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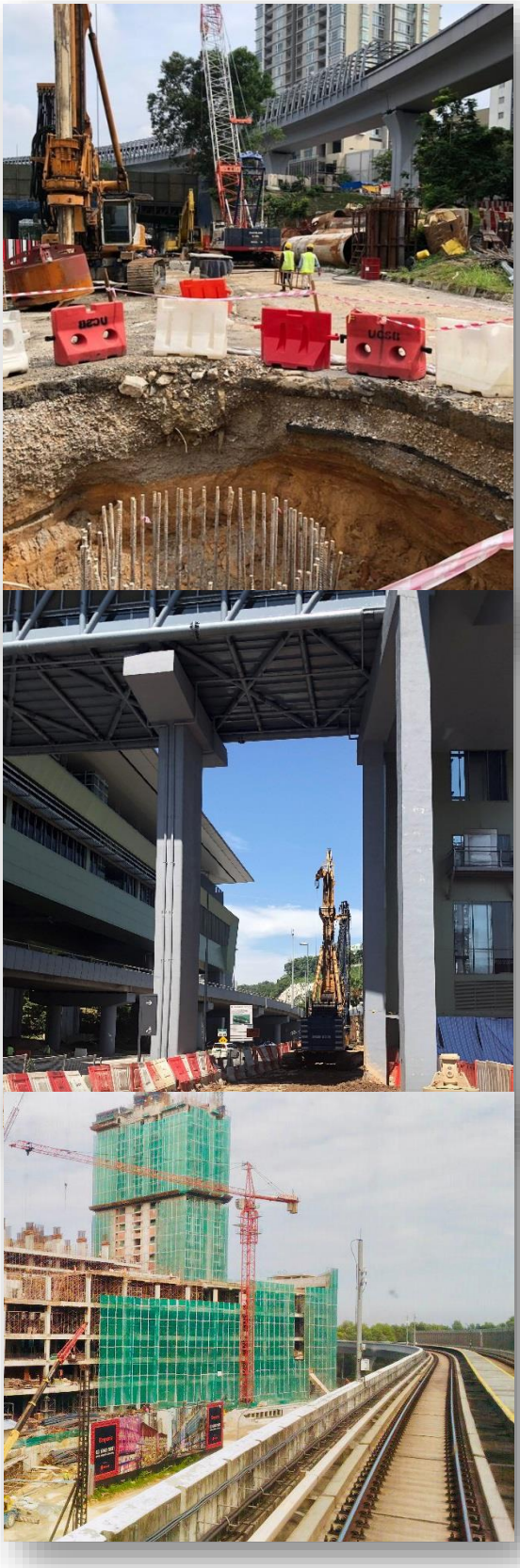


Instrumentation & Monitoring Guidelines for Works Within MRT Railway Protection Zone

December 2018 Edition

MRT Corp Development Building Control (DBC)

REVISION HISTORY

REVISION NO	Date	DETAILS OF AMENDMENT
00	11 December 2018	First Release

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

1.0 General

This guideline outlines the minimum requirements for instrumentation and monitoring works to be carried out by the Project Proponent for development and building works in Railway Protection Zone (RPZ) in accordance with Railways (Railway Protection Zone) Regulations 1998. Mass Rapid Transit Corporation (MRT Corp) reserves the right to impose any additional requirements deemed necessary to safeguard the MRT system. The submitting Professional Engineer shall be responsible to the monitoring report for Works within MRT RPZ.

2.0 Instrumentation

The instrumentation proposal shall be prepared and endorsed by a Professional Engineer (with valid Practicing Certificate) who is registered with the Board of Engineers, Malaysia. The objectives of the instrumentation shall be aimed, but not limited, to provide confirmation of the predicted behaviour of the railway structures during the execution of development and building works and, if required, to enable the further assessment of the long-term effects of the proposed works on railway system and structures. It shall enable the works to be carried out safely and soundly at every stage and provide a record of performance. Where required, it enables appropriate contingency measures to be implemented in time.

2.1 Ground Instrumentation

2.1.1 The ground shall be monitored for changes in ground / groundwater conditions and ground movements which may result from the proposed development and building works.

2.1.2 The proposed ground instrumentation shall be appropriate to the ground conditions and adequately provided to a degree that any adverse changes to the ground conditions can be captured.

