from direct sunlight during use. Probes which are used inside access tubes shall be placed inside the tube and allowed to come to a stable temperature for at least 10 minutes before use. Zero or starting values shall only be taken once temperature stabilisation is complete.

4.0 LABELLING AND MARKING OF INSTRUMENTS

All instruments shall be labelled with their reference number at the location where readings or measurements are taken. The labelling shall be permanent using a method or material to be agreed with the Engineer.

For instruments which are located beneath a drainage blanket where vertical drains are later to be installed, their locations and the locations of any connecting tubes or cables shall be marked using 1.6m lengths of 20mm diameter steel bar. The bars shall be driven vertically 0.9m into the ground as c lose as practicable to the instrument before the drainage blanket is placed. The tops of the steel bars shall be painted in bright colours, with a colour coding if necessary. During placing of the drainage blanket around the bars the Contractor shall ensure that the bars remain vertical, and clearly visible on completion of the drainage blanket.

5.0 SURVEY EQUIPMENT AND TEMPORARY BENCHMARK

All surveying equipment used in conjunction with the monitoring of instrumentation, including measuring tapes, precise levels and theodolites shall be maintained and calibrated as required by the manufacturers. Certificates of calibration for all equipment shall be submitted to the Engineer and approved by the Engineer prior to carry out the field work. Levels shall be checked for horizontality of the line of sight every four weeks.

The temporary benchmarks shall be installed at the nearby structure or remote from the reclamation area and marked on an end bearing pile or similar structure. The levels for all TBMS shall be checked/survey every three months or sooner as instructed by the engineer.

6.0 BOREHOLES FOR INSTRUMENTS

Boreholes for instruments may be drilled by approved method provided that it results in a clean and stable hole of the required diameter to the correct depth. Boreholes shall be cased to their full depth unless strata are sufficiently competent for the hole to stay open under dry conditions. Boreholes shall be drilled using clean water. Drilling mud or polymer additives shall only be used with the approval of the Engineer. In the case of installation of piezometers, drilling mud or polymer additives shall not be permitted.

During drilling care shall be taken to ensure that minimum material is lost from outside the casing. Surging of casing shall not be allowed, and flushing of drilling water up the outside of the casing shall be minimised.

The method of forming boreholes, including the procedure for advancing casing, shall be submitted to the Engineer for approval before commencement of the works.

6.1 Grouting of Boreholes

For all instruments placed in boreholes, grouting is required of part or all of the borehole during installation. The grout shall be a bentonite : cement mixture with sufficient water to achieve a pumpable mix. The proportions of the mix shall be such as to imitate as closely as possible the strength or consistency of the natural soils present. The Contractor shall conduct trials on different mixes of bentonite : cement (from 4:1 to 8:1) to ascertain the relationship with strength. Specimens shall be cured and stored, then tested in undrained triaxial compression after 1 day, 2 days, 7 days, 14 days, 1 month and 3 months. 3 specimens shall be tested on each occasion, and the sources of bentonite and cement shall be the same as used for eventual installation. On the basis of these trials, the Engineer shall decide on the bentonite : cement proportions to be used, which may be varied depending on the application. Grout shall be poured or pumped into boreholes using a tremie pipe.

For inclinometer installed in the wall, the annulus between inclinometer access tube and wall shall be filled up with neat grout of grade 35.

7.0 INSTALLATION AND MONITORING

7.1 Settlement Markers

Details of settlement markers shall be as shown in the drawings. The contractor shall install settlement markers in locations indicated in the drawing or as directed by the Engineer. For each layer of fill, the Contractor must survey, relocate, transfer and reinstall the settlement markers to the next level. The Contractor must take readings on the settlement markers prior to relocation to the next level. Base readings are to be taken on all relocated settlement markers immediately after relocation. The period and frequency of monitoring shall follow the requirements as stipulated by the Engineer.

Levels of the top of the rods of settlement markers shall be measured using standard levelling

techniques. The datum used shall preferably require only one set up of the level, and levelling shall be closed back to the datum.

