GEOTECHNICAL ASSESSMENT ON THE FAILURE AT MEETHOTAMULLA WASTE FILL

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1. INTRODUCTION

The garbage mound located at Pothwillkumbura, Meethotamulla, Kolonnawa collapsed on 14th April 2017 at 14.45 hrs., destroying houses and infrastructure situated at the toe region of the south-western side of the garbage mound. According to the situation report of "***Meethotamulla Municipal Solid Waste Dump Disaster***" by the Disaster Management Center, 60 houses have been completely destroyed, 27 houses partially damaged while 32 bodies have been recovered from the damaged area. The Meteorology Department weather report indicated that there was an intense rainfall during 11th – 13th April 2017.

Soon after the failure, a team of experts of National Building Research Organisation (NBRO) visited the site to investigate the existing situation, to determine the probable cause of failure and to identify possible remedial actions to prevent further catastrophic situations.

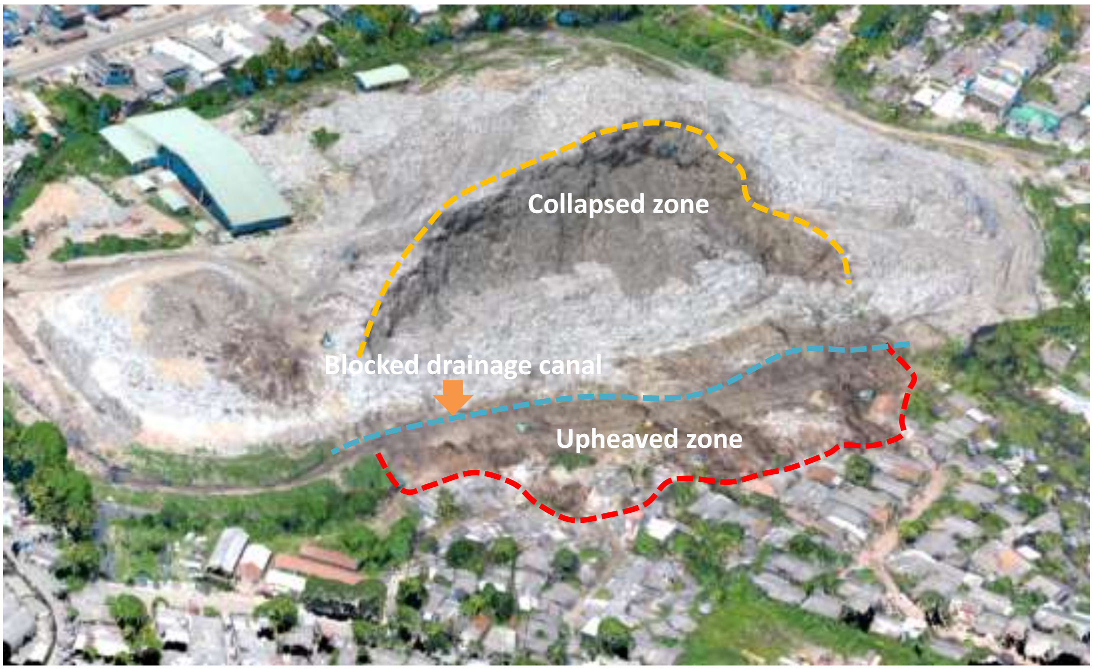


Figure 1: Aerial image indicating the failure face of the waste fill

According to the eye witnesses the collapse had taken place initially as a progressive failure followed by an accelerated movement and then it had come rest while smashing a section of South Western (SW) toe area. At the time of investigations there were no notable movements of waste or ground.

The on-site observations and aerial images after the incident show that a part of SW side slope of the waste fill had collapsed at its crest height, and the collapsed mass had almost moved down and subsided, while the toe region of the slope had upheaved **(Figure 1).** Furthermore, the collapse had made the SW canal section completely blocked due to lateral movement and ground upheaving. This was causing minor flood situation by blocking the flow from East to West, and as a result the houses at the South East (SE) side were partially inundated.

The interpretations, analyses, conclusions and recommendations presented in this report are based on the information gathered at the site after the incident by visual observation, drone image surveys, geotechnical investigations conducted during previous occasions, published literature on similar incidents in other countries, analysis of slope stability using geotechnical modeling software, and opinions based on best professional judgment by a team of experts from relevant disciplines.