2.1.3 The ground instrumentation listed in Tables 1a, 1b and 1c shall be provided where applicable.

2.2 MRT Structure and Track Instrumentation

2.2.1 The MRT structures and tracks shall be monitored if the proposed development and building works have implications on the integrity of the railway structures and system as well as its operation.

2.2.2 The monitoring instruments shall be adequately provided to a degree that any adverse changes or impacts to the MRT structures and tracks can be captured.

2.2.3 The structure and track instrumentation listed in Tables 1a, 1b and 1c shall be provided where applicable.

2.2.4 The MRT tunnels shall be monitored for any movement and distortion along its length at intervals of not more than 5m within the predicted zone of influence (at least two times the depth of excavation). At least five points around tunnel ring shall be monitored with two points below the tunnel spring line as shown in Figure 1.

Table 1a: Instrumentation at Underground and Portal Structures for Works within Railway Protection Zone

Type of Monitoring Instruments			Underground and Portal Structures			
			Foundation Works		Excavation Works	
			In First Reserve (If permitted) *	In Second Reserve	In First Reserve (If permitted) *	In Second Reserve
On Ground	Vertical Movement	Settlement Marker	Yes	Yes	Yes	Yes
		Extensometer	Yes	Yes	Yes	Yes
	Lateral Movement	Inclinometer	Yes	-	Yes	Yes
		Displacement Marker	Yes	-	Yes	Yes
	Groundwater	Open Standpipe	Yes	-	Yes	Yes
		Piezometer**	Yes	-	Yes	Yes
On MRT Structures and tracks	Vertical Movement	Building Settlement Marker or Optical Prism	Yes	Yes	Yes	Yes
	Lateral Movement	Optical Prism	Yes	Yes	Yes	Yes
	Distortion	Tiltmeter	Yes	Yes	Yes	Yes
		Electrolevel Beam	Yes	Yes	Yes	Yes
	Vibration	Vibrometer	Yes	Yes	Yes	Yes
	Tunnel Movement	Optical Prism (Convergence Method)	Yes	Yes	Yes	Yes
		Electrolevel Beam	Yes	Yes	Yes	Yes
	Crack Measurement	Crack Meter	Required if there are existing/ new cracks that maybe aggravated by the development and building works			

Notes:
* Borehole drilling for installation of ground instrumentation is strictly not permitted within MRT First Reserve.
** The type and depth of piezometer to be agreed between MRT Corp and submitting Professional Engineer.

Table 1b: Instrumentation at Above-Ground Structures for Works within Railway Protection Zone

Type of Monitoring Instruments			Above-Ground Structures			
			Foundation Works		Excavation Works	
			In First Reserve (If permitted)	In Second Reserve	In First Reserve (If permitted)	In Second Reserve
On Ground	Vertical Movement	Settlement Marker	Yes	Yes	Yes	Yes
		Extensometer	Yes	-	Yes	Yes
	Lateral Movement	Inclinometer	Yes	-	Yes	Yes
		Displacement Marker	Yes	-	Yes	Yes
	Groundwater	Open Standpipe	Yes	-	Yes	Yes
		Piezometer*	Yes	-	Yes	Yes
On MRT Structures and Tracks	Vertical Movement	Building Settlement Marker or Optical Prism	Yes	Yes	Yes	Yes
	Lateral Movement	Optical Prism	Yes	-	Yes	Yes
	Distortion	Tiltmeter	Yes	-	Yes	Yes
		Electrolevel Beam	Yes	-	Yes	Yes
	Vibration	Vibrometer	Yes	Yes	Yes	Yes
	Crack Measurement	Crack Meter	Required if there are existing/ new cracks that maybe aggravated by the development and building works			

Note:
* The type and depth of piezometer to be agreed between MRT Corp and submitting Professional Engineer.

