JULY 2019
ROYAL LONDON ASSET MANAGEMENT - RLAM

CASTLEWOOD HOUSE & MEDIUS HOUSE

INSTRUMENTATION & MONITORING SPECIFICATION

Davies Maguire

COWI

ADDRESS COWI UK Limited
Bevis Marks House
24 Bevis Marks
London
EC3A 7JB

TEL +44 207 9407 600
WWW cowiuk.com

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1 General

Royal London Asset Management (RLAM) are redeveloping two commercial buildings on New Oxford Street:

- Castlewood House, 77-91 New Oxford Street
- Medius House, 63-69 New Oxford Street

Other parties involved in the project include:

- CBRE – Project Manager
- Davies Maguire (DMAG)– Structural Engineer
- APT - Architect
- Gardiner and Theobold - Quantity Surveyor
- GDM Parternship - Building Services Engineer
- Gerald Eve - Planning Consultant

All Contractors TBC

COWI UK and Davies Maguire were appointed to provide structural and geotechnical services for the redevelopment of the site. The purpose of the Instrumentation and Monitoring Specification is to specify the *'Monitoring Contractor's*' responsibilities for recording and reporting of movement of the LUL tunnels underlying the site caused by the works.

Section 2 describes the general responsibilities of the *'Monitoring Contractor'* and the *'Principal Contractor'*. Specific requirements of the monitoring contract are given in Section 3.

1.1 Terminology and Definitions

Parties named within this specification document are shown in Table 1.

Table 1: Key parties within the monitoring specification

Key Party	Company/Appointee
'Employer'	Royal London Asset Management (Project Manager CBRE)
'Monitoring contractor'	To be appointed by the Employer
'Principal Contractor'	To be appointed by the Employer
'Geotechnical Engineer'	COWI UK and Davies Maguire
'Asset Owner'	London Underground Limited (LUL)

The following terminology is used throughout this document:

Baseline Monitoring: Several rounds of surveying of all control points to establish an absolute position of all points.

Calibration: Calibration is required where an instrument records data in the form of, say, voltages and requires calibration for conversion to movement in millimetres, and is normally performed in a laboratory.

Instrumentation: Includes all equipment from the reading instrument throughout the entire monitoring system up to and including:

- In the case of remote data capture, all telecommunication elements.
- In the case of manual data capture the reading/storage unit.

Instruments: For the purpose of this document, prisms and measuring studs are considered part of the instrumentation.

Manual Data Capture: (MDC) Data that is collected and transmitted back to the office by manual methods.

Monitoring Cross Section: A group of points at a specific section of platform tunnel, running tunnel, elevator or cross passage.

Processed Reading: Raw reading converted to meaningful value (settlement, heave, deflection etc.) by appropriate formulae/conversion factors.

Raw Data: Actual instrument reading.

Remote Data Capture: (RDC) Data that is collected and transmitted back to the office without manual intervention.

1.2 Statutory Authorities

The *'Asset Owner'* reserves the right to request information with regards to surveyed tunnel movement at any time during the Monitoring Contract. It is expected that the *'Asset Owner'* may be involved with regular meetings as part of the Monitoring Contract.

1.3 Procurement Process

Prior to submission of the tender, the *'Monitoring Contractor'* shall visit the site to examine the above and below ground conditions present including the relationship of existing buildings on and adjacent to the site, the site boundaries, means of access and accommodation required. On submission of their tender, the *'Monitoring Contractor'* shall be deemed to have visited the site and considered the above conditions in relation to risks, contingencies and all other circumstances influencing or affecting their tender.

1.4 Project Location

The site is located in Central London, immediately south of New Oxford Street and currently holds the existing Castlewood House and Medius House. It is bordered by Earnshaw St., Bucknall St. and Dyott St., with adjacent structures all used for commercial and residential use.

London Underground Limited (LUL) Central line tunnels run underneath New Oxford Street parallel to the site boundary.

1.5 Monitoring Plan & Geotechnical Analysis

The '*Geotechnical Engineer*' has undertaken a Ground Movement Impact Assessment Report (A108303-RPT-002) highlighting the potential ground movement and impact on LUL assets induced by the construction.

