Building and Construction Authority

We shape a **safe**, **high quality**, **sustainable** and **friendly** built environment.

Our Ref : APPBCA-2019-12

2 September 2019

For enquiries, please contact:
Building Engineering Group (#12-01)
Tel : 1800 3425 222 (1800-DIAL-BCA)
or use our Online Feedback Form at:
https://www.bca.gov.sg/feedbackform/

See **Distribution List**

Dear Sir/Madam

FRAMEWORK ON OBSERVATIONAL METHOD FOR THE DESIGN AND CONSTRUCTION OF ERSS WORK, AND GROUND WATER CONTROL FOR DEEP EXCAVATION

Objective

This circular is to inform the industry on the guidelines for the Observational Method (OM) for **A)** the Design and Construction of ERSS work, and **B)** Ground Water Control System for Deep Excavation

Background

2 The adoption of OM in the Design and Construction of ERSS work and Ground Water Control System for Deep Excavation is expected to promote work efficiency and construction productivity without compromising safety. BCA-Industry Joint Working Committee (JWC) was formed to develop and standardise the guidelines for the OM frameworks to suit local practice. Over the past months, BCA has met up with Institution of Engineers Singapore (IES), Association of Consulting Engineers Singapore (ACES), Geotechnical Society of Singapore (GeoSS) to gather feedback on these frameworks. This circular, which has incorporated inputs from the professional institutions, is for compliance by Qualified Persons ("QP"), Accredited Checkers ("AC"), site supervisors, builders and developers that are submitting proposals adopting OM.

3 The guidelines for the adoption of OM in ERSS projects allows project parties to adopt optimised design during construction if better performance is realised. Developer/builder is advised to engage experienced QPs with good track records for the adoption of OM and factor in the additional resources for additional designs and closer monitoring during construction. If adopted successfully, cost and time savings without compromising safety throughout the construction phase may be realised.

Guidelines for OM approach

4 Before adopting OM, QPs for the Design and Construction of ERSS work shall ensure the project is applicable for OM approach and that the specific requirements in the Annex A for the Design and Construction of ERSS work and Annex B for Ground Water Control System for Deep Excavation of this Circular are satisfied. Projects that are intending to consider the above OM approaches should write in via BCA's Online Feedback Form at https://www.bca.gov.sg/feedbackform/ to arrange for pre-consultation with BCA to confirm the suitability of OM.

5 Nothing contained in this circular is meant to replace or negate the need to comply with the provisions of the Building Control Act and building regulations in all aspects. QPs are to note that they have duties under the Building Control Act, amongst others, to take all reasonable steps and exercise due diligence to ensure that building works are designed in accordance with the provisions of the Building Control Act and building regulations.

6 I would appreciate it if you could disseminate the contents of this circular to your members. Please submit your enquiry through BCA's Online Feedback Form at https://www.bca.gov.sg/feedbackform/ or call us at 1800 342 5222.

Yours faithfully

Er. Dr. POH TEOH YAW
DIRECTOR, GEOTECHNICAL ENGINEERING DEPARTMENT
BUILDING ENGINEERING GROUP
For COMMISSIONER OF BUILDING CONTROL

Members of BCA-Industry Joint Working Committee (JWC) who contributed to the framework on OM for ERSS projects

Chairman
Er. Dr. Poh Teoh Yaw

Members
Ms. Mariela Angeles
Er. Dr. Chin Kheng Ghee
Mr. Charles Im
Er. Khoo Kok Sing
Er. Kong Tze Foong
Er. David Ng Chew Chiat
Er. Dr. Ng Tiong Guan
Mr. Calvin Ng
Er. Dr. Ooi Poh Hai
Mr. Nick Osbourne
Er. Dr. Oskar Sigl
Er. Thomas Tang Sek Kwan
Er. Dr. Vallipuram Ganeshan
Er. Dr. Wen Da Zhi

CIRCULAR DISTRIBUTION LIST

ASSOCIATIONS / SOCIETIES

PRESIDENT
INSTITUTION OF ENGINEERS, SINGAPORE (IES)
70, BUKIT TINGGI ROAD
SINGAPORE 289758
ies@iesnet.org.sg

PRESIDENT
ASSOCIATION OF CONSULTING ENGINEERS, SINGAPORE (ACES)
18 SIN MING LANE
#06-01 MIDVIEW CITY
SINGAPORE 573960
secretariat@aces.org.sg

PRESIDENT
SINGAPORE CONTRACTORS ASSOCIATION LIMITED (SCAL)
CONSTRUCTION HOUSE
1 BUKIT MERAH LANE 2
SINGAPORE 159760
enquiry@scal.com.sg

PRESIDENT
SINGAPORE INSTITUTE OF ARCHITECTS (SIA)
79 NEIL ROAD
SINGAPORE 088904
info@sia.org.sg

PRESIDENT
SOCIETY OF PROJECT MANAGERS (SPM)
MACPHERSON ROAD P.O.BOX 1083
SINGAPORE 913412
sprojm@yahoo.com

PRESIDENT
SINGAPORE INSTITUTE OF BUILDING LIMITED (SIBL)
70 PALMER ROAD,
#03-09C PALMER HOUSE
SINGAPORE 079427
josephine@sibl.com.sg

PRESIDENT
REAL ESTATE DEVELOPERS' ASSOCIATION OF SINGAPORE (REDAS)
190 CLEMENCEAU AVENUE
#07-01 SINGAPORE SHOPPING CENTRE
SINGAPORE 239924
enquiry@redas.com

PRESIDENT
SINGAPORE INSTITUTE OF SURVEYORS & VALUERS (SISV)
110 MIDDLE ROAD #09-00
CHIAT HONG BUILDING
SINGAPORE 188968
sisv.info@sisv.org.sg

PRESIDENT
SINGAPORE STRUCTURAL STEEL SOCIETY (SSSS)
1 LIANG SEAH STREET
#02-11/12 LIANG SEAH PLACE
SINGAPORE 189022
secretariat@ssss.org.sg

PRESIDENT
GEOTECHNICAL SOCIETY OF SINGAPORE (GEOSS)
C/O GLOBEWERKS INTERNATIONAL PTE LTD
22 SIN MING LANE
#03-85 MIDVIEW CITY
SINGAPORE 573969
secretariat@geoss.sg

PRESIDENT
PROFESSIONAL ENGINEERS BOARD, SINGAPORE (PEB)
52 JURONG GATEWAY ROAD, #07-03
SINGAPORE 608550
registrar@peb.gov.sg