7.2 Rod Settlement Gauges

Rod settlement gauges shall be as shown in the Drawings and the Contractor shall be responsible for installation of all gauges at locations specified by the Engineer as work proceeds. The base plate and first length of rod shall be placed before any significant filing (including any drainage blanket) has been placed. Extension lengths shall be installed when the level of compacted embankment is 250mm below the top of the preceding lengths.

Should a rod settlement gauge be damaged or should the Contractor fail to extend the gauge when required, he shall stop all filing in the vicinity of the gauge until the necessary remedial works have been carried out. The Contractor shall be liable for any delay in his programme, or any additional work that has to be done as a result of such damage.

Should any rod settlement gauge be damaged in such a way as to make it useless for its purpose, the Engineer shall assess the settlement for measurement purposes and this assessment shall be accepted by the Contractor as final.

Rod settlement gauges shall be monitored by precise levelling techniques. Levels shall be taken of the top of the rod itself and the fill adjacent to the gauge on each occasion. The datum used shall preferably require only one set up of the level, and levelling shall be closed back to the datum. When rods are extended, levels shall be measured immediately before and immediately after adding the extension.

7.3 Inclinometers

The Contractor shall install inclinometer at locations, and with depths and details as specified by the Engineer.

Inclinometer access tube shall consist of broached PVC tubing with four keyways set at right angles to each other and shall be supplied in 3.0m lengths with 0.3m long couplings and end caps. The spiral twisting of the keyways shall not exceed 0.75 degrees per metre length of the tubing. Where necessary, the Engineer may instruct the Contractor to obtain spiral metric measurements of the keyways in the inclinometer tubing after installation. After assembly joints and rivets shall be coated in sealing mastic and wrapped in sealing tape. The tube shall be coated with thick grease over its upper part when it passes through compressible subsoils. The assembled tube shall be lowered into a 125mm diameter borehole backfilled with a suitable bentonite : cement grout mix. Alternatively the tube may be placed in an open borehole and grout placed afterwards. In granular material, the backfill may be sand or pea gravel. The keyways shall be orientated such that movements are measured parallel to and right angles to the embankment/slope axis.

Where the access tube passes through upper stiff crusts or fill material, it shall be sleeved by a larger diameter tube so that it can pass freely through these materials as settlement takes place. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended in lengths which are multiples of 0.5m as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover.

Angular movements shall be measured by an inclinometer torpedo which shall be a biaxial type with a gauge length of 500mm, and the system shall be capable of measuring lateral deformation to an accuracy of ±10mm over a depth of 30m. The casing of the inclinometer probe shall be constructed of stainless steel and the probe shall be fully waterproof and corrosion proof. The inclinometer probe shall be supplied with a rigid carrying case fully lined with shockproof padding. The cable supplied for use with the inclinometer shall be a polyurethane sheathed cable with a minimum length of 40m, incorporating a central kelvar straining wire. The cable shall be

graduated in intervals of 500mm and shall be supplied complete with a portable cable reel.

The inclinometer data logger unit shall display the readings from the inclinometer torpedo on an alphanumeric display. The readout unit shall be powered by a re-chargeable battery with a minimum life of 12 hours continuous use between charges. A suitable automatic battery charger shall be supplied with the readout unit. The readout unit shall incorporate an RS232C port and a solid state data storage unit with the capacity to store at least 30000 readings directly from the inclinometer probe together with time and date of reading. The following facilities are also required within the readout unit :

a. Scan stored data.
b. Display of face errors as readings are being obtained.
c. Display of mean deviation and cumulative deviation of any one set of readings.
d. Graphical display of displacement profile between any two sets of readings.
e. Backlit LCD display.

A calibration frame shall be supplied to enable the inclinometer calibration to be checked at vertical and 10 degrees either side of vertical.

Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling techniques. Before passing the torpedo down the access tube, a dummy torpedo should be lowered to the base of the tube and pulled up to check for obstructions or constrictions. The inclinometer torpedo shall then be lowered to the base of the access tube and raised taking readings every 0.5m until the torpedo reaches the top. The readings shall be read by and stored in the data logger. The procedure shall be repeated on the opposite face following the manufacturer's method and sign convention.