An I&M Plan has been developed (A108303-RPT-004) specifying the location and frequency of survey readings to be carried out within LUL assets. The Monitoring Contract includes the collection of baseline data, data collection during all major demolition, superstructure and substructure construction.

The Monitoring Contractor is required to design, supply, deliver and install all elements of the monitoring scheme.

The I&M Plan includes anticipated tunnel movements defined by the *'Geotechnical Engineer'* (trigger values) for:

- Global tunnel lining movement.
- Longitudinal differential tunnel movement (vertical and horizontal change in gradient).
- Track movement and subsequent gauge clearance TBC.

The movement limits specified by the *'Geotechnical Engineer'* and the *'Asset Owner'* have the objective of ensuring the safe operation of LUL assets and safety of all LUL staff, passengers and other users.

1.6 Monitoring Phases

The on-site monitoring scheme is deemed to include the following phases:

- Baseline monitoring – Establishing baseline absolute coordinates for all points to be monitored as part of the scheme.
- Monitoring scheme – Considered to include all demolition, sub-structure and superstructure construction.

1.7 Tender Drawings

This Specification shall be read in conjunction with the following Tender Drawings:

- Monitoring Layout as reproduced in I&M Plan

2 General Requirements

2.1 Instrumentation & Monitoring Plan

2.1.1 An I&M Plan (A108303-RPT-004) has previously been produced by the *'Geotechnical Engineer'* and shall form the basis for this specification.

2.2 Requirements of the Principal Contractor

2.2.1 The *'Principal Contractor'* shall provide information relating to construction progress at monitoring review meetings.

2.3 Requirements of the Monitoring Contractor

2.3.1 The *'Monitoring Contractor'* shall provide survey verification and quality control throughout the monitoring contract. This includes establishing a baseline survey and control traverse, reading, processing, presenting and interpreting and taking action in response to readings.

2.3.2 A requirement of the I&M Plan is that all relevant information is obtained, processed, collated, interpreted and reviewed in a timely manner.

2.3.4 A baseline datum shall be established by the *'Monitoring Contractor'* for all monitoring points.

2.3.5 The specification of monitoring performance requires that the monitoring system is accurate, robust, easy to read and follow trends, validated by the *'Geotechnical Engineer'* before reaching a trigger level and translated into documents that are clear and legible.

2.3.6 The *'Monitoring Contractor'* will check all data for anomalous results. Survey data often only give relative movements directly and must be tied into other survey systems to give absolute movements. The *'Monitoring Contractor'* shall make checks on the internal consistency of data. Any anomalous readings shall not be ignored and shall be recorded as erroneous based on investigation, interpretation and agreement with the *'Geotechnical Engineer'*.

2.3.7 The *'Monitoring Contractor's'* monitoring engineer shall be responsible for preparing information obtained from survey instrumentation and providing it to the *'Geotechnical Engineer'*

2.3.8 The *'Monitoring Contractor'* may provide options of both an MDC and RDC system within their tender return.

2.3.9 The *'Monitoring Contractor'* shall explicitly demonstrate how the requirements of this specification shall be met within their tender return.

2.3.10 The *'Monitoring Contractor'* shall produce Method Statements in accordance with Clause 3.11 and all necessary assurance documents for third parties in particular London Underground Limited (in accordance with LUL standards).

2.3.11 The *'Monitoring Contractor'* will be responsible for the collection, processing, storage, interpretation and reporting of the data. The *'Monitoring Contractor'* will be responsible for maintaining a database containing all monitoring and construction progress information. The *'Monitoring Contractor'* will export data from this database in Microsoft Excel format and provide this to the *'Geotechnical Engineer'*.

2.3.12 All work is to comply with all relevant:

- Current British Standards and codes of practice.
- LUL standards and codes of practice.
- LUL safety regulations within and around LUL structures and Infrastructure.

2.4 Monitoring Review Meetings

2.4.1 As set out within the I&M Plan, where a trigger level is breached the Principal Contractor shall convene a meeting between the Key Parties. The meeting shall include a representative of the *'Geotechnical Engineer'*, *'Asset Owner'*, *'Monitoring Contractor'*, *'Principal Contractor'*, *'Employer'* as a minimum. The meeting must discuss modification to monitoring procedures and site works as a minimum.