1.1. Details of the Waste Dump Site

1.1.1. Location of the site

The Meethotamulla Waste Dump site is located about 4.0 km East of Colombo and can be accessible when travelled along the old Avissawella road (Low-level Road). The administrative boundaries are Western Province, Colombo District, Kolonnawa

Figure 2: Location and the surrounding details of the Municipal Solid waste dump Site-Meethotamulla

The aerial imagery shows that before 1990, this location had been a low-lying, marshy ground **(Figure 3).** At this time the terrain had been almost flat, and there was no indication of inhabitants within the area marked by the red line in the **Figure 3**.

The analysis of previous records at this site reveals that the site had been used for waste dumping even before 1998. With the urban growth and rapid development, the location has been receiving waste in increasing amounts in subsequent years. Initially, the site had received waste only from the Kolonnawa area. But, due to the closure of the Bloemendhal solid waste dump, the waste of Colombo Municipal Council area was also dumped at the site.

According to the Colombo Municipal Council, at the time of disaster, approximately 800-900 tons of waste were being dumped at the site daily. Over the time, people have settled in the area by gradually filling the marshland. The Google images of the site in Figure 3 show the lateral expansion of the waste fill and occupation of the marshland by houses over the time since 1990.

1.1.2. The type of the waste fill and operational details

The on-site investigations reveal that this waste fill is an unregulated open fill where waste of all forms is dumped. The waste appear poorly compacted with no or thin cover soil while waste material is dumped on bare soft soils without any bottom liner. Also, no leachate or a gas collection system are installed. Only a shallow canal is present around the waste fill to collect the leachate which is generated in combination of rainfall infiltration and as a byproduct from decomposition of waste.