PRESIDENT
BOARD OF ARCHITECTS (BOA)
5 MAXWELL ROAD
1ST STOREY TOWER BLOCK
MND COMPLEX
SINGAPORE 069110
boarch@singnet.com.sg

DIRECTOR OF INFRASTRUCTURE
SCHOOL CAMPUS DEPARTMENT
MINISTRY OF EDUCATION
1 NORTH BUONA VISTA DRIVE
SINGAPORE 138675
choo_boon_chiao@moe.gov.sg

DIRECTOR
BEST SOURCING DEPARTMENT
PUBLIC UTILITIES BOARD
40 SCOTTS ROAD #18-01
ENVIRONMENT BUILDING
SINGAPORE 228231
herman_ching@pub.gov.sg
lim_kim_tee@pub.gov.sg

DEPUTY CHIEF EXECUTIVE
INFRASTRUCTURE & DEVELOPMENT
LAND TRANSPORT AUTHORITY
1 HAMPSHIRE ROAD
BLOCK 8 LEVEL 1
SINGAPORE 219428
chong_kheng_chua@lta.gov.sg

DEPUTY DIRECTOR
PROJECT DEVT & MGT SECT 1 (C&S)
BUILDING QUALITY GROUP
HOUSING & DEVELOPMENT BOARD
HDB HUB
480 LORONG 6 TOA PAYOH
SINGAPORE 310480
low_kiang_heng@hdb.gov.sg

AG DIRECTOR
TECHNICAL SERVICES DIVISION
JTC CORPORATION
THE JTC SUMMIT
8 JURONG TOWN HALL ROAD
SINGAPORE 609434
tan_su_chern@jtc.gov.sg

DIRECTOR
BUILDING
PEOPLE'S ASSOCIATION
9 STADIUM LINK
SINGAPORE 397750
foo_soon_leng@pa.gov.sg

PRESIDENT
THE TUNNELLING AND UNDERGROUND
CONSTRUCTION SOCIETY SINGAPORE (TUCSS)
C/O CMA INTERNATIONAL CONSULTANTS PTE LTD
1 LIANG SEAH STREET
#02-12 LIANG SEAH PLACE
SINGAPORE 189022
info@tucss.org.sg

PRESIDENT
SOCIETY OF ROCK MECHANICS AND ENGINEERING GEOLOGY
1 LIANG SEAH STREET
#02-12 LIANG SEAH PLACE
SINGAPORE 189022
srmeg@cma.sg

DEPUTY CHIEF EXECUTIVE OFFICER
SENTOSA DEVELOPMENT CORPORATION
33 ALLANBROOKE ROAD, SENTOSA
SINGAPORE 099981
agencies_circulars@sentosa.com.sg

HEAD (FIRE SAFETY AND BUILDING CONTROL)
BUILDING AND INFRASTRUCTURE
DEFENCE SCIENCE & TECHNOLOGY AGENCY
1 DEPOT ROAD
DEFENCE TECHNOLOGY TOWER A
SINGAPORE 109679
hahmeng@dsta.gov.sg

DIRECTOR
BUILDING AND INFRASTRUCTURE
DEFENCE SCIENCE & TECHNOLOGY AGENCY
1 DEPOT ROAD
DEFENCE TECHNOLOGY TOWER A
SINGAPORE 109679
lee_eng_hua@dsta.gov.sg

ALL CORENET E-INFO SUBSRIBERS

Annex A

(OM for Design and Construction of ERSS Works)

Guidelines for OM Approach – Design and Construction of ERSS work

1 Before adopting OM, QPs for the Design and Construction of ERSS work shall ensure the project is applicable for OM approach and that the specific requirements in the Annexes of this Circular are satisfied. The Criteria and flowchart on the adoption of OM approach are included in **Annex A1** and **Annex A2** respectively.

2 Plan submissions based on the OM approach shall incorporate relevant considerations upfront via the design for the Characteristic Scenario (**CS**), and an additional Probable Scenario (**PS**) at the design stage (see **Annex A3**), based on 'characteristic' and 'most probable' design parameters, respectively (see **Annex A4**). The various OM levels and zones (see **Annex A5**) on when to adopt the appropriate scenario at the **Decision Stage** shall be determined, specified in the approved plans by QPs, and administered diligently depending on the actual ERSS performance at the site via site instrumentation results and observations (see **Annex A6** for instrumentation requirements).

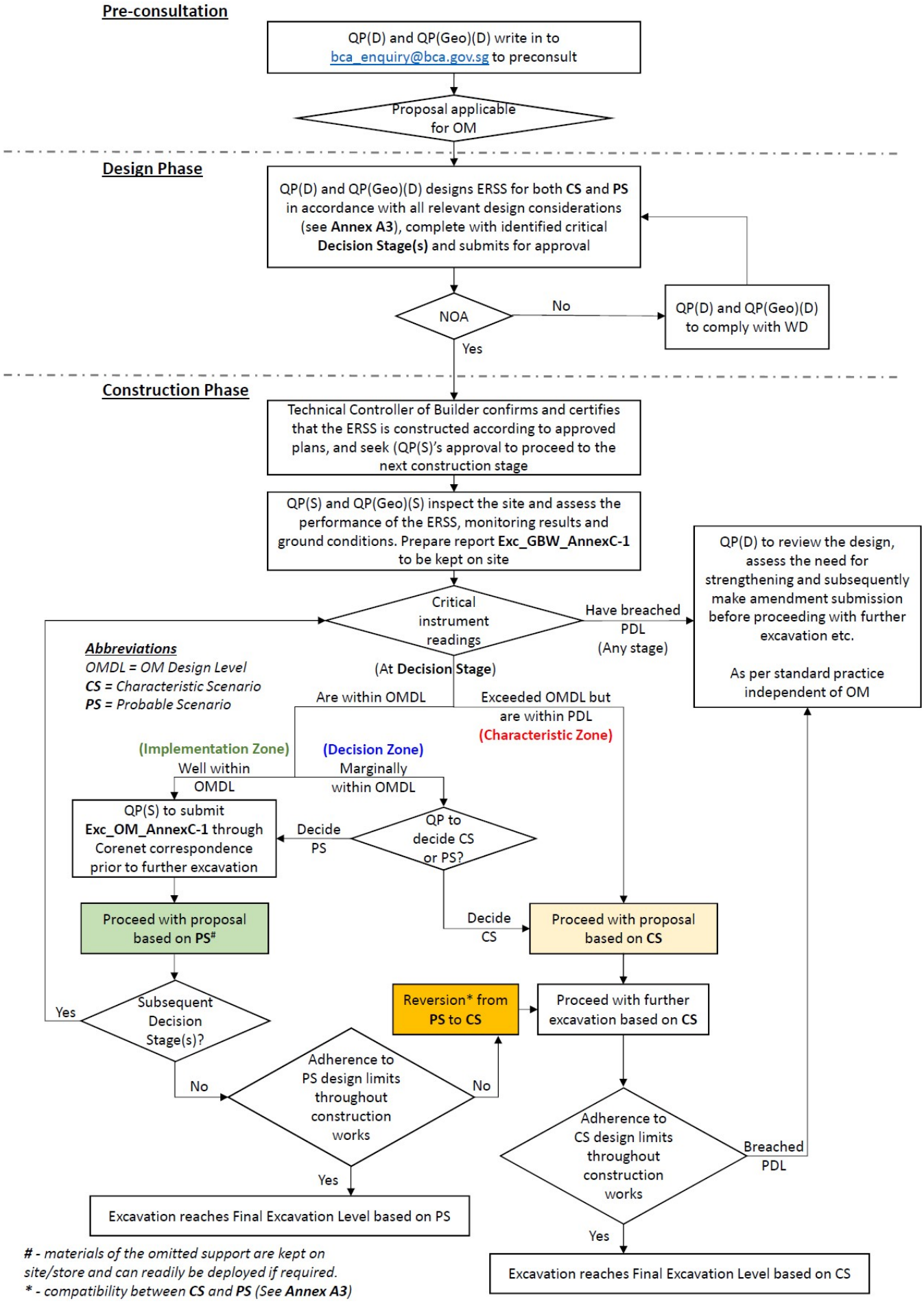
3 During construction phase, site inspection and approval records as per **Appendix A1** shall be completed for the adoption of **PS** at each **Decision Stage** and corresponded via Corenet to the Permit to carry out structural works. QPs are reminded to ensure Performance Requirements stipulated in the Fifth Schedule of the Building Control Regulations are adhered to throughout the proposed works.