2.4.2 Throughout the monitoring scheme where monitored movement is below trigger levels it is deemed unnecessary to hold regular review group meetings. The *'Geotechnical Engineer'*, *'Asset Owner'*, *'Monitoring Contractor'* and *'Principal Contractor'*, *'Employer'* all reserve the right to convene a meeting should a project matter arise.

2.5 Trigger Levels & Emergency Preparedness Plans

2.5.1 Trigger Levels

The Monitoring Contractor shall use the trigger levels set out in the I&M Plan (A108303-RPT-004).

2.5.2 Emergency Preparedness Plans

In the event of a breach of trigger level, the *'Monitoring Contractor'* shall follow the emergency procedure and response times as set out in the Emergency Preparedness Plan contained within the I&M Plan (A108303-RPT-004).

3 Specification Requirements

3.1 Survey Control

3.1.1 The *'Geotechnical Engineer'* has indicated preferred survey control locations (see I&M drawing). These locations are not expected to be within the zone of influence of the works.

3.1.2 The *'Monitoring Contractor'* shall propose any secondary control points they wish to install for acceptance by the *'Geotechnical Engineer'.*

3.1.3 The *'Monitoring Contractor'* shall be responsible for making all necessary arrangements with the *'Asset Owner'* for access for the purpose of installing and monitoring instrumentation. All subsequent surveys are to be arranged between the *'Monitoring Contractor'* and *'Asset Owner'*.

3.2 Monitoring Equipment

3.2.1 The *'Monitoring Contractor'* may provide the option of both an RDC and MDC with their tender return. The *'Employer'* shall determine which is to be used and the *'Monitoring Contractor'* shall install one system to be used for the duration of the works.

3.2.1 The Contractor shall use surveying equipment such as levels, precise levels, optical plumbs, tilt sensors, theodolites and total stations with a level of quality, accuracy and precision to provide monitoring readings such that lining movement can be identified to ±2mm.

3.3 Programme

3.3.1 The *'Monitoring Contractor'* shall make suitable allowance in his overall programme of work for supply, the installation, testing, calibration, reading, and maintenance of the instrumentation, interpretation and reporting of the field readings and implementation of appropriate corrective measures.

3.3.2 The *'Monitoring Contractor'* shall make suitable allowance in his overall programme of work for LUL approval for access and installation of equipment.

3.3.2 The monitoring programme shall extend as described in Section 3.9.

3.4 Instrumentation Personnel

3.4.1 All instrumentation personnel shall be briefed on the sensitivity of the information being collected prior to engagement in the monitoring works.

3.4.2 The *'Monitoring Contractor's'* personnel shall be trained and qualified to a level commensurate with the duties on which they are engaged.

3.4.3 The *'Monitoring Contractor'* shall provide his instrumentation personnel with all necessary equipment in accordance with the specification and access to the Works to carry out their work in a safe and secure manner at times to be agreed with the *'Asset Owner'*. Readings shall be taken by the same personnel to maintain consistency. If personnel need to be replaced, for any reason new staff must receive full project and task briefing prior to engagement in the monitoring works.

3.4.4 All *'Monitoring Contractor'* personnel to attend site must be trained to all relevant LUL standards and safety critical courses.

3.5 Provision of Measuring Devices

3.5.1 For instrumentation installation all equipment and installation accessories required for the operation of the instrumentation system and recording of measurements shall be supplied by the *'Monitoring Contractor'* and shall be available immediately as required during installation and prior to baseline survey.

3.5.2 All equipment and installation accessories shall be securely stored where they will not suffer physical damage or damage arising from excessive moisture, extremes of temperature or other adverse conditions.

3.5.3 Serial numbers of instrumentation shall be recorded and noted on the measurement records.

3.5.4 All measuring devices shall be manufactured by companies with proven experience in the field of tunnel and/or geotechnical instrumentation. All materials, designs and construction shall be of the highest quality to provide robust, corrosion and vibration resistant instruments. All instrumentation shall have a satisfactory, proven working life. The accuracy and dependability of the equipment shall not be significantly affected by changes in temperature, humidity, stray currents or other adverse conditions that may be encountered. Calibration certificates, where appropriate, shall be provided by a reputable testing company accredited by UKAS (United Kingdom Accreditation Service). A list of laboratories accredited by UKAS may be obtained from:

UKAS, 21-47 High Street, Feltham, Middlesex. TW13 4UN;

www.ukas.com

3.5.5 The instrument manufacturer shall provide drawings and data describing the principal features, mode of operation, the measuring range and the degrees of accuracy of the equipment. The manufacture of all items shall be in accordance with the Drawings provided and with the Specification and shall comply with the relevant British Standards. The accuracy of instruments shall be agreed with the *'Geotechnical Engineer'* and the *'Asset Owner'*.