7.4 Magnetic Extensometer

Magnetic extensometers provide a method of measuring settlement or heave at a point or a series of points below the ground surface. The Contractor shall install magnetic extensometers at locations and with depths and details as specified by the Engineer.

The magnetic extensometer shall consist of an access tube and a series of magnetic targets which are free to slide down the tube, together with a datum magnet which is fixed to the tube near its base. The access tube shall be a rigid PVC tube 33.5mm o.d. and 24.5mm i.d. with threaded ends which provide both an internal and external flush coupling. A rigid PVC endcap shall be fixed to the lower end of the series of tubes. Compression/extension tubes shall be provided where required by the Engineer. All joints shall be sealed with a suitable PVC solvent cement.

The compression/extension tubes shall allow axial movement of access tubes to minimize distortion due to vertical strain. The tubes shall have treaded ends to provide an internally and externally flush coupled joint. The smaller diameter end tubes are fitted with ‘O’ rings or equivalent, and are free to slide within the larger diameter central cylinder. The minimum allowable compression and extension length shall not be smaller than 0.6m and 1.0m respectively.

A datum ring magnet shall be fixed approximately 2m above the lower end of the tube. Spider magnets shall be used within the subsoil, and plate magnets within fill where magnets can be placed during construction.

The tubes and magnets shall be assembled prior to installation in such a way that the magnets remain in the correct position in relation to the tube. The tube shall be coated with a thick grease over its upper part where it passes through compressible subsoils. It shall then be lowered together with all magnets and necessary accessories fixed in position into a 100mm diameter borehole backfilled with a suitable bentonite : cement grout mix of equivalent strength of the surrounding soil. Once in position the spider magnets shall be released.

Where the access tube passes through upper stiff crusts or fill material, it shall be sleeved by a larger diameter tube so that it can pass freely through these materials as settlement takes place. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover with facility for locking.

The readout device shall consist of a nickel plated brass probe containing a reed switch encapsulated in silicone rubber. The probe shall be connected via a nylon coated steel tape to a reel buzzer.

Magnetic extensometers shall be monitored by passing the probe down to the base of the access tube. The probe shall then be pulled upwards measuring the position of each magnet from the top of the tube. The position of each magnet shall be measured twice, once while moving upwards and once while moving downwards towards the magnet. Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling technique.

7.5 Combined Inclinometers and Magnetic Extensometers

Combined inclinometers and magnetic extensometers provide a method of measuring both vertical settlement and horizontal displacement at a series of points below the ground surface.

The Contractor shall install combined inclinometers and magnetic extensometers at locations, and with depths and details as specified by the Engineer.

This specification should be read in conjunction with the specifications for inclinometers and magnetic extensometers; and only specifies requirements where they differ from the individual systems.

The access tube shall be telescopic inclinometer access tube, and magnetic targets shall be suitable for use with this tube .

The magnets shall be positioned in relation to sleeved joints such that they can move downwards without obstruction sufficiently to monitor the expected settlement. The borehole shall be 150mm diameter or size agreed by the Engineer.

7.6 Standpipe Piezometers

The Contractor shall install standpipe piezometers at locations, and with depths and details as specified by the Engineer. Standpipe piezometers shall be installed as shown on drawings.

The piezometer tip shall consist of a porous ceramic or plastic element not less than 150mm long with a diameter not less than 30mm, and shall be protected at each end by unplasticised polyvinylchoride (uPVC) fittings. The filter element shall have a pore diameter in the order of 60 microns and a permeability in the order of 0.0003m/s. The tubes shall be jointed together and to the porous element with threaded couplings, PTFE tape and glue in such a manner that the joints remain leakproof under the anticipated head of water.