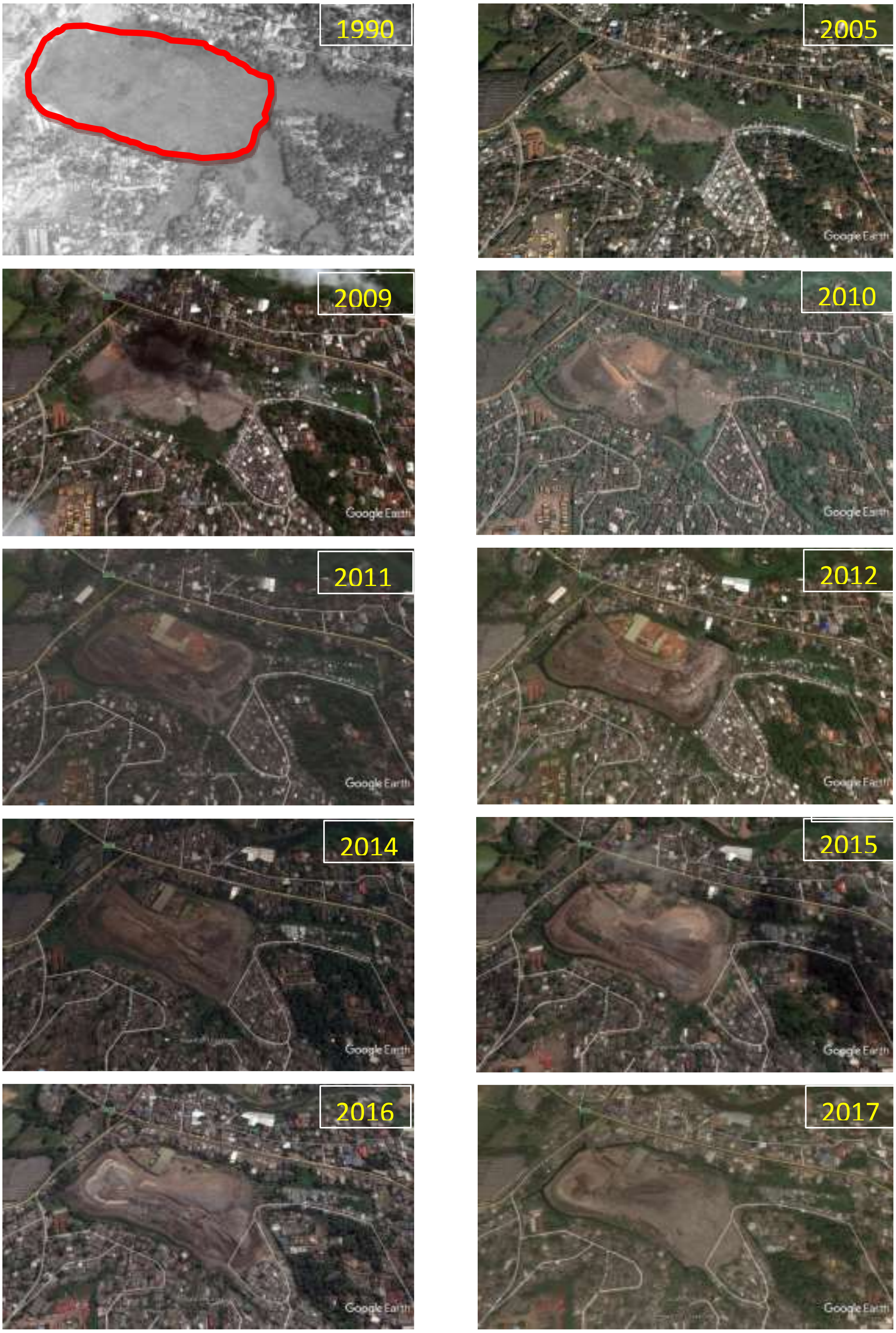


Figure 3: Aerial photo and Google images at the site showing lateral expansion of the waste fill from 1990-2017: Note marshy ground in 1990 and progressive expansion of waste load and occupations of' mash by settlements over the time

1.1.3. Geometry of the waste dump at the time of failure

The geometry of the waste dump at the time of failure were studied by visual imaging at site by experts, drone imagery and by studying the failure patterns. However, pre failure geometry couldn't be elucidated precisely, due to the limited availability of site information, pre-failure history and engineering documents.

Drone survey was conducted in the area to study the physical geometry, and to obtain spatial data and cross sections of the waste dump. The spatial data obtained from the drone survey shows that at the time of collapse, the dump has occupied an area of 78000 m^2, having a maximum length of approx. 413m in the NW to SE direction and a approx. width of 189 m in NE and SW direction. The maximum crest height of the mound was in the range of 45- 50m. At this height, the garbage placement has made a ridge like shape in the NW to SE direction, and its slope inclination towards SW direction was in a range of 35^0-60^0 **(Figure 4).** Compared to the failed segment of the waste fill, the rest of the segments are low in height and inclination.

Figure 4: Spatial details of the Municipal solid waste dump in February 2017 before the collapse: Source: Google earth

2. OBJECTIVES OF THE STUDY

The study comprises of following objectives:

- To establish the factors and conditions that have triggered the failure
- To assess the stability condition of the waste fill after the failure
- Analyze and report future risk of failure
- Propose short term remedial measure to minimize immediate risks of failure and associated impacts

3. THE STUDY METHODOLOGY

In order to achieve the objectives mentioned in Section 02, efforts have been made to collect information pertinent to the site conditions and failure as much, and as accurate data as possible. Accordingly, pre-failure site conditions and site operation activities that could possibly contributed to the waste slide were investigated and documented.

After evaluating the information on pre-failure site conditions, the visual inspections at the site following detailed studies were decided:

- Detailed assessment on site condition pertaining to nature of collapse
- Study previous incidents of ground movement and instability
- Study the underlain soil profiles and properties at the site
- Study the profile picture of the waste fill considering it material properties, age and nature of waste management, and considering these facts respective engineering properties and parameters of the waste fill were determined reviewing literature on similar studies published journals.
- Numerical model analysis was conducted to assess the stability of the waste fill along the failure section and as well as other sections

4. SITE CONDITION PERTAINING TO NATURE OF COLLAPSE

Geometry of the waste fill and other spatial data are described in the Section 1.1.3. Due to irregular geometry of the waste fill, pre-failure geometry cannot be evaluated and therefore, correct estimation on volume of waste cannot be deduced. However, according to the available information on spatial data in year 2015, the maximum height of the waste fill was 5m below the current level (43.5m). Assuming that there is an increment of 10% in volume since 2015 until present, the volume of waste, which was subsided, is estimated to be about 72,342 m^3.