3.5.6 Where specified or indicated on the drawings, instruments shall be capable of being monitored remotely by portable remote readout units should the *'Employer'* select RDC methods. The readout units and the appropriate plug-in leads shall be supplied by the *'Monitoring Contractor'* and shall be compatible with the instruments being monitored. The readout units shall plug into appropriate readout boxes supplied by the *'Monitoring Contractor'*.

3.5.7 The *'Employer'* may instruct that additional instrumentation be installed in the event of unforeseen conditions being encountered for which more extensive monitoring might be required.

3.5.8 The *'Monitoring Contracto*r' may offer alternative types of instrumentation to those specified provided they are of equal or better accuracy, precision and quality and are manufactured by companies with proven experience in the field of tunnel and/or geotechnical instrumentation. Alternatives will be subject to the acceptance of the *'Employer'*. The *'Monitoring Contractor'* shall provide proposals for alternative systems to the *'Employer'* at least one month before installation.

3.6 Installation and Maintenance of Instruments

3.6.1 The *'Monitoring Contractor'* is required to make a pre-installation condition survey which shall comprise a photographic and written record of the conditions at the locations of all monitoring equipment prior to installation. The *'Monitoring Contractor'* shall note any defects immediately adjacent to the monitoring installation point. The photographs and notes on condition shall be written up and provided to the *'Employer'* as a section in an Installation Report (as required by this specification (Clause 3.12.3). The *'Monitoring Contractor'* shall carry out the works with due regard to the condition of the structures.

3.6.2 Where possible, proof testing of the instruments, reading equipment and monitoring systems shall be carried out in the LUL running tunnel environment.

3.6.3 The *'Monitoring Contractor'* and the *'Asset Manager'* shall agree the most appropriate hours for installation and maintenance of the instruments. The *'Monitoring Contractor'* shall assume all work will be carried out in Engineering Hours.

3.6.4 The location and proposed type of instruments shall be as indicated on the Tender Drawings. The *'Monitoring Contractor'* is at liberty to propose alternative instrumentation that meets the requirements. The final location of each monitoring point shall be agreed with the *'Geotechnical Engineer'* and, where required, the *'Asset Manager'*.

3.6.5 Remotely read instrumentation shall be capable of being read without interruption to public or LUL activities.

3.6.6 Additional instruments shall be installed as deemed necessary in the event of unforeseen conditions being encountered for which more extensive monitoring might be required.

3.6.7 The *'Monitoring Contractor'* shall install the equipment according to the manufacturer's recommendations. Testing shall be undertaken as necessary to ensure satisfactory functioning of the equipment at each stage of the installation. Instruments found to be malfunctioning at any time shall be replaced at the earliest opportunity.

3.6.8 Adequate temporary works design must be carried out to locate machinery outside the swept path of LUL trains where necessary.

3.6.9 Installation of instrumentation shall be in accordance with approved method statements and may be subject to third party approvals. All instruments shall be securely fixed and their terminations including any attendant wiring and terminal panels, shall be adequately protected against mechanical damage and ingress of water and dirt. The equipment shall be fixed such that it is capable of resisting air movement and pressure changes underground, or adverse climatic conditions at surface locations.

3.6.10 Installation of instrumentation shall be at appropriate times in advance of and during monitoring as indicated on the Drawings or otherwise determined by the Project Manager.

3.6.11 The *'Monitoring Contractor'* shall take every practical measure to prevent damage to the instruments and ancillary equipment during handling, installation and subsequent operation. The *'Monitoring Contractor'* shall maintain all the instruments required for long term monitoring in a satisfactory working order for the duration of the monitoring programme.