Annex A1 – Criteria for Adoption of OM - Design and Construction of ERSS Works

QPs are required to fulfil the following criteria to ensure that the risks associated with the OM approach is minimised to an acceptable level.

S/N	Criteria to be fulfilled for adoption of OM	
1	Good track records of QPs in design and construction of ERSS	QPs demonstrate good track records in design and construction of ERSS works At least 2 projects with well documented design and monitoring reports of: - ➢ similar scale and; ➢ in similar ground condition QPs have no record of no stop work order related to inadequate design within past 3 years
2	Applicability for adoption of OM	The ERSS scheme is multi-propped and **do not** fall under the following categories: ➢ Floating ERSS (where wall toe is not embedded into stiff soil with SPT N value more than 15) that are within Zone 1 or Zone 2 as defined in BCA's Advisory Note 1/09 for ERSS. ➢ Slopes – earth slopes, open-cut slopes and nailed slopes ➢ Cantilever / Single Strut ERSS ➢ Mined Excavation
	Pre-consultation with BCA	QPs pre-consult BCA to confirm the applicability of the OM proposal
3	Design for both characteristic and most probable parameters	QPs design using characteristic and most probable parameters in accordance to **Annex A3** and **Annex A4** of this circular
4	Adequate ground investigation	QPs conduct adequate ground investigation and testing to satisfy the minimum requirements on selection of characteristic and most probably design parameters in accordance to **Annex A4** of this circular
5	Review level for OM approach	QPs adopt review level for OM approach in accordance to **Annex A5** of this circular
6	Sufficient instrumentation	QPs satisfy instrumentation and monitoring requirements specified in **Annex A6** of this circular

Annex A2 – Flow chart for OM Approach



 # - materials of the omitted support are kept on site/store and can readily be deployed if required.
** - compatibility between **CS** and **PS** (See **Annex A3**)*

Annex A3 – Design using Characteristic and Most Probable Parameters

Key aspects	Criteria
Stability checks (e.g. wall toe embedment, global stability)	Based on 'characteristic' parameters
Analysis for retaining wall(s) and support(s)	Minimally 2 set of runs: • Run-1 based on 'characteristic' parameters corresponding to the Characteristic Scenario (**CS)** • Run-2 based on 'most probable' parameters corresponding to the Probable Scenario (**PS)**
Design of retaining wall & support(s)	Based on the most onerous analysis of **CS** and **PS** (i.e. envelope of Run-1 and Run-2)
Compatibility between **CS** and **PS**	The adopted systems shall be compatible all the way such that the switch back to CS from PS can be made at any time during the construction process without creating structural issues or obstructions that makes the reversion impossible.
Design adopted at the **start** of construction for retaining wall and support(s)	Based on **CS**
Potential optimisation during construction phase	Applicable to the reduction of struts/props only when the actual performance of the ERSS at the **Decision Stage** and subsequent stages of construction are within the design limits of the **PS**
Ground water	Onerous ground water condition is to be adopted.

In general, the **CS** should correspond to the usual design methodology (without OM).

Annex A4 – Characteristic and Most probable design parameters

'Characteristic' parameters may be more conservative values, within 1 standard deviation of the mean value, satisfying the following:	**'Most probable' parameters** may be taken as the average of available values, satisfying the following:
▪ Adopted for the normal designs using EC7 ▪ Cautious estimate of the value affecting the occurrence of the limit state	▪ Likely behaviour of the ERSS during construction ▪ Average design parameters which are higher than "characteristic"
Minimum requirements on selection of Characteristic and Most probably design parameters:	
➢ Derived based on statistical methods* ➢ Comprehensive ground investigation has been performed, satisfying the following: o Minimally fulfilling required number of data points i. Strength – minimum 10 samples ii. Stiffness via pressure meter test – minimum 10 samples iii. If data from adjacent site is used, some test shall be carried out at the site to verify the data from the adjacent site o Provision of soil sampling within each layer o Conduct of appropriate type of lab test for critical design parameters; strength and stiffness	