Soon after the incident, a series of cracks oriented perpendicular to the axis was clearly observed within the subsided segment of the waste fill. But, no cracks could be observed at the crest of the waste fill soon after the incident. Through the site inspection, it was revealed that several uneven cracks, slumps, inverted earth blocks etc. existed within the upheaved zone. No significant cracks were observed entirely over the other segments of the waste mound.

The observation soon after the failure revealed that there was seepage of water from the failure surface. Also, the lower portions of the exposed section of the waste fill appeared wet after the collapse and at this time the water table was observed to be as closer to the ground level.

4.1. Subsoil profile at the site

The soil formations and hydrology pertinent to ground movement are important information because behavior of the subsurface depends greatly on critical parameters such as water table, degree of soil saturation and other shear strength parameters inherent to underlain soil formation. Therefore, on-site investigations, analysis of borehole data and other geotechnical parameters obtained from previous investigations were used to study shear strength properties of prevailing subsurface conditions.

4.1.1. Types of soils and formation

The waste site area comprises of Bog and Half-bog soils and Red Yellow Podzolic soils with soft or hard laterite (Dr. C.R. Panabokke in 1996). They are characterised by grey brown to yellowish brown top soils & mostly yellow or yellowish red subsoil, which has developed on the deeply weathered gneisses, the latter are often associated with lateritic caps and alluvium. The top soil is replaced with, peat, organic silt, organic clay and silty sand.

The Lateritic formation was observed as a thick stratum from 3-5 meters depth to 8-10 meters depth level on completely weathered rock throughout the area. The sub soil profile drawn based on borehole in the site shows that the top most layer is soft peat/clay with a thickness varying from 2 – 8 m overlain by a residual formation. (Refer **Annexure I)**

4.2. The hydrology and drainage condition in the site area

The site is located in the wet zone of the country in lower basin of the Kelani River, which is a flat terrain characteristic with broader flood plains with spans of marshy lands. The hydrological regime of the area is governed mainly by the high rainfall most of the year. As the site is located in a marshy ground it is subjected to frequent storm water floods of varied intensities.

Figure 5: Surface drainage network in the site area

In 2016, most parts of the surrounding area of waste fill were completely inundated by heavy floods due to an extreme precipitation event. The storm water drainage has been a problem, as most of the reclaimed low-lying areas have no satisfactory gradient to facilitate natural drainage. The rate of water flow has reduced due to existing bottle neck places especially in culvert locations, resulting water logged condition generally throughout the year. The **Figure 5** shows the drainage system in the site area.

4.3. Previous incidents on ground movement and instability

The past records of ground movement and slope instability were assessed due to their significance to understand the behavior of subsurface soil layers and ground movement characteristics. Previous records on ground movement and instability were analyzed studying the investigations conducted in the past.

The analysis of historical records on waste dumping, ground movement/instability reveal that the site had been used for waste dumping after 1990 but, there were no indications or reporting of failure of the waste fill or movement of the ground until the first crisis recorded in 10th October 2012.

Collapse of houses and flooding in the SW section of the toe area of the waste fill had been reported in 10th October 2012. The canal, which was situated at the toe of SW slope had been deepened and widened to drain storm water which has inundated the houses during rain, and that could have initiated the failure. Due to this, the houses in the toe area had tilted, cracked and collapsed (**Figure 6**). At this time the height of the waste fill was about 28 m. (*Refer Detailed soil investigation for solid waste disposal site at Meethotamulla – February 2013*)

Figure 6: Ground movement and damages to houses due to deepening of' the drainage canal; which removed toe support in the toe region at the South-West section in Oct 2012: Source: NBRO: 2013

5. WASTE FILL & SUBSOIL PROFILES AND PROPERTIES

The most appropriate subsurface profiles were determined from the field observations and borehole investigations carried out by NBRO in year 1998 and 2012. Cross-sections were drawn with the aid of drone survey images produced by NBRO.