3.6.12 The *'Monitoring Contractor'* shall ensure that all the instrumentation in use has been correctly calibrated. The *'Monitoring Contractor'* shall also carry out periodic checks to confirm the validity of calibration of equipment in accordance with the manufacturer's instructions and carry out any adjustments that are found necessary. Suspect and Anomalous readings shall be repeated immediately. Records shall be kept of checks, errors recorded and whether adjustment was undertaken.

3.6.13 The *'Monitoring Contractor'* shall be responsible for keeping records of all calibration certificates and for sending equipment off site for recalibration by reputable testing laboratories when required. Calibration laboratories used shall be accredited by UKAS.

3.6.14 The *'Monitoring Contractor'* shall record the location of all instrumentation on As Built drawings. As-built drawings shall include (all cabling for RDC), the control traverse and absolute levels and co-ordinates of control stations. Hidden electrical instrumentation shall be identifiable by colour codes and/or tagged cables. The reference coding shall also be recorded on the As-built drawings.

3.6.15 Measures shall be taken to ensure that electrical instrumentation is not adversely affected by other temporary or permanent electrical services and, likewise, the electrical instrumentation does not affect other services or equipment.

3.6.16 All instruments required for monitoring shall be maintained in a satisfactory working order for the duration of the monitoring programme. Manual survey instruments shall be serviced at a maximum of six monthly intervals or after any collisions. A maintenance schedule shall be submitted prior to installation or first use of any instrumentation.

3.6.17 The installation and subsequent operation of monitoring equipment shall not disrupt or be disrupted by normal site operations or cause hazard to others.

3.6.18 Any non-metallic items shall be self-extinguishing in the event of fire and emit no toxic fumes.

3.6.19 Where transformers are used they shall have safety cut-outs devised to guard against overheating.

3.6.20 On removal of the instrumentation surfaces shall be made good.

3.6.21 All cabling shall make allowance to accommodate predicted movements.

3.7 Instrument Reading and Records

3.7.1 All instrumentation shall be operated in accordance with the manufacturer's instructions.

3.7.2 Whenever readings are collected from a particular instrument, they shall be compared to previous readings on the same instrument and to the expected accuracy of the instrumentation before further readings are taken from other instrumentation. If unexpected anomalous readings are present they shall be checked to ascertain whether the anomaly is due to a measurement or reduction error. If the anomaly is not due to a measurement or reduction error, the *'Monitoring Contractor'* shall inform the *'Geotechnical Engineer'* immediately. The frequency of readings shall be increased and if the readings remain persistently anomalous, an investigation shall be carried out to determine the cause.

3.7.3 A logical reference system for all the instrumentation equipment shall be established by the *'Monitoring Contractor'* so that records for any particular location can easily be recovered for interpretation or review.

3.7.4 Both Manual Data Capture (MDC) and Remote Data Capture (RDC) instruments shall be read as soon as possible after installation to establish datum readings which shall be established from a minimum of two independent

reading operations giving consistent results within the capability of the instrument used. Any specific Datum readings and reading frequencies related to a particular instrument type are stated under the relevant section describing the details and use of the instrument.

3.7.5 When recording instrumentation readings, all site conditions that may affect the results shall be recorded, including temperature and humidity readings, tunnel air movements, activity and progress on site at ground level. Instrument type, location reference, data and time of reading, personnel carrying out the readings and measuring instrument or readout unit reference shall also be recorded. Comments shall be recorded where observations of unusual conditions could influence the instrumentation or the structure being monitored.

3.7.6 Instrument readings shall be recorded on record sheets designed for the purpose or preferably recorded directly on to tape, disc, memory stick or other non-volatile memory medium for subsequent analysis by computer. Corrections shall be made for temperature difference or other factors by the *'monitoring contractor'* and the *'geotechnical engineer'* as appropriate, but both raw and processed data shall be available. Plots of deformation, stress, etc. against time shall be produced together with plots of temperature and humidity when relevant.

3.7.7 The same recording devices, e.g. demec gauges, tape extensometers, dial gauges, pressure gauges, digital readouts etc. shall be used at any given location throughout the monitoring programme. If for any reason this becomes impractical, due to instrument breakage for example, new datum readings shall be taken immediately with a replacement instrument, and the new instrument used for the future readings. Similarly, should a monitoring location become unavailable the instrument previously read from this point shall, as soon as practicable after becoming unavailable, be read from an alternative point, the latter then being used for subsequent readings.