Table 1c: Instrumentation at At-Grade Structures for Works within Railway Protection Zone

Type of Monitoring Instruments			At-Grade Structure			
			Foundation Works		Excavation Works	
			In First Reserve (If permitted)	In Second Reserve	In First Reserve (If permitted)	In Second Reserve
On Ground	Vertical Movement	Settlement Marker	Yes	Yes	Yes	Yes
		Extensometer	Yes	-	Yes	Yes
	Lateral Movement	Inclinometer	Yes	-	Yes	Yes
		Displacement Marker	Yes	-	Yes	Yes
	Groundwater	Open Standpipe	Yes	-	Yes	Yes
		Piezometer*	Yes	-	Yes	Yes
On MRT Structures and Tracks	Vertical Movement	Building Settlement Marker or Optical Prism	Yes	Yes	Yes	Yes
	Lateral Movement	Optical Prism	Yes	-	Yes	Yes
	Distortion	Tiltmeter	Yes	-	Yes	Yes
		Electrolevel Beam	Yes	-	Yes	Yes
	Vibration	Vibrometer	Yes	Yes	Yes	Yes
	Crack Measurement	Crack Meter	Required if there are existing/ new cracks that maybe aggravated by the development and building works			

Note:
* The type and depth of piezometer to be agreed between MRT Corp and submitting Professional Engineer.

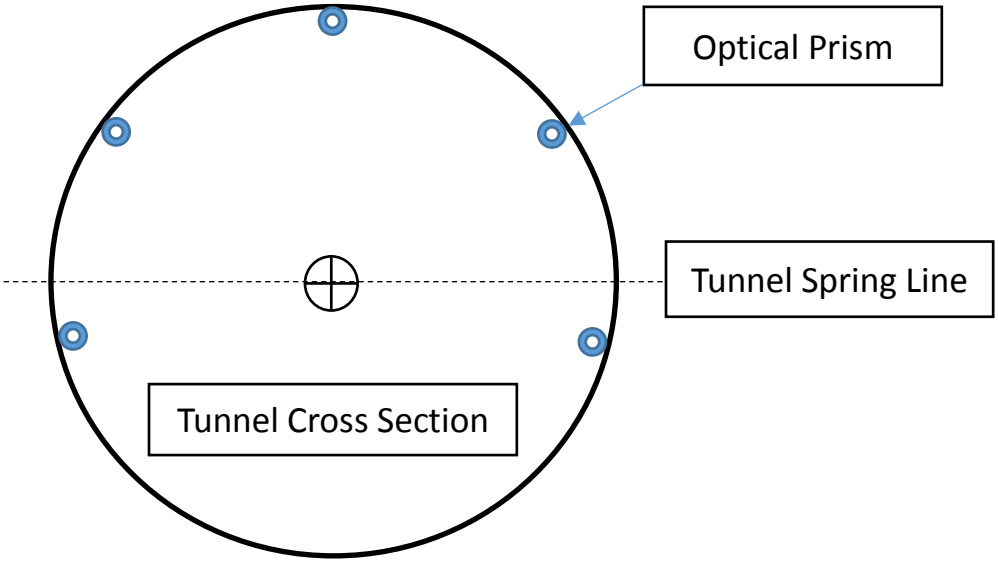


Figure 1: Typical Array of Tunnel Convergence Monitoring

2.3 Calibration

2.3.1 The monitoring instruments used shall have calibration done within the last 6 months prior to installation. The certificates of calibration shall be submitted to MRT Corp for record.

2.4 Protection of Monitoring Instruments

2.4.1 The Project Proponent shall be responsible for the protection of all monitoring instruments. MRT Corp shall be notified immediately of any damaged instruments. Damaged instruments shall be promptly replaced or reinstated within 14 days to the acceptance of MRT Corp. Meanwhile, the abandoned drilling hole for the damaged instrument shall be closed and properly backfilled with approved materials (e.g. cement bentonite grout).

3.0 Monitoring

Where the cumulative movement of the underground or at-grade MRT structures and tracks are expected to exceed 5mm, a real-time monitoring of the structures and tracks shall be provided. In any cases, an automatic remote-control monitoring system shall be provided for MRT operating tunnels. MRT above-ground structures may be monitored manually, however, real-time monitoring shall be required depending on the nature and criticality of the construction works.

3.1 Accuracy of Readings

3.1.1 The readings shall attain the level of accuracy when monitoring instruments are installed properly and maintained in good working condition. The Project Proponent shall be responsible for the accuracy and reliability of all readings during the monitoring periods.

3.1.2 The readings taken by automatic tunnel monitoring system must be consistent and stable. The deviation from the mean readings which is taken as actual reading must be less than +/- 1mm for 90% confidence level. Provision shall be made for regular manual monitoring to confirm the continued accuracy of the system.