The standpipe piezometer shall be installed in a 100mm diameter borehole. The sand filter surrounding the porous element shall be clean and fall wholly between the limits of grading 600 and 1200 microns. The Contractor's arrangements shall ensure that no sand adheres to the soil in the sides of the unlined borehole. There is water in the borehole the Contractor shall allow sufficient time for all the sand to settle. The final elevation of the top of this sand shall be recorded. The porous element shall be placed in the hole and the remaining sand filter shall be added as described above. A flat-ended sounding rod shall measure the final elevation of the top of the sand filter.

Seals consisting of bentonite pellets shall be placed above, and if necessary, below a sand

filter. The remainder of the hole shall be filled with a bentonite: cement grout, and the top part with concrete with caps and air vents as indicated on the drawing. Before taking initial readings the Contractor shall carry out a simple falling head test by raising the water level 1.5m above the static level, using an extension pipe if necessary, and measuring the water level over a 30 minute period. The depth to water in standpipe piezometers shall be measured using a dipmeter. The dipmeter shall be of the electric type, but simple metal probes attached to nylon cord may be used with the approval of the Engineer for shallow depths.

7.7 Pneumatic Piezometers

Pneumatic piezometers are used to measure water pressures at specific depths within variety of soil types. The Contractor shall install pneumatic piezometers at locations, and with depths and details as specified by the Engineer. 'Push-in installation method shall be used.

Pneumatic piezometer tips shall be of high air entry ceramic type with an average pore diameter of 1 micron using marine brass or stainless steel bodies. The piezometer system shall be capable of measuring water pressures to an accuracy of ±0.2m head of water in the range 0 - 100m head of water.

The piezometers shall be connected to tubing comprising suitably coded twin 1.9mm i.d. and 3.2mm o.d. nylon tubes and covered with a polythene sheath 1mm thick. Joints in the tubes other than at the piezometer tip or at the terminal panel shall not be permitted. The tubes from individual piezometers shall be colour-coded and marked every 3m. The tubing shall be connected either to suitable quick release couplings or a terminal panel which shall be housed in a lockable steel cabinet.

The arrangement of the equipment and the three methods of installation are shown in the Drawings.

Installation shall be by pushing into the base of the borehole method. A 100mm diameter borehole shall be terminated 0.3m above the required position of the piezometer tip. The piezometer tip with cable attached shall be pushed into the base of the borehole to the required depth using an arrangement of sufficiently stiff tubes. The borehole shall then be sealed with bentonite pellets and bentonite: cement grout as shown on the Drawings.

The piezometer leads shall either be connected to quick release couplings set inside a suitable cover, or be taken to a terminal panel fixed inside a lockable steel cabinet. The cabinet shall be set on a concrete plinth typically 0.6x1.0x0.3m thick (plan dimensions may be adjusted to suit the cabinet size). Where cables are laid in trenches the backfill shall be sand. The cable shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.

The pneumatic readout unit shall be capable of storing 500 readings and shall incorporate an electronic pressure transducer, backlit digital display, RS232C interface and cable link, rechargeable battery providing at least 12 hours continuous are between charges, a rechargeable gas reservoir bottle, a reservoir pressure gauges, return + flow indicator, flow control valve and quick release self sealing leads for connection to the supply and return manifolds of the terminal panel. The readout unit shall be housed in a rigid weatherproof case with carrying handles and shall be capable of resolving readings to 1 kPa. An automatic charger for the readout unit battery shall be supplied suitable for 240V, 50Hz electricity supply. The Contractor shall make facilities available for recharging the gas reservoir with nitrogen.

Before installation and taking initial readings the Contractor shall pressure test the pneumatic piezometer tip in a container of water after connection to the tubing with a pressure of 500 kPa to check for leaks or poor connections. The ceramic element shall be deaired under vacuum and precautions shall be taken to ensure that it remains saturated during installation. During installation readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base

readings are taken.

Readings shall be taken by and stored on the readout device. Care shall be taken to ensure that the flow and return leads are connected correctly.

7.8 Building Settlement Marker

Vertical deformation of adjacent structures shall be determined by means of precision devices to an accuracy of +/- 0.5mm. The Contractor shall install building settlement points at locations as specified by the Engineer.