** - Derivation process should be presented and explained in the design documentation.*

Example of assessing Characteristic and Most Probable Parameters

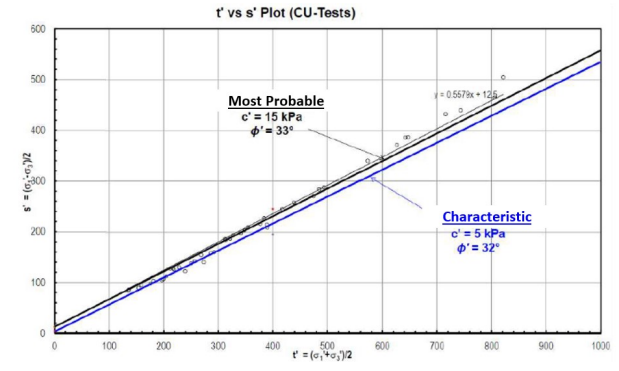


Figure A4-1

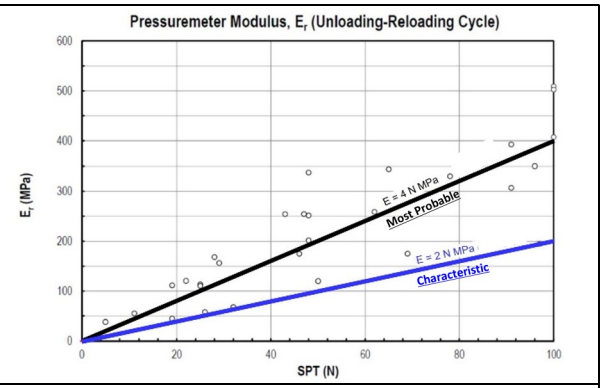


Figure A4-2

Annex A5 – Review levels for OM approach

For projects adopting the OM approach, QPs are to determine the various OM Levels (OM Design Level and OM Implementation Level) and zones at each critical stage of construction based on **CS** and **PS** as shown in **Figure A5-1** and **Figure A5-2.** These OM levels, in addition to the usual Work Suspension Level and Alert Level for typical ERSS work are all to be specified in the approved plans. The OM levels will include **but not limited to wall deflection and support forces etc**.

The **Decision Stage** is the excavation stage that the QPs will decide to exercise **CS** or **PS** for the next stage of construction. When deciding the adoption of **PS**, QP shall also check that the building instruments are within the limits assessed at that stage. The actions to be taken by QPs at the respective OM levels based on site performance for the appropriate scenario are also illustrated in the **Table A5.1**.

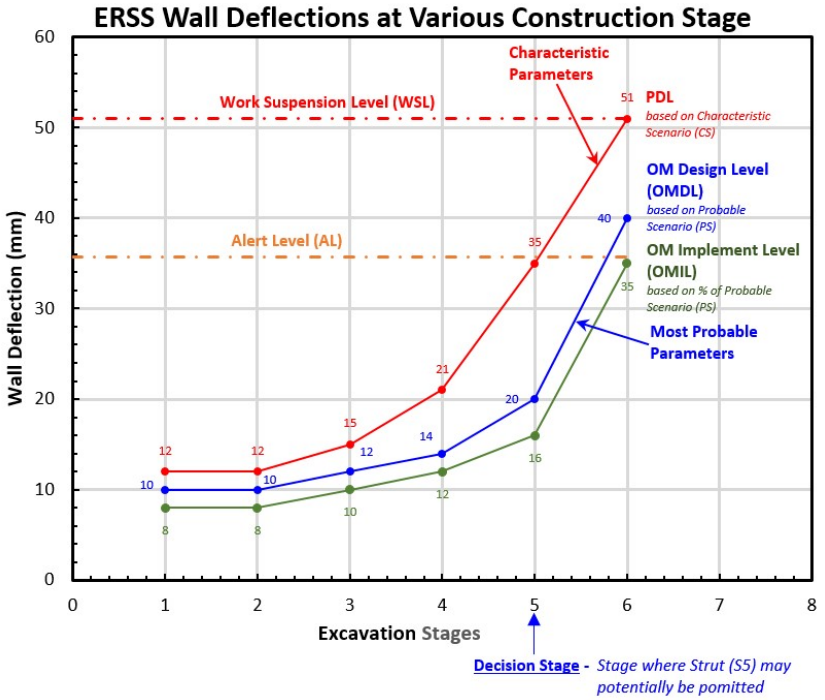


Figure A5-1 – Example of WSL, AL and OM Level for wall deflection

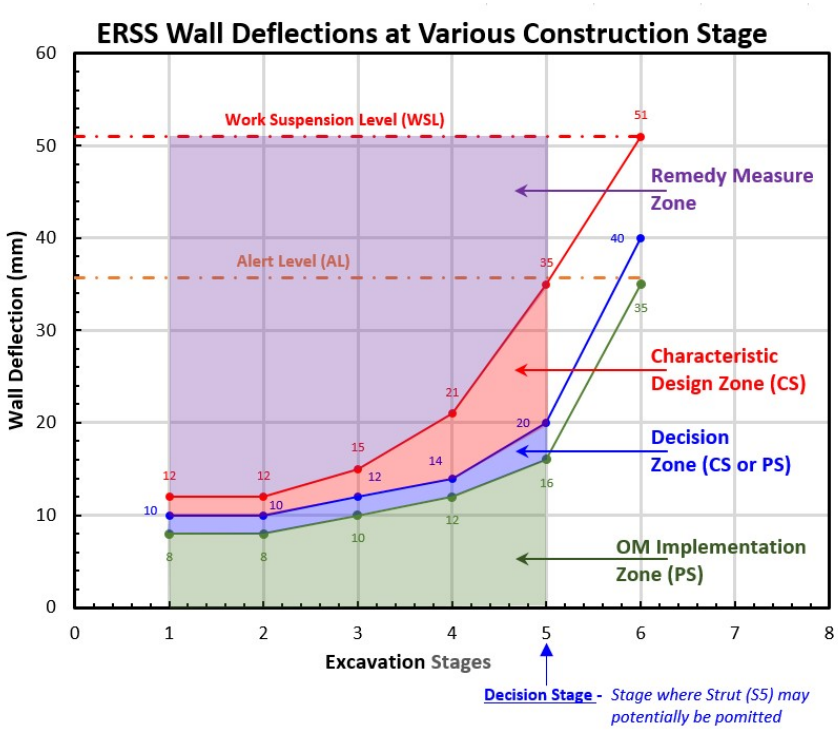


Figure A5-2 – Example of OM zones for wall deflection

Table A5.1 Actions to be taken by QPs at the respective OM levels based on site performance for the appropriate scenario

#	Terminology	Performance of ERSS at the stage of construction considered	Action
1	OM implementation Zone	Within OM Implementation Level	Performance via PS is well on route. QP may proceed with the next stage of excavation via PS#
2	Decision Zone	Between OM Implementation Level and OM Design Level	Performance via PS is marginally on route QP to deliberate the adoption of CS or PS
3	Characteristic Design Zone	Exceeded OM Design level but still within PDL	OM cannot be materialised. <u>Current scenario – CS</u> QP to proceed with the next stage of excavation via CS <u>Current scenario – PS</u> QP to immediately instruct the erection of supports# and reversion* of the proposal to CS
4	Remedy Measure Zone^	Breached PDL (still within WSL)	QP to review the design, assess the need for strengthening and subsequently make amendment submission before proceeding with further excavation QP to report to BCA via email
5	Alert Level^ (AL)	Breached Alert Level	QP to closely monitor the performance of the ERSS
6	Work Suspension Level^ (WSL)	Breached Work Suspension Level	QP to immediately suspend all excavation work, report to BCA and carry out strengthening works

- to specify in the approved plans that the material of supports based on CS design (not erected when adopting the PS design) are to be kept on site/store that can readily be deployed within a day; from the Decision Stage till casting of base slab or any subsequent critical stage.