3.1.3 Manual survey shall be carried out using 1sec theodolite and distance accuracy of 1mm +/- 2ppm or better. The results shall be certified by Licensed Surveyor for submission to MRT Corp.

3.1.4 Sufficient control and reference points shall be located outside the zone of influence of the construction works and such that they do not impact on the accuracy of monitoring results. In addition, control points must be located on very stable structures which would not be affected by the adjacent developments.

3.2 Baseline Readings

3.2.1 Baseline readings shall be taken at least one (1) month prior to commencement of any construction activities. The most representative readings of the baseline condition taking into consideration the effects of train operation and changes in ambient conditions such as vibration, changes in air pressure and temperature shall be taken as the base readings.

3.2.2 The construction works within railway protection zone will not be allowed to commence until all instrumentation is in place and baseline readings have been submitted and accepted by MRT Corp.

3.3 Monitoring Frequency

3.3.1 The monitoring frequency specified in Table 2 shall apply when active construction works or any other works that could potentially lead to significant changes in the conditions of ground or MRT structures and tracks. The frequency may be relaxed according to the stages of construction as well as the relationship between the monitoring instruments and areas of current activity subject to acceptance from MRT Crop.

3.3.2 MRT Corp reserve the right to change the monitoring frequency based on case to case basis.

Table 2: Monitoring Frequency for Works within Railway Protection Zone

Type of Monitoring Instruments			Underground and Portal Structures	Above-Ground Structures	At-Grade Structures
On Ground	Vertical Movement	Settlement Marker	Daily	Twice weekly	Twice weekly
		Extensometer	Daily	Twice weekly	Twice weekly
	Lateral Movement	Inclinometer	Daily	Twice weekly	Twice weekly
		Displacement Marker	Daily	Twice weekly	Twice weekly
	Groundwater	Open Standpipe	Daily	Twice weekly	Twice weekly
		Piezometer	Daily	Twice weekly	Twice weekly
On MRT Structures and Tracks	Vertical Movement	Building Settlement Marker or Optical Prism	Daily	Twice weekly	Twice weekly
	Lateral Movement	Optical Prism	Daily	Twice weekly	Twice weekly
	Distortion	Tiltmeter	Daily	Twice weekly	Twice weekly
		Electrolevel Beam	Daily	Twice weekly	Twice weekly
	Vibration	Vibrometer	Continuous*	Continuous*	Continuous*
	Tunnel Movement	Optical Prism	Continuous*	-	-
		Electrolevel Beam	Continuous*	-	-
	Crack Measurement	Crack Meter	Weekly (where applicable)	Weekly (where applicable)	Weekly (where applicable)

Note:
*High level monitoring frequency to be agreed with MRT Corp.

3.4 Termination of Monitoring

3.4.1 The monitoring shall continue until all works that may affect the movement of the MRT structures and tracks have been completed and monitoring readings shall show that both the MRT structures and tracks and surrounding ground have stabilized and no further movement or change would be anticipated in the long term. In any cases, sub-structural works must be completed before termination of monitoring. If the construction of superstructure is expected to affect adversely on the ground conditions and MRT structures and tracks, monitoring shall be continued until their completion and stable readings obtained.

3.4.2 For termination of monitoring, a closing monitoring report shall be prepared and endorsed by the submitting Professional Engineer for acceptance by MRT Corp. All the drilling holes for monitoring instruments shall be closed and properly backfilled with appropriate materials approved by MRT Corp.

4.0 Review Level and Control

4.1 Review Levels

4.1.1 Instrumentation readings shall be monitored against the Alert, Action and Alarm (AAA) trigger levels or review levels as defined for individual monitoring instruments. The values for review levels shall form part of design submission.

4.1.2 The Alert Level and Action Level are two stage readings at predetermined level prior to the Alarm Level; for example, 50% and 80% of the values specified at Alarm Level. The Alarm Level is defined as the anticipated value based on the impact assessment or the relevant limiting control values as per Table 3, whichever is more onerous. Levels predicted in the design shall be set for each of critical stage of construction.