The precise levels shall have robust tripods. Levelling studs are to be provided for the purpose of precise levelling. Levelling studs shall be:

a) Manufactured from stainless steel, grade 316 S13 to BS970: Part 1 or equivalent.
b) Fixed to the building linings in the same manner and standard.
c) Designed such that their use in conjunction with the appropriate precise instruments allow precision levelling to an accuracy of +/-0.5mm.
d) Designed such that the heads of the levelling studs on the walls can be easily levelled without the studs being vulnerable to damage.
e) When locating levelling rods and staffs onto levelling rods and staffs onto levelling studs, care shall be taken to ensure that the surface in contact is clean. Proper access shall be provided to the crown levelling studs for cleaning during surveying operations.

7.9 Tilt-meters

Tilt-meter shall be used to monitor changes in the inclination or rotation of structures and to provide an accurate history of movement and early warning of potential structural damage.

Tilt plates shall be mounted on the structure at locations specified by the Engineer. They must be either securely bonded using an approved rapid setting epoxy adhesive compound or screwed to the surface of the structure. Extra care shall be taken to ensure proper alignment of the tilt plate to the required orientation.

The tilt-meter system shall include the required number of tilt plates, the portable tilt-meter and a readout unit. Tilt plates must be dimensionally stable and weather resistant. The portable tilt-meter shall be in metric unit system and housed in a rugged frame with precise machined surfaces to facilitate accurate positioning on the tilt plate which may be mounted horizontally or vertically as specified by the Engineer. The readout unit to be used must be suitable for the abovementioned tilt-meter unit and applications and shall be of a rugged, weather-proof design with easy to read display and rechargeable battery or equivalent. Sufficient length of jumper cable shall be provided for connecting the tilt-meter to the readout unit. The tilt-meter shall conform to:

Range	+/- 30° from vertical
Resolution	8 arc seconds
Temperature Coefficient	+/- (0.05% of reading + 5 arc seconds)/ °C

Tilt reading shall be taken by positioning the tilt-meter on the tilt plate and connecting the tilt-meter to the readout unit. At least two readings shall be taken by rotating the tilt-meter at 180^0 for each reading.

8.0 INSTRUMENTATION RECORDS AND REPORTING

8.1 Commissioning and Base Readings

After installation the functioning of each instrument shall be demonstrated to the Engineer, including the recording of measured values using the appropriate readout device. As part of the commissioning three sets of readings shall be taken and compared. When instruments are installed before earthwork starts, then these three sets of readings shall also be taken before earthwork starts. If there are significant differences or anomalies, then further readings shall be taken. Once three sets of comparable readings have been taken, these shall be averaged to form the base readings, representing conditions before earthwork starts.

In cases where instruments are installed during earthworks, three sets of readings shall be taken in quick succession and the results compared. These results shall be used to provide base readings in a manner to be agreed with the Engineer.

8.2 General Information on All Records

All records of instrumentation, either installation, readings or monthly summaries, shall contain the following information :-

- Project name
- Contract name and number
- Instrument reference number and type
- Dates of installation, reading or summary
- Times of installation or reading
- Chainage and Offset (or coordinates if appropriate)
- Personnel responsible
- Relevant comments or remarks
- Reduced level

8.3 Installation Records

The Contractor shall prepare an installation record sheet for each instrument installed. The format of the sheet shall be prepared by the Contractor and submitted to the Engineer for approval at least one week before installation commences. The record sheet shall include the following information in additional to the general information required:

- Existing ground level at the time of installation
- Planned location in plan and elevation
- Planned orientation
- Planned lengths, widths, diameters, depths and volumes of backfill
- Plant and equipment used, including diameter and depth of any drill casing used
- Spaces for necessary measurements or readings required during installation to ensure that all previous steps have been followed correctly, including acceptance tests
- A simplified log of ground conditions (obtained during rotary wash boring)
- Type of backfill used
- As-built location in plan and elevation
- As-built orientation
- As-built lengths, widths, diameters, depths and volumes of backfill
- Weather conditions
- A space for notes, including problems encountered, delays, unusual features of the installation, and any events that may have a bearing on instrument behaviour
- A record of commissioning information and readings
- Any colour coding used

The Contractor shall submit to the Engineer the specified number of copies of each installation report within one working day of completion on the installation, including taking of base readings.