5.1. Properties of the waste fill

The properties of the waste fill under wet condition were considered in the stability analysis. The waste materials in landfills are greatly heterogenic in nature due to its composition, degree of compaction, decomposition etc. Therefore, respective shear strength parameters significantly differ over the waste fill. The shear strength decreases if the waste contains excess moisture, especially in upper part of waste fill (Yamawaki et al). Further, most of the degraded old waste has a relatively higher unit weight compared to fresh garbage, and as a result, unit weight increases with depth of the waste.

Considering above facts and with appropriate assumptions, the waste was categorized into four layers of varying thicknesses: Waste Fill (WF) – fresh waste in the top-most layer, Upper Waste (UW) - underlain by fresh waste, Intermediate Waste (IW) - followed by upper waste and partially decomposed and Lower Waste (LW) – immediately above the existing ground which is fully decayed.

The unit weights of the waste fill layers had to be accurately assigned in order to obtain a realistic model. To this end, average unit weight values were assigned to different waste layers by considering the assumed variations of compaction effect, cover soil content of the layers, overburden stress applied on each layer and the moisture content.

Since no actual shear strength parameters are available for waste material in Sri Lanka, the shear strength parameters for the analysis were obtained from published literature on engineering properties of waste materials. According to the following details given in Dixon et al; 2005, shear strength parameters were selected for the different waste layers incorporated for the study.

a. Corresponding to very low stress ($0 \text{ kP} \leq \sigma < 20 \text{ kPa}$) where the Waste behavior can be described as being only cohesive. In this case, C = 20 kPa

b. Corresponding low to moderate stresses ($20 \text{ kPa} \leq \sigma < 60 \text{ kPa}$). In this case, C=0kPa and $\varnothing \approx 38^{\circ}$

c. Corresponding to higher stresses ($\sigma \geq 60 \text{ kPa}$). In this case, C = 20 kPa and $\varnothing \approx 30^{\circ}$

The corresponding shear strength parameters and unit weight used in the stability analysis are given in table 1.

Table 1: Shear strength parameters considered for waste fill under wet condition

Waste Type	Notation	Υ(kN/m^3)	φ'	C'(kPa)
Waste 4 (WF)		5.0	0	20
Waste 3 (UW)		6.5	38	0
Waste 2 (IW)		8.0	30	20
Waste 1 (LW)		9.5	30	20

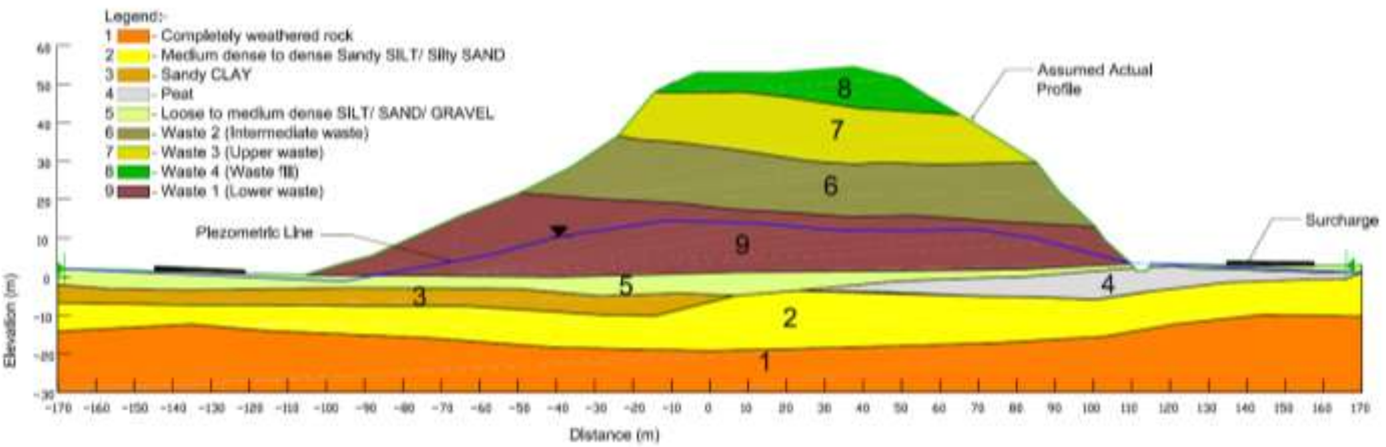
5.2. Properties of sub-soil layers

The strength parameters and the unit weight for soil layers were estimated from borehole investigation data, and past experiences related to same type of materials existing in Sri Lanka.