3.7.8 Records shall be kept of all calibration certificates and for sending equipment off site for re-calibration by reputable testing laboratories, when required. Copies of all certification shall be held on site.

3.7.9 The monitoring systems shall provide:

- Both raw and processed readings for all MDC monitored locations within twelve hours of collection.
- Both raw and processed readings for all RDC monitored locations within four hours of collection.

3.7.10 Monitoring data transmitted files and summary plots shall include a reference to such changes.

3.7.11 System checks shall be performed on all RDC systems.

3.7.12 The initial location of all monitored points eastings, northings and level shall be supplied to within ±2mm to original survey control traverse.

3.8 Frequency of Readings

3.8.1 The frequency of readings throughout various stages of excavation and construction is determined by the *'Asset Owner'.*

3.8.2 Proposed frequency of readings is provided in The I&M Plan A108303-RPT-004.

3.9 Duration of Monitoring

3.9.1 Baseline readings shall be taken for a period prior to the start of any demolition works on site.

3.9.2 For an MDC system, baseline monitoring shall be undertaken on a weekly basis over a six week period with the readings being undertaken within the same two hour period on the same day of the week. A consistency of ±3mm is required across the six week period in order to conclude the baseline period.

3.9.3 For an RDC system, baseline monitoring shall be undertaken for a 1 month period. A consistency of ±3mm is required in order to conclude the baseline period.

3.9.2 The main monitoring contract shall be undertaken throughout site works until completion of the superstructure frame. Monitoring shall then continue until rate of increase of movement reduces to less than 1mm per month in addition to reading accuracy and/or LUL agree that monitoring can cease.

3.10 Interpretation of Readings

3.10.1 The *'Monitoring Contractor'* shall ensure that the Instrumentation Personnel are competent to check, process and interpret the readings.

3.10.2 Procedures shall be prepared by the *'Monitoring Contractor'* for the regular interpretation and review of the readings.

3.10.3 All the raw readings shall be checked, vetted and processed by the monitoring team and distributed to the *'Geotechnical Engineer'*, via a medium to be agreed, before 12noon the workday following the survey, so that the *'Geotechnical Engineer'* can interpret the monitoring data before calling a trigger level breach.

3.11 Method Statements

3.11.1 Method statements shall make reference to engineering specifications, health and safety plans, environmental plans, quality assurance, emergency response plans, risk assessments and the like.

3.11.2 The *'Monitoring Contractor'* shall provide to the *'Employer'* and *'Asset Owner'* detailed Method Statements describing the proposed procedures for installation of the I&M system for defined areas to be proposed by the Contractor. They shall be submitted not less than 4 weeks prior to the programmed start of Baseline Readings.

3.11.3 The *'Monitoring Contractor'* shall supply as part of his Method Statement for installation of instruments, the following information for the *'Employer's'* approval:

i. details of Instrumentation to be installed (as specified or proposed alternatives) including: manufacturers drawings showing dimensions, manufacturers specification, principal features, mode of operation, measuring range and accuracy, type, serial number, principle of measurement, installation details, environmental limitations, power requirements, logging system, data format;

ii. method of fixing and replacement procedures and proposed format and contents of the installation report;

iii. methods for De-commissioning and Re-instatement and the materials and equipment required;

iv. cable type, fixings, dimensions, environmental limitations, routes and installation details;

v. datalogger / Read-out boxes location, type, fixings;

vi. longevity of materials used, grout/ resin types and setting times;

vii. a programme for the Installation, testing, calibration, commissioning readings and maintenance of the monitoring systems;

viii. data management system including hardware, details of the software, file structure, security systems, maintenance support, input systems, graphics capability, report types, audit procedures, data format and computer virus protection system (type, scope, update procedure);

ix. examples of previous application and efficacy of the software/ data management system;

x. sample data presentation sheets for each of the different types of Instrumentation to be installed;

xi. method of checking / validation of the data to ensure that erroneous data is not entered into the database;

xii. permits and permissions obtained/ pending;

xiii. monitoring personnel Curriculum Vitae (experience/qualification) and availability;

xiv. CDM risk assessments and emergency/ safety provisions;

xv. proposals for onsite storage facilities.