8.4 Installation Report

The Contractor shall submit an installation report once installation of all instruments is completed. Submission shall be within two weeks of completion including taking of all base readings. The report shall include :

- A text describing the scope of work, the site, the work carried out and the types of instrument installed
- All installation record sheets
- Plans and cross section drawings at a scale of 1:200 or other agreed scale showing the locations, elevations and details of all instruments
- Photographs of all the instruments used, illustrating installation and method of reading
- Values of all base readings taken together with any subsequent readings up to the time of submission

8.5 Readings

On each occasion that readings are taken from an instrument or set of instruments, the measured values shall be recorded on a record sheet. The format of the record sheet for each type of instrument shall be prepared by the Contractor and submitted to the Engineer for approval at least one week before readings commence. For readings that are recorded on data loggers, a record sheet shall be required giving references to the data stored. A computer system including interfaces, plotter, printer and software shall be available to make the data transfers, listings and plots required.

The format of plotted results shall be submitted to the Engineer for approval. Details of information and values to be stored on each record sheet in addition to the general information required are given below :

Instrument		Data required
Settlement marker	-	reduced level of top of rod (mRL)
	-	change in reduced level of top of rod relative to base readings and previous reading (mm)
Displacement	-	distance from fixed point (m) marker (details to be given)
Survey station	-	offset, coordinates and reduced level of top of rod (m)
Deep datum	-	reduced level of datum (mRL)
	-	reduced level of toe (fixed point) (mRL)
Rod settlement	-	reduced level of top of rod gauge (mRL)
	-	original ground level at gauge location (mRL)
	-	reduced level of ground adjacent to gauge (mRL)
	-	record of fill placed (m)
	-	total thickness of fill (m)
	-	record of extensions (m)
	-	settlement of plate relative to base readings and previous reading (mm)
Inclinometers	-	reduced level of top of access tube (mRL)
	-	reduced level of ground adjacent to access tube (mRL)
	-	horizontal movements of top of access tube by survey
	-	file name of data stored in data logger
	-	file name of data after transfer to floppy disk

	-	listing of deflection values and face errors every 0.5m
	-	graph and listing of horizontal movement of access tube relative to base readings against depth
	-	status of fill height
Standpipe piezometer	-	time and date
	-	reduced level of top of tube (mRL)
	-	reduced level of ground (mRL)
	-	depth of water from top of piezometer tube (m)
	-	water pressure readings (m water)
	-	change of water head relative to base readings (m)
	-	water pressure readings (m water)
	-	daily weather chart
Magnetic Extensometer	-	reduced level of top of access tube extensometers (mRL)
	-	reduced level of ground adjacent to access tube (mRL)
	-	distance of each magnet from top of tube (m)
	-	reduced level of each magnet (mRL)
	-	settlement of each magnet relative to base readings (mm)
Combined magnetic extensometer and inclinometer	-	as for magnetic extensometer and inclinometers
Pneumatic piezometers	-	water pressure readings (m water)
	-	file name of data stored in data logger
	-	file name of data after transfer to floppy disk
	-	reduced level of piezometer tip as installed (mRL)
	-	estimated or measured settlement of piezometer tip (m)
	-	water head (mRL)
	-	change in water head relative to base readings (m)
Building Settlement marker	-	reduced level of centroid of point or stud (mRL)
	-	change in reduced level of centroid of point or stud relative to base readings and previous reading (mm)
Tilt-meter	-	time and date
	-	differential in pegs
	-	change in tilt with respect to initial reading

The Contractor shall submit to the Engineer the specified number of copies of each record sheet with necessary listings and graphs within one working day of taking the readings unless otherwise directed by the Engineer.