Table 2: Shear strength parameters considered for sub-soil layers of the waste fill site

Soil Type	Notation	ϒ(kN/m³)	φ'	C'(kPa)
Disturbed soil		12	10	10
Berm soil		13	20	10
Loose silt/sand/gravel		16	28	5
Sandy Clay		16	25	20
Peat		14	0	10
Medium dense sandy silt/ silty sand		17	30	10
Completely weathered rock		20	38	10

The assumed full cross section across the waste fill together with the subsoil profile and waste profile is shown in **Figure 7.**



6. ANALYSIS OF THE WASTE FILL STABILITY

Figure 8 shows the topography of the failure site generated from the drone images. The stability along 04 different cross sections were modelled covering all the critical areas of the waste fill site **(Figure 9)**. The most suitable profiles for the different cross sections of the waste fill were developed based on the visual observations and the expert judgment. The profiles generated for different cross sections are shown in the **Annexure-2** with the results of the model analysis.

Figure 8: Map showing the selected sections considered for Stability Analysis

Although, several factors may have contributed to the failure such as pre-failure slope geometry, strength parameters of the waste materials and subsoil, drainage conditions of the site, erosion, weathering etc. for the stability analysis, only pre-failure slope geometry, strength properties of waste material and subsurface soil, and the maximum possible water table were considered as the primary factors in the model analysis.

The stability analyses was carried out using GeoStudio 2016 from Geo Slope. The Spencer method was utilized in the analysis as the actual slip surface geometry of the failure was of an irregular in shape.

In order to describe the degree of stability of a slope, Factor of Safety (FoS) concept is used. The Factor of Safety (FoS) is defined as the ratio of the shear strength to shear stress required for equilibrium. If the value of FoS is less than 1.0, the slope is considered to be unstable, and a minimum requirement of FoS for short term stability is considered as 1.25 for this analysis.