3.11.4 Information shall not be duplicated for subsequent method statements but the 'Monitoring Contractor' shall ensure that adequate cross-referencing to the first method statement is included.

3.12 Reporting

3.12.1 General

3.1.12.1 The *'Monitoring Contractor'* shall collate detailed digital survey records throughout the construction phases with potential to induce ground movement. A timeline of surveyed movement will include a narrative of site activity carried out by the *'Principal Contractor'* and appointed sub-contractors.

3.12.1.2 The *'Geotechnical Engineer'* shall be passed information in a timely manner as described in clause 3.10.3.

3.12.1.3 The results of all readings shall be made available to the Project Manager in the specified format or as set out in the method statements and agreed with the Project Manager.

3.12.2 Presentation of Data

3.12.2.1 Data shall be presented in a format to be agreed with the *'Geotechnical Engineer'*. The Excel data shall be provided alongside tables and graphs.

3.12.2.2 Tables shall be prepared comparing readings with any previous readings and with the base readings. Graphs shall be prepared to show readings against time or other relevant parameter.

3.12.2.3 Columns of numbers in tables shall be labelled and units stated. Numbers should not be reported to a greater precision than is appropriate.

3.12.2.4 Graph axes should be linear, real scale and labelled with units. The direction of displacement shall be identified. The axis scales shall be set appropriately to identify trends in data. Graphs shall cover a limited time period in arrears (generally three weeks) such that sufficient detail can be obtained

from the most recent data. The actual period of time covered on graphs shall be adjusted in agreement with the *'Geotechnical Engineer'* to provide a clear representation of the data. Important dates shall be marked with a brief explanation of their significance. The occurrence of errors shall be indicated. For time graphs, time shall be the horizontal axis. Where nearby construction activities at the site may have influenced the readings, these shall be noted on the graph. Graphs shall be presented in a clear manner. Excess data shall not be plotted onto one graph. Separate graphs shall be produced as appropriate. Individual data points shall be included on line plots to indicate true reading frequency. They shall be omitted only in the interest of clarity and where the frequency of reading is marked on the graph. Green, Amber and Red trigger levels shall be reproduced on graphs.

3.12.2.5 For plotting longitudinal displacement from monitoring prisms by total stations, graphs shall be presented showing the longitudinal deformation profile of the tunnel.

3.12.2.6 Data relating to site conditions should be included within the reports.

3.12.3 Installation Report

3.12.3.1 The *'Monitoring Contractor'* shall submit a final installation report within one month of the installation of all instrumentation. The final report shall include the following:

i. A brief description of the site;

ii. A pre-installation condition survey;

iii. A description of the scope of work carried out by the '*Monitoring Contractor*' and the Instrumentation installed;

iv. Collated installation records;

v. A summary of installation records;

vi. As-built Drawings providing the location of instrumentation (including cabling routes, terminal boxes and dataloggers). Instrumentation shall be labelled with its unique identification codes.

3.12.4 Weekly Reports

3.12.4.1 Throughout the site activities a weekly report shall comprise the principal means of publishing the data. Data shall be presented in graphical form.

3.12.4.2 The reports shall contain the following information:

i. Assessment of the cause of anomalous readings such as reading or data reduction errors;

ii. Assessment of change in reading instruments upon data obtained;

iii. An assessment of changes in trends or variations in rates of change of the data and the causes of those changes;

iv. An assessment of any environmental factors which influence the data;

v. A construction progress plan shall be included to indicate the extent of construction current to the date of issue.

3.12.5 Close Out Report

3.12.5.1 Prior to the de-commissioning of any instrumentation, the *'Monitoring Contractor'* shall produce a "close-out" report which summarises the data from the instrumentation the *'Monitoring Contractor'* wishes to remove and relates it to the construction activities which produced any observed changes. The report shall demonstrate that the rate of change in the data has reached an acceptably small rate.

3.13 Disclosure

3.12.1 The *'Monitoring Contractor'* shall not disclose any instrumentation data to third parties and shall not publish data without prior written consent of the *'Employer'*.