8.6 Frequency of Measurement

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

a) During filling
- Every morning before subsequent filling commences.

b) After a formation is reached
   i) For first three months
      - Every alternative day
   ii) For fourth and subsequent months
      - Between twice a week to once a fortnight depending on the

rate of settlement as shown in the Appendix B or as instructed by the Engineer, the time interval should allow reasonable settlement to be plotted.

8.7 Anomalous Readings

Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which differ from the expected value or trend, then further readings shall be taken immediately and the Engineer shall be informed. If the anomalous values persist, then the Engineer shall be informed and an investigation shall be carried out to find the reasons for the anomalous readings.

8.8 Monitoring Report

The Contractor shall submit a report at the end of each calendar month of monitoring but fortnightly for treated areas with vertical drains. A proposal for the format of the report shall be submitted to the Engineer including all graphical presentations for approval at least one month before submission of the first monthly report. Each monthly report shall include:

- a description of monitoring works which have been in operation during the preceding month
- information on reading anomalies or corrections, and factors which may influence measured data
- observations or remarks
- diagrams showing installed locations of instruments (taken from installation report)
- data tabulations or plots of instrument readings as given below. The Contractor shall have available suitable software for generating the required plots and tabulations. Zero time to be used in all plots and tabulations shall be agreed with the Engineer. The time axis shall be days from "day zero", and an indication of date or months shall be included on the axis. The plots and tabulations presented each month shall be an update of the previous plots and tabulations, giving a complete record starting from the time of installation.

Instrument		Plots and Summaries required
Settlement marker	-	settlement v. time (tabulation and plot)
Rod settlement gauge	-	thickness of fill and settlement of plate v. time (tabulation and plot)
Displacement marker	-	displacement vs time indicating direction of movement (tabulation and plot)
	-	displacement profile with distance from wall (tabulation and plot)
Survey station	-	coordinates and reduced level (tabulation)
Deep datum	-	reduced level (tabulation)
Inclinometer	-	file name of data on floppy disk
	-	latest graph of horizontal movement of access tube relative to base readings against depth

	-	maximum horizontal movement relative to base readings v. time (tabulation and plot)
Magnetic extensometer	-	settlement of each magnet vs time (tabulation and plot)
	-	settlement of each magnet vs depth for 4 latest sets of readings (tabulation and plot)
Combined magnetic extensometer and inclinometer	-	as for magnetic extensometers and inclinometers
Standpipe piezometer	-	water head (mRL) vs time (tabulation and plot)
	-	water level profile with distance from wall (tabulation and plot)
	-	changes of water head (tabulation and plot)
	-	water head with depth for latest 4 sets of readings (tabulation and plot)
	-	Important activity like excavation or ground water pumping should be highlighted in the graph.
Pneumatic piezometer	-	excess water head v. time (tabulation and plot - all instruments in a profile plotted on the same graph)
	-	excess water head v. depth for latest set of readings (plot)
	-	excess water head v. height of fill (plot)
Building Settlement marker	-	building settlement vs. time (tabulation and plot)
	-	building settlement vs. monitoring stations (plot)
Tilt-meter	-	change in tilt (seconds) vs. time (tabulation and plot)

All plots where time is the horizontal axis shall have the same scale for the time axis. Where fill thickness, settlement and excess water head are all available at the same location, the plots shall be combined on the same sheet where possible. Final layouts, scales and details shall be agreed with the Engineer at the time of submitting the format.
The Contractor shall submit the required number of copies of the monthly monitoring report to the Engineer within 7 working days of the end of the month being reported. If there are anomalies or sudden significant changes in the results, the Engineer should be informed within 1 day after monitoring.

8.9 Presentation of Reading in Graphic Format

The Contractor will have to submit to the Engineer for comment on the graphic presentation of the monitored readings. The presentation will have to be agreed by the Engineer prior to the field work. Hand plotted graphs are not acceptable. During the contract period, the Engineer can directed the Contractor to carry out additional plotting in format suggested by the Engineer with no additional cost or time allowed.

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