6.1. Model Validation

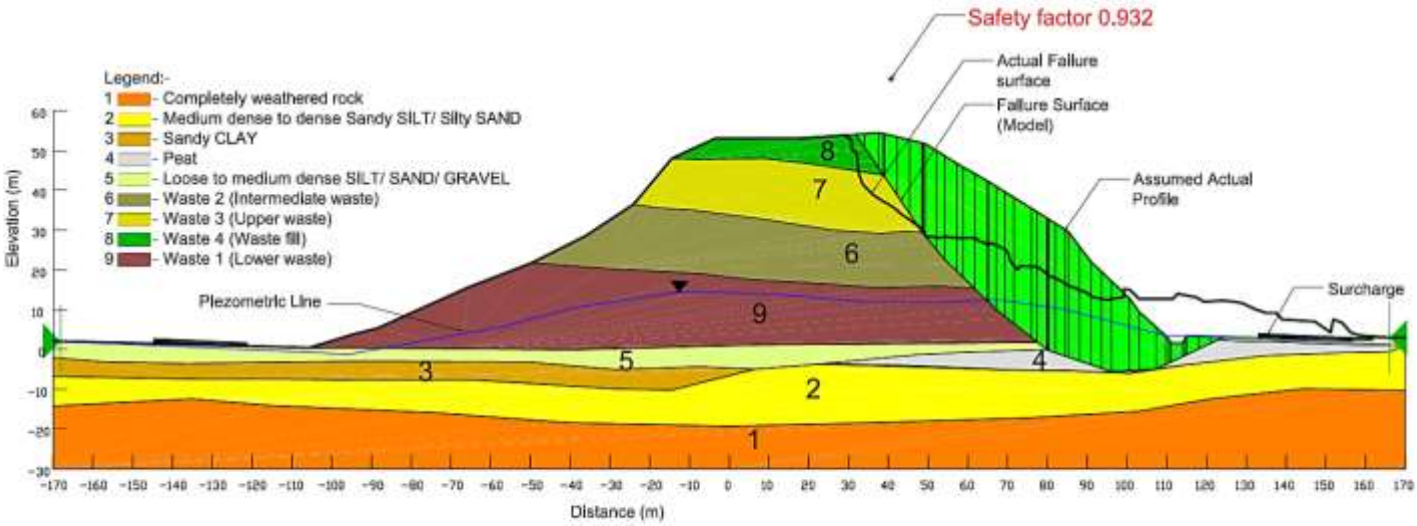


Figure 10: Results from Stability Analysis done for Section B-B

The applicability of the model was checked by carrying out an analysis for the full cross-section along Section B-B (**Figure 10)**. Stability analysis was carried out by considering the generated cross-section and assumed material properties given in the section 4.2 and 4.3. The results indicate that the instability occurs at the Right Hand Side (RHS) of the section (where exact failure took place) and further, the failure predicted by the model conforms to the actual failure condition. Therefore, the model seems to be capable for analyzing the section with the assigned parameters of the sub-soil and waste.

Stability analysis done for each cross section and their results are given in the **Annexure 2**.