* - compatibility between **CS** and **PS** (See **Annex A3**)

^ - as per standard practises independent of OM

Table A5.2 Definition of review level for OM approach

#	Terminology	Definition
1	OM Implementation@ Level (OMIL)	Review levels based on a % of OMDL.
2	OM Design Level (OMDL)	Review levels based on PS adopting most probably design parameters
3	Predetermined Level^ (PDL)	Review levels based on CS adopting characteristic design parameters

^ - as per standard practises independent of OM

@ - OM Implementation Level are shown as OM Implement Level (short form) in the figures

Annex A6 – Instrumentation and monitoring requirements

Description	Requirements
Instrumentation interval	Array @ maximum 30m interval
Instrumentation per array	Inclinometer, support strain gauge or load cell.
Instrumentation frequency	After Decision Stage of adopting PS till casting of base slab or any subsequent critical construction stage. Inclinometer – Daily Support strain gauge or load cell – at least daily. QP to review and decide the need for real-time monitoring with SMS.

Appendix A1

Exc_OM_AnnexC-1

SITE INSPECTION & APPROVAL RECORDS - FOR PROBABLE SCENARIO (PS) OF OM APPROACH

Project Ref: _____ Project Name: _____

This form in addition to **Exc_GBW_AnnexC-1** is to be prepared and certified for ERSS (designed under OM approach) to proceed with **Probable Scenario (PS)** at **each Decision Stage, as stipulated in the approved plans**. The duly completed form (Exc_OM_AnnexC-1 **only**) shall be submitted to BCA through e-correspondence on Corenet to the Permit to Carry Out Structural Works for record before proceeding with **PS** at each **Decision Stage**.

Location/Section: _____

Section A: To be completed and certified by Builder		**Section B: To be completed by QP(S) & QP(Geo)(S)**	
Decision Stage and Support	**Declaration of Builder**	**Date of inspection**	**Status and Comments** (Report any deviations from approved plans.)
Approved ST: _____ At Decision Stage No: _____ to adopt Probable Scenario and without the erection of support _____ # - materials of the above support are kept on site/store and can readily be deployed if required.	I confirm that the ERSS has been constructed according to the approved plans and hereby seek QPs' approval before proceeding with the next construction stage. _____ Name & Signature of Technical Controller _____ Name and UEN number builder Date: _____	By QP(S) on _____ By QP(GEO)(S)** on _____	

Section C: To be completed and certified by QP(D) and QP(GEO)(D)
We have assessed and reviewed the adequacy of the as-installed key structural elements of the ERSS, results of instrumentation and monitoring readings, actual ground conditions and the changes highlighted by the QP(S) and QP(Geo)(S), and conclude that the ERSS works to the next construction stage can proceed based on **PS** (based on OM approach) in accordance to the approved plans.

_____ _____

Name, stamp & signature of QP(D) **Name, stamp & signature of QP(Geo)(D)****

Date: _____ **Date: _____**

****For geotechnical aspects, where applicable**

Appendix A2 – OM examples for potential to omit strut

The examples below are based on a proposed ERSS via Top down construction method with 2 layers of struts (S1 and S5) where strut S5 at Excavation Stage 5 has been designed to potentially be omitted via OM approach. This example will focus only on wall deflection to illustrate the adoption of OM approach. **The same is to be extended to other critical designs of the proposal such as support forces (not included in the example for clarity)** etc.

Design stage - OM levels and zone specified in approved plans

Figures A5-1 and **A5-2** in **Annex A5** shall be referred to for the review levels to be specified in the approved plans.

At stage 5 excavation (Decision Stage to potentially omit S5 strut - see **Figure E0-1**) and based on the performance of the ERSS, QP is to decide the appropriate action to be adopted in accordance to **Table E0.1.**

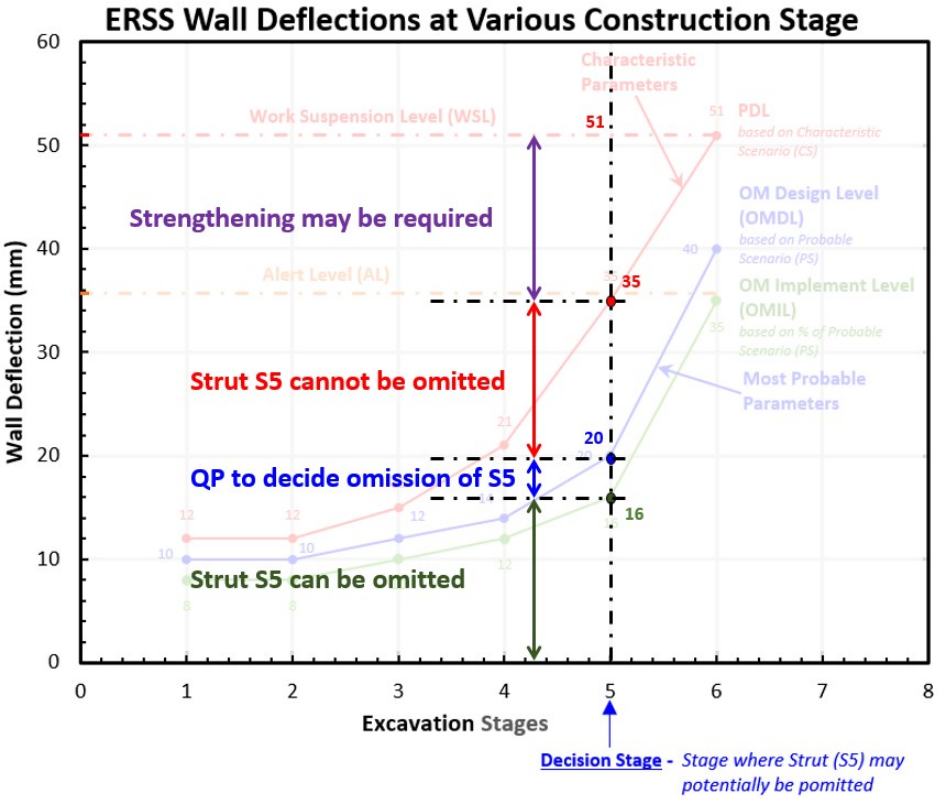


Figure E0-1 – OM Decision Stage

Table E0.1

Scenario	ERSS wall deflection at Stage 5	Decision
1	δ < 16mm	Strut S5 can be omitted
2	16mm < δ < 20mm	QP to deliberate the omission of Strut S5
3	20mm < δ < 35mm	QP cannot omit Strut S5 and is to proceed with the next stage of excavation adopting CS proposal
4	35mm < δ < 51mm	QP to review the design, assess the need for strengthening and subsequently make amendment submission before proceeding with further excavation