Table 3: Limiting Control Values for Monitoring of Works within Railway Protection Zone

Type of MRT Structures		Railway Structures and Tracks				Piezometric Changes (kPa)
		Surcharge Load at ground level (kPa)	Total Movement in any direction (mm)	Differential Movement in any plane*	Peak Particle Velocity (mm/sec)	
Underground and Portal	Tunnel	50	<15	< 1/2000	<15	<10
	Station	25	<15	< 1/2000	<15	
Above-Ground	Viaduct	25	<15	< 1/2000	<15	<10
	Station	25	<15	< 1/2000	<15	
At-Grade	Embankment	25	<15	< 1/2000	<15	-
	Cutting	25	<15	< 1/2000	<15	-

Note:
* For railway track, it is measured at 3mm in 6m longitudinally.

4.1.3 The submitting Professional Engineer shall continuously monitor the effects of construction works on the MRT structures and tracks and the surrounding ground. He shall analyse the monitoring results, predict the likely trends and notify MRT Crop of any deviation from the predicted results and trends. He shall also make proposal to change the method of working or to implement mitigation plan as a result of monitoring. The submitting Professional Engineer shall be responsible for the interpretation of factual monitoring results for the installed instruments with relation to the work construction sequence and endorse the interpretation report for submission to MRT Corp.

4.2 Control Measures and Procedures

4.2.1 Principally, if the Alert Level is reached, the related monitoring data shall be reviewed and construction shall be closely monitored and supervised. If the review concludes that the ground responses and structures perform as per design, work can proceed. If the review shows the Action Level is likely to be exceeded, the contingency / mitigation measures shall be proposed and agreed upon with MRT Corp. The Project Proponent shall immediately instigate the approved contingency measures when the Action Level is breached at any location. Works may proceed if the contingency / mitigation measures have been implemented and are in the opinion of the submitting Professional Engineer to be effective, subject to MRT Corp acceptance. If any reading exceeds the Alarm Level, the related part of the works shall be made safe and ceased until a full re-assessment is completed and remedial measures are implemented to ensure safety of the MRT system.

4.2.3 The submitting Professional Engineer shall develop the conceptual contingency / mitigation measures as part of design submission.

4.2.4 MRT Corp is to be immediately informed within 24 hours of breaching AAA levels as per procedures outlined in Figures 2a, 2b and 2c.