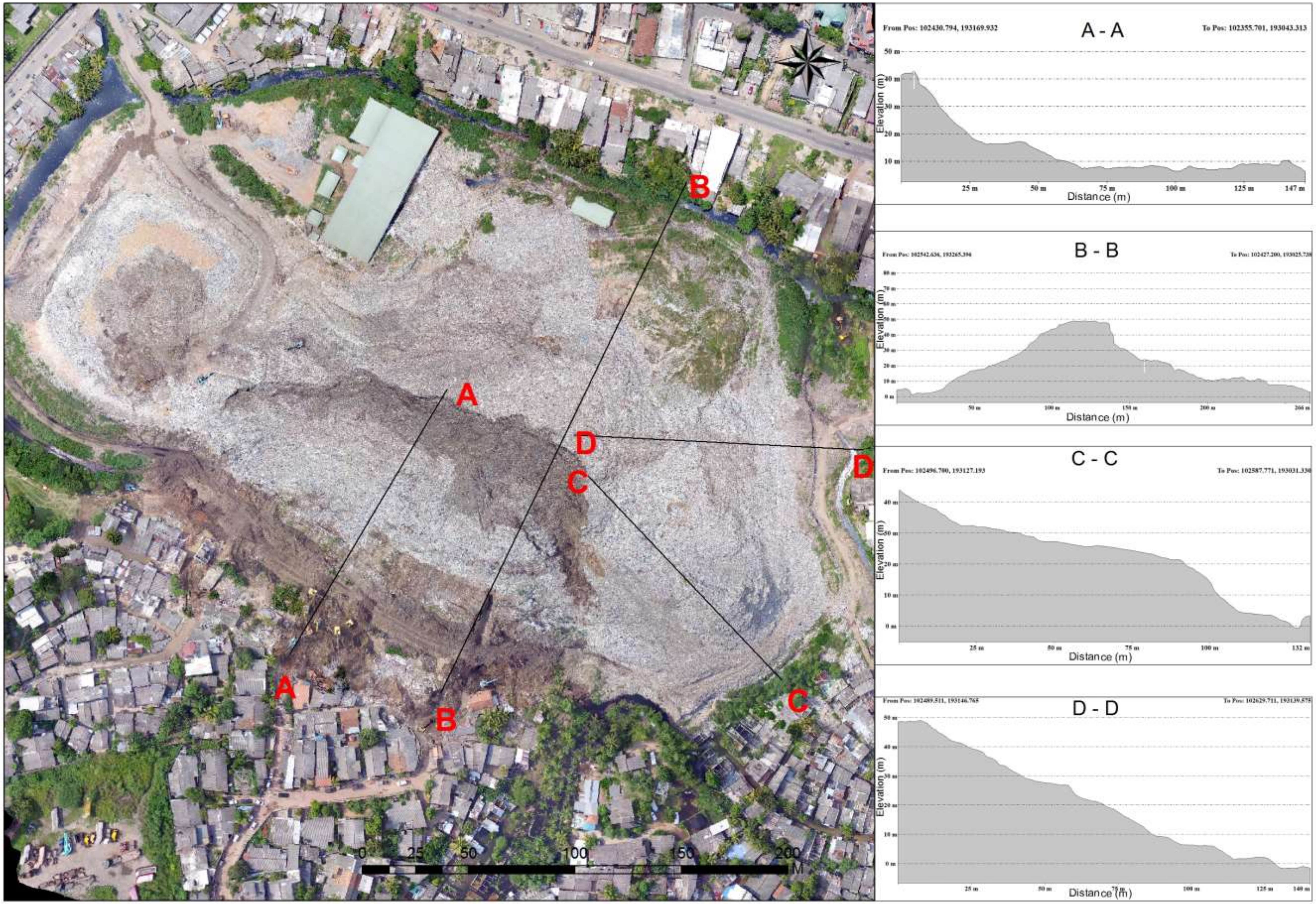


Figure 9: Cross sections selected for the stability analysis

6.2. Results and discussion

Stability analysis done for each cross section and their results are given in the **Annexure 2**. The calculated Factor of Safety values for the critical slip surfaces for each cross sections are presented as follows.

Table 3: Factor of Safety for the critical slip surfaces of the waste fill

Section	Figure No.	Remarks	Factor of safety
A – A	II	At the time of failure	0.807
B – B	III	At the time of failure - RHS	0.932
	IV	At the time of failure - LHS (direct opposite to failed area)	1.338
C – C	V	At the time of failure	0.813
D – D	VI	At the time of failure	1.276

The results clearly show that low factor of safety of 0.807 and 0.932 are at the failed sections A- A and B-B respectively.

In addition, the factor of safety of 0.813 calculated for the section C-C revealed that section C-C is also at unstable condition. Therefore, if the load imposed on the slope C-C is increased by further waste dumping or due to rapid rainwater infiltration, it may become unstable and collapse.

According to the results, Section D-D and LHS of the Section B-B stay at stable condition relative to the other sections with higher factor of safety greater than 1.25.

From the results of stability analysis it can be stated that the waste sections containing fresh garbage with higher fill height and greater slope angles underlain by very soft/soft soils are prone to higher risk of failure especially under wet condition. In contrary, the risk of failure is comparatively low for waste fills with older waste due to its decomposition, at low fill height and low slope angles, underlain with medium stiff/stiff sub soil and drainage conditions.

Moreover, the remediation work such as construction of earth berms in the toe area of the failed section and improvement of drainage have increased the stability of the failed section by a factor of 1.287 **(Annexure 2 – Figure VII)**.

7. PROBABLE CAUSE OF FAILURE

Considering the facts and findings of the investigations at site after the failure, analyzing the factors pertinent to previous incidents on ground movement at the site, and the outcome of waste fill slope stability the probable cause of failure of waste fill can be determined as follows.

The waste fill had been in a marginally stable condition prior to the rain spell. The additional increase of weight caused by the infiltration of the rainwater could have caused the instability in underneath soft soil resulting failure in the waste fill. Increase in water table and the decrease in shear strength in upper layer of the waste fill due to excessive moisture could have been the other contributory factors for the failure. As a consequence, a lateral movement of the peat layer in the direction of houses and a significant ground upheaving has taken place at the toe region. The houses/other built structures in the toe region were severely damaged. Further, the movements in the toe area had blocked the drainage canal passing through causing minor flood situation in the Eastern side.

8. RECOMMENDATIONS

- Considering the analysis, it is recommended that the houses demarcated red and yellow in **Figure 11** should be kept free from human occupation or future development activities under the present condition. At the present, the other areas are at relatively low risk. However, if the geometry of the waste fill is changed, the toe region is disturbed or the drainage conditions are altered without following correct stability norms, the low risk areas that are relatively stable at present may also become unstable.
- A comprehensive monitoring system (including monitoring rainfall intensity at site, movement of slopes and toe area, appearance of tension cracks, abnormal settlements of waste, water table fluctuations, cracks in building etc) should be implemented to identify possible waste fill instability and risks of failure in order to decide actions early. (Refer **Annexure 3**: Proposed Instrumentation Plan)
- The decision on emergency response should be based essentially on information obtained from proper monitoring system until a permanent remediation strategy is established. Therefore, the authorities should issue early warning and should carry out immediate evacuation when necessary based on the predicted risk of slope instability reported by the monitoring system.
- If rehabilitation projects such as re-configuration of slopes, drainage management and alternative development activities are envisaged, extreme care should be exercised to ensure that such activities are carried out with systematic assessment of site conditions including flood risk, and by application of proper engineering designs following correct construction norms, and also complying to the norms of environmental regulations with the involvement of competent