Example A1 – Section A

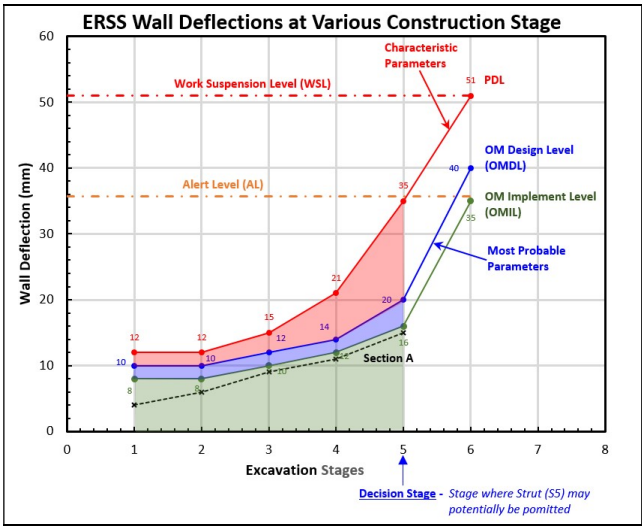


Figure E1-1 – Excavation at Stages 1 to 5

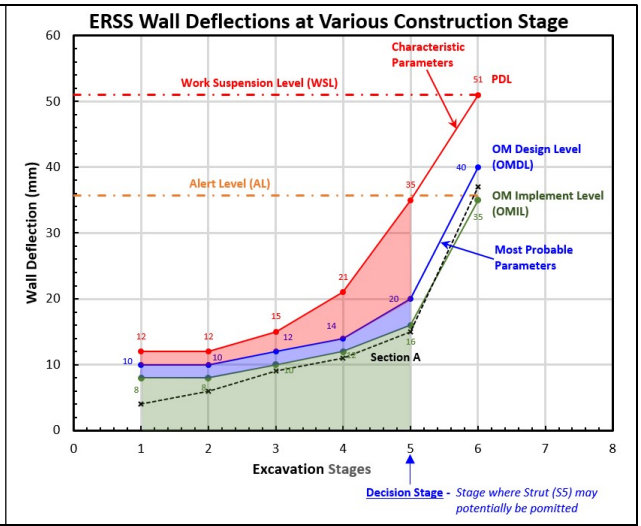


Figure E1-2 – Excavation at Stage 6

- During Construction Stage – Stages 1 to 5 excavation **(Figure E1-1)**
  The measured wall deflection at **Section A** is in line with **PS** design and well within OM Implementation Level. Strut S5 may be omitted for this section. Materials for Strut S5 are to be kept at site/store that can readily be deployed within a day.

- During Construction Stage – Stage 6 excavation **(Figure E1-2)**
  The measured wall deflection at **Section A** is within OM Design Level and in line with **PS** design.

Example A2 – Section B

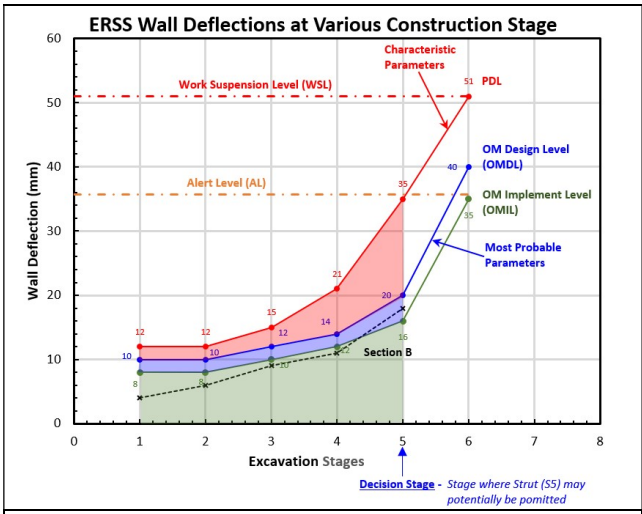


Figure E2-1 – Excavation at Stage 5

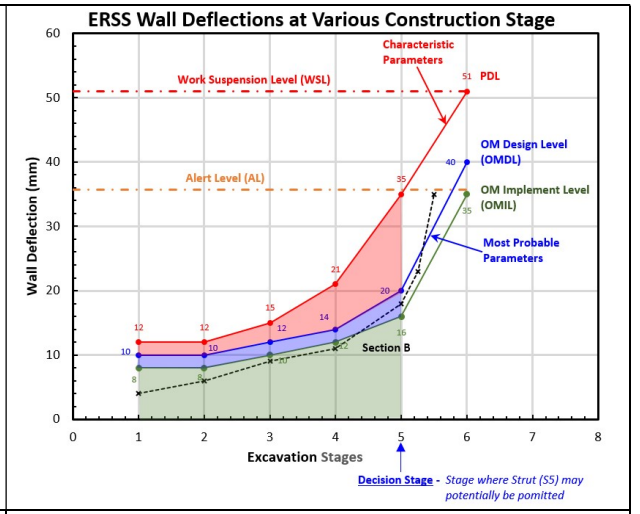


Figure E2-2 – Excavation after Stage 5

- During Construction Stage – Stage 5 excavation **(Figure E2-1)**
  The measured wall deflection at **Section B** is in line with **PS** design and is between OM Design and OM Implementation Levels. QP to deliberate the omission of Strut S5.

  QP decides to adopt **PS** and omit Strut S5. The materials for Strut S5 are to be kept at site/store that can readily be deployed within a day.

- During Construction Stage – After Stage 5 excavation **(Figure E2-2)**
  The measured wall deflection at **Section B** has exceeded the **PS** design. QP to instruct Builder to immediately retrieve the materials for Strut S5 stored at site/store for erection and reversion to **CS**.