Figure 2a: Breaching of Alert Level

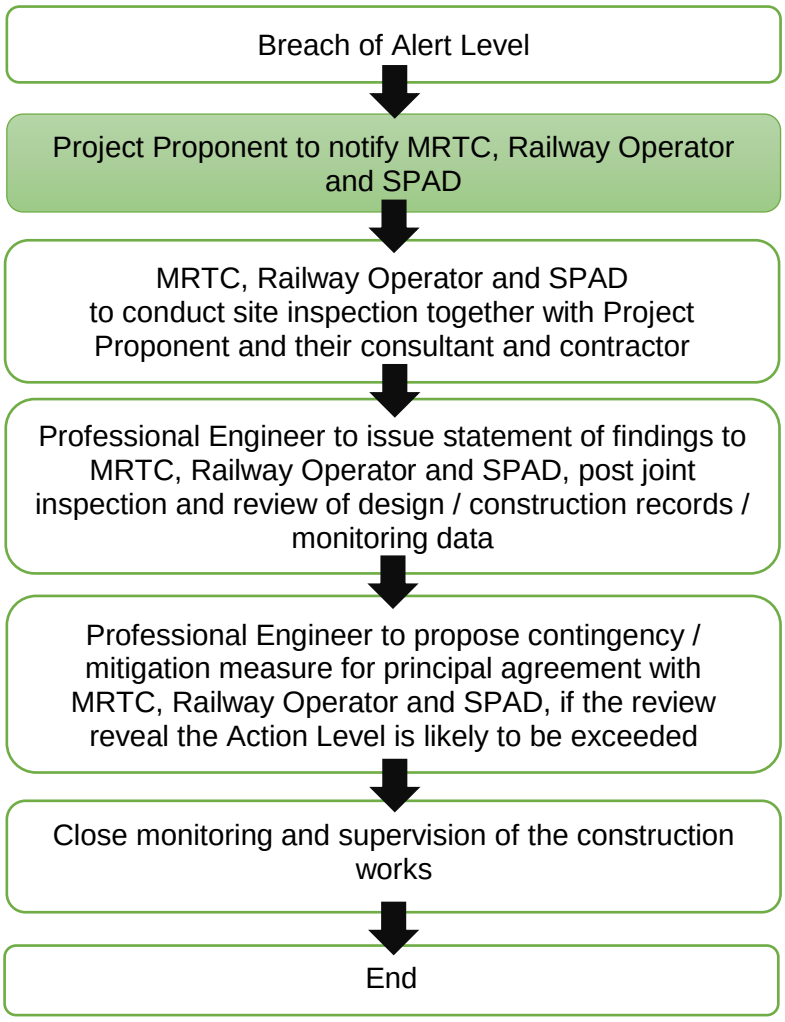


Figure 2b: Breaching of Action Level

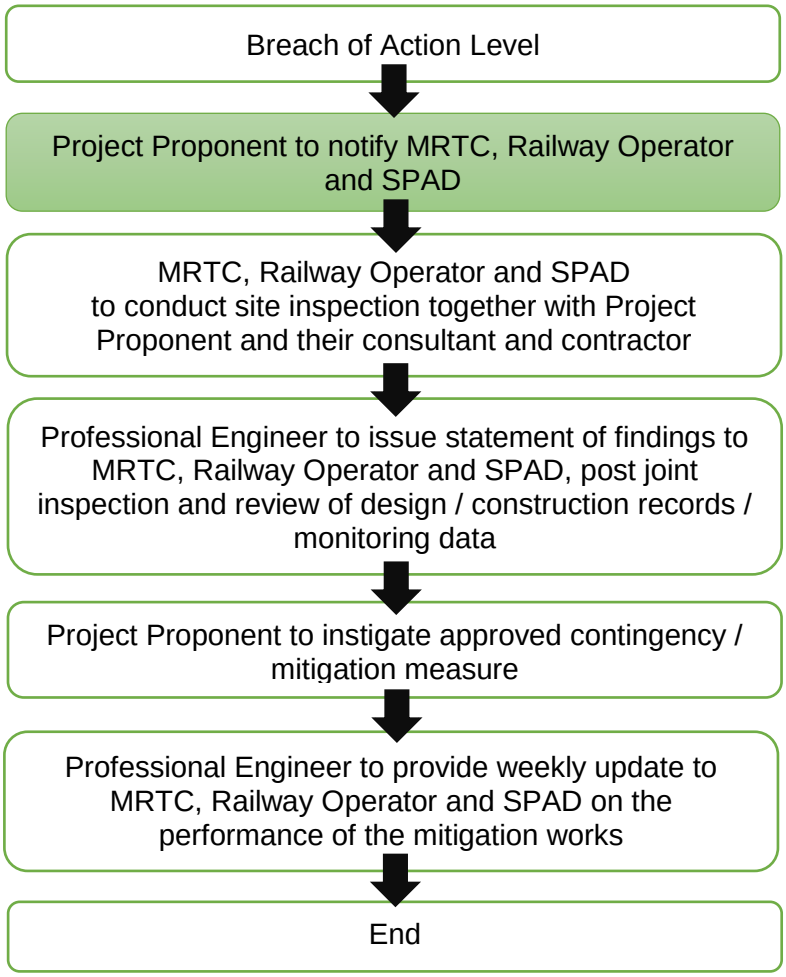
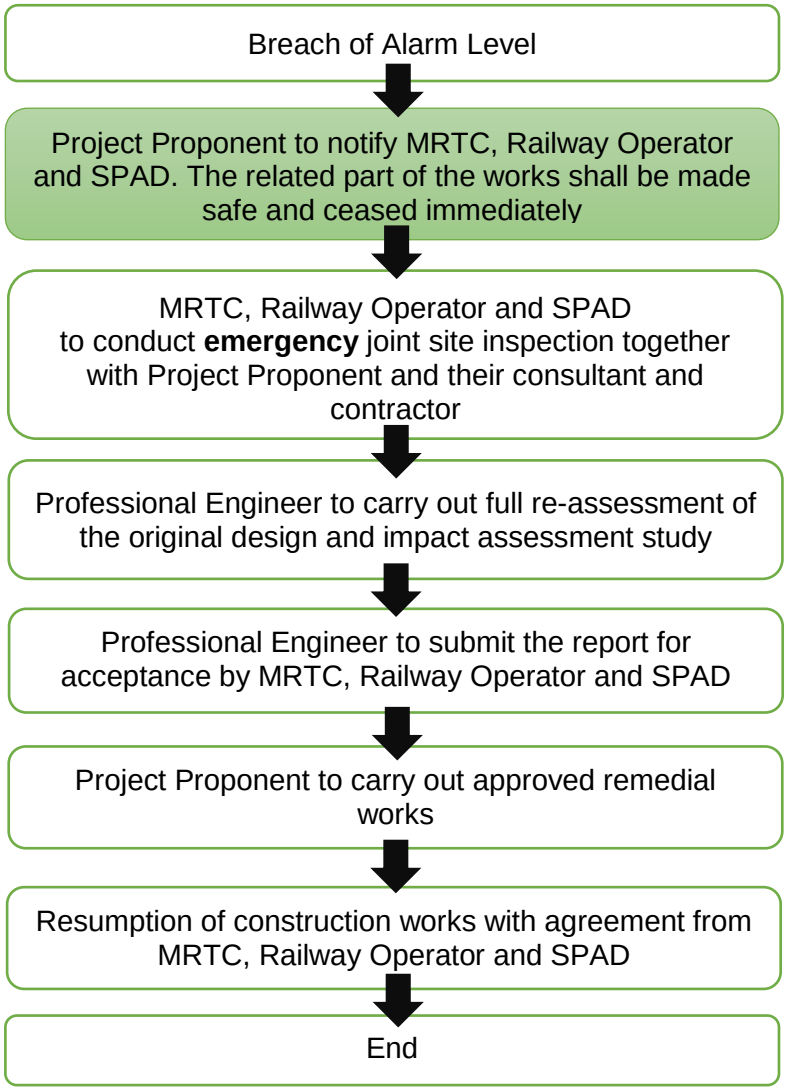