Example A3 – Section C

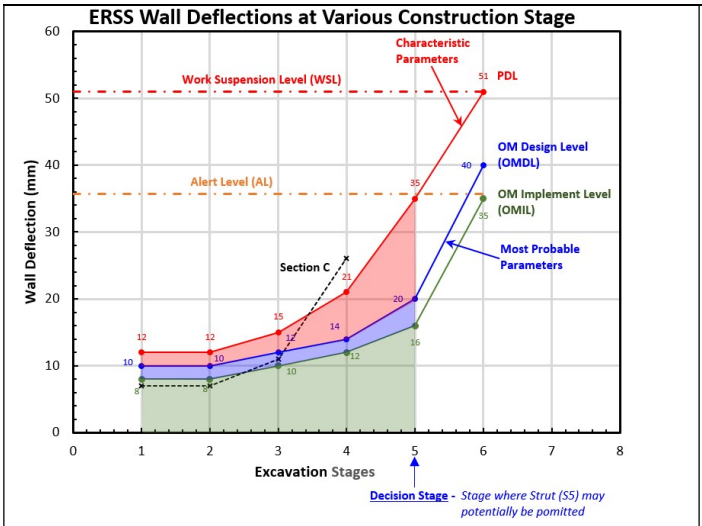


Figure E3-1 – Excavation at Stage 4

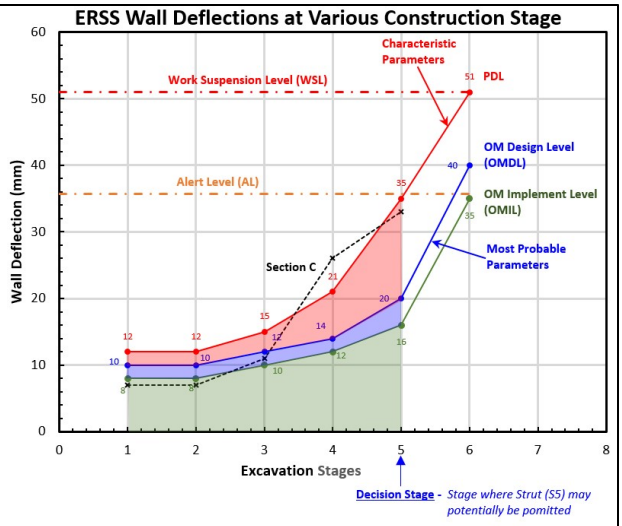


Figure E3-2– Excavation at Stage 5

- During Construction Stage – Stage 4 excavation **(Figure E3-1)**
  The measured wall deflection at **Section C** had exceeded PDL. QP to review the design and assess the need for strengthening before proceeding with further excavation.

  QP to notify BCA via email for breaching of PDL.

- During Construction Stage – Stage 5 excavation **(Figure E3-2)**
  The measured wall deflection at **Section C** is in line with **CS** design. Excavation to proceed based on CS design. Optimisation via **PS** cannot be realised.

Annex B

(OM for Ground Water Control System for deep Excavation)

Guidelines for OM approach - Ground Water Control System for Deep Excavation

1 This framework allows QPs to optimise the design and construction of the base slab for deep excavation during the temporary stage, subjected to successful implementation of effective water control system during construction. The Criteria and flowchart on the adoption of OM approach for ground water control system for deep excavation are included in **Annex B1**.

Annex B1 – Observation Method for Ground Water Control system for deep excavation

For deep excavation where active or passive ground water pressure relief is assumed, QPs shall specify a detailed performance-based water control regime and action plan to ensure the assumed condition is realized on site throughout the construction period.

The key aspects of ground water control system and its design consideration or items to be included in the approved plan is shown in **Table B.1** below.

Table B.1

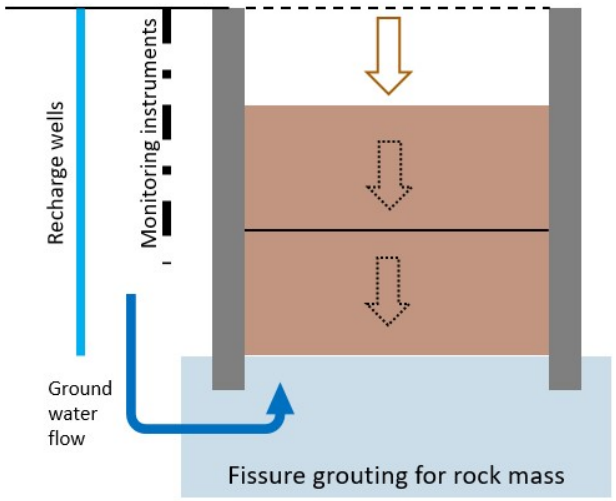
S/N	Criteria to be fulfilled for adoption of OM		Remarks
1	Good track records	QP demonstrate at least one case of successful control of ground water for deep excavation and; Builder or QP do not have any Stop Work Order related to ground water drawdown over the past 3 years	
2	Pre-consultation with BCA	QPs pre-consult BCA to confirm the applicability of the OM proposal	
3	Ground water control measures	<u>Water cut-off measures:</u> QPs provide adequate water cutoff measures such as adequate wall embedment or fissure grouting, supported by seepage analysis. Field permeability tests shall be carried out to substantiate the permeability adopted in the design of the ERSS system	Design requirements to include the contingency measures.
		<u>Recharge wells:</u> QPs specify adequate recharge wells that shall be pre-installed if there is building located within the influence zone. These recharge wells shall be activated when AL of Piezo/Standpipe has been breached	To specify in approved plan
		<u>Quality control:</u> QPs to review the need to carry out pumping tests to verify that the anticipated groundwater inflow at FEL is not likely to exceed the design limit prior to bulk excavation	

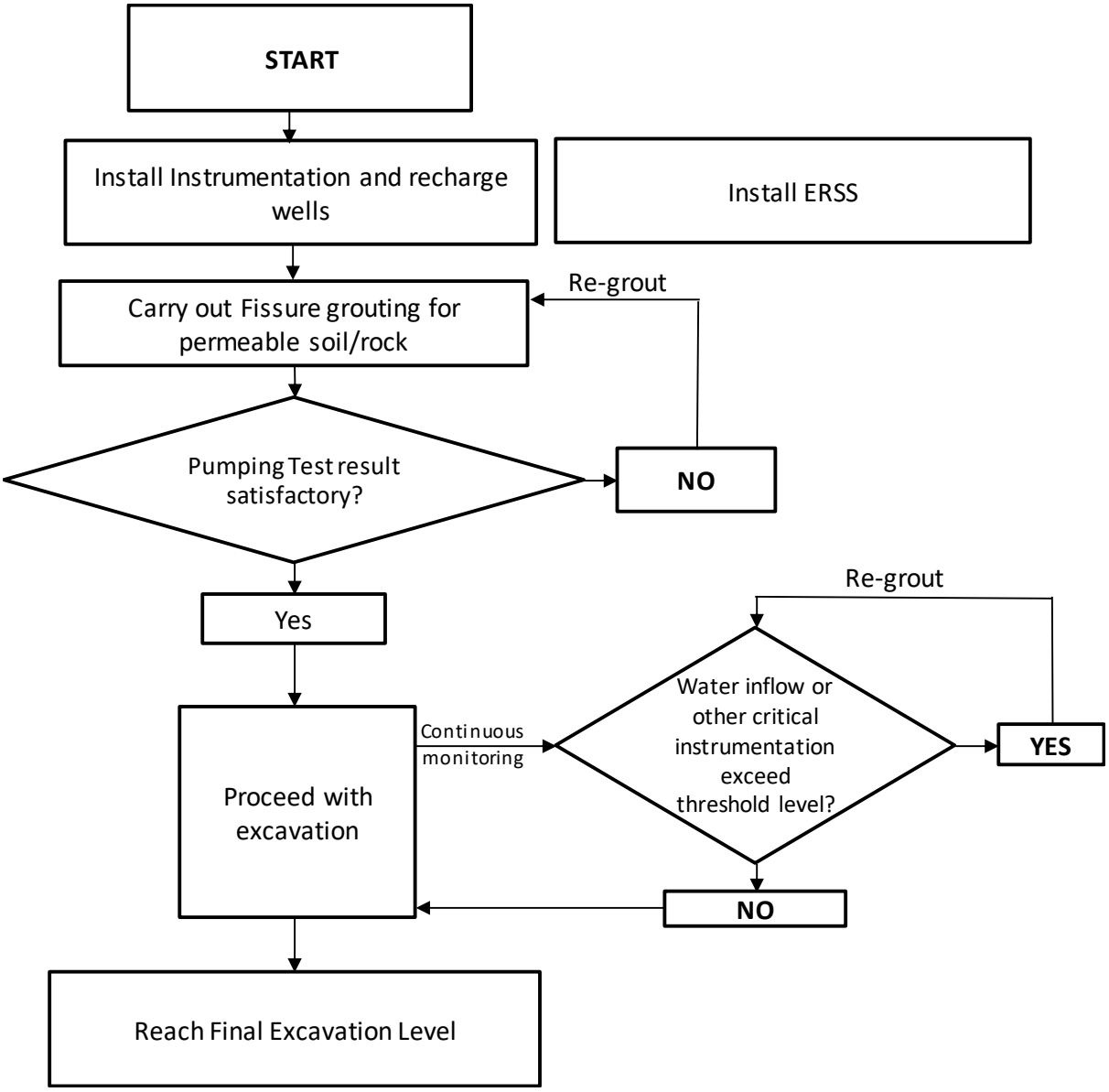
S/N	Criteria to be fulfilled for adoption of OM		Remarks
4	Additional piezometers	QPs provide piezometer at the border of the determined influence zone to verify there is no drawdown beyond this perimeter as assumed in the design.	To specify in approved plan See Example B3.
5	Building Settlement Markers *H = depth of excavation	<u>Building within influence zone</u> All buildings to be monitored <u>No Building present within influence zone</u> Where there is no building within the influence zone, the initial settlement reading to the nearest building within 5H* of each boundary or quadrant of each boundary (circular shaft) shall be taken. Measurement of settlement for this building shall resume if there is breach of Piezo/WSP PDL	To specify in approved plan See Example B3.
6	Contingency plan	QP specify action plan to activate contingency measures based on results of Instrumentation and Monitoring readings Examples of contingency plans: - • Flooding of shaft • Additional grouting and recharge well • Sealing off relief wells and strengthen the base slab • Underpinning / compensation grouting of affected structure	To specify in approved plan

In the event the water pressure relief and / or recharge system do not perform as expected resulting in ground water drawdown and the breach of Alert Level of adjacent building / structures settlement, QP/Builder shall activate pre-determined contingency measures to eliminate the risk of wide-spread ground water drawdown.

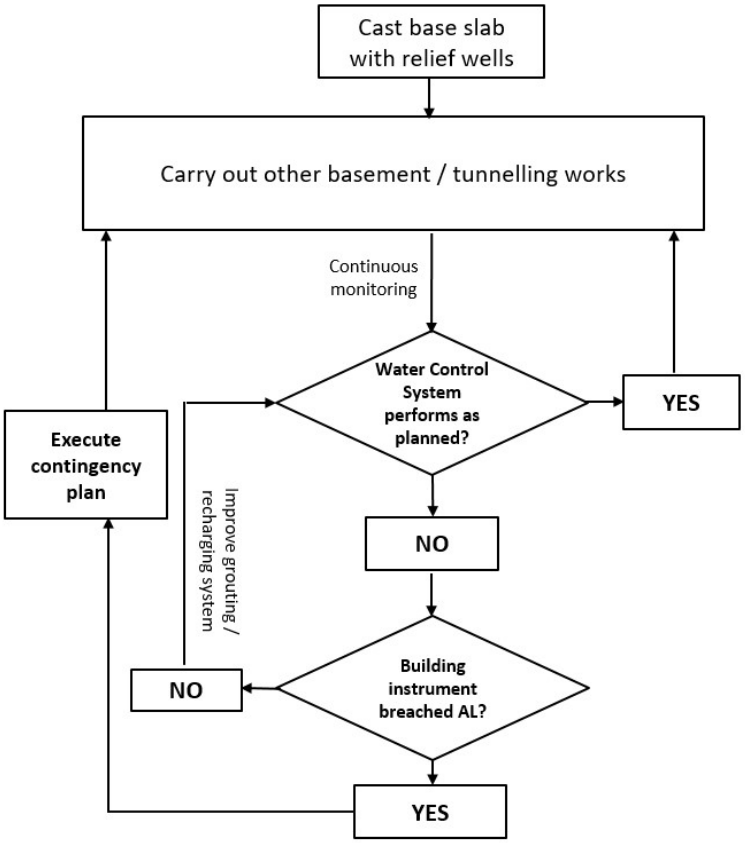
For proposals adopting prolonged water pressure relief, the action plan shall cover for periods over and above excavation stages to include duration in which the FEL is left exposed; as illustrated in Examples B1 and B2.

Example B1: Action plan for ground water control regime **during excavation** into fractured rocks





Example B2: Action plan for ground water control regime **after excavation**, with base slab not designed as water-tight and allowing seepage



Example B3: Instrumentation example

(Note: - The number of instruments are indicative only)