Figure 2c: Breaching of Alarm Level



5.0 Submission-related

5.1 Instrumentation & Monitoring Proposal

5.1.1 Instrumentation proposal shall be prepared and endorsed by the submitting Professional Engineer for the acceptance by MRT Corp. The proposal shall include the following items, but not limited to:

a) Comprehensive instrumentation system to monitor the behavior of the existing MRT structures and the ground adjacent to it;

b) Layout plans and relevant cross-sections indicating the locations of proposed monitoring instruments relative to the MRT structures and railway reserves;

c) Details of the monitoring instruments or equipment, including the types, function of instruments, depth of installation, etc.;

d) Frequency of monitoring;

e) Review levels (AAA) and control procedure; and

f) Specification of monitoring instruments (if relevant).

5.2 Method Statement of Instrument Installation Works

5.2.1 Method statement for carrying out the installation works shall be submitted for acceptance by MRT Corp. The proposal shall be accompanied by the following items, but not limited to:

a) Layout plan and cross-sections showing the location/ depth of the monitoring instruments relative to the MRT structures and railway reserves;

b) Write-up and/ or plans indicating step-by-step sequence of carrying out the installation works and monitoring activities;

c) Hazard analysis identifying all possible risks that may be posed to the MRT system and a description of the safety and precautionary measures to mitigate these risks; and

d) Product information and samples (if necessary).

5.3 As-built Instrumentation and Baseline Readings

5.3.1 The submitting Professional Engineer shall also provide MRT Corp with location reference plans for all 'as-built' instrumentation, which shall include coordinate, existing ground level and depth (if relevant).

5.3.2 Baseline readings shall be submitted for the acceptance by MRT Corp before commencement of construction works within railway protection zone.

5.4 Monitoring Report

5.4.1 Monitoring report shall be submitted to MRT Corp on a monthly basis and shall be endorsed by the submitting Professional Engineer. The monitoring report shall be accompanied with the interpretation which briefly summarizes and explains the factual data of the installed instruments as part of requirement outlined in Clause 4.1.3. The Project Proponent shall provide MRT Corp with the login details to view the automatic real-time monitoring data on online platform.

5.4.2 For termination of monitoring, a closing monitoring report shall be prepared and endorsed by the submitting Professional Engineer for acceptance by MRT Corp. All the drilling holes for monitoring instruments shall be closed and properly backfilled with appropriate materials approved by MRT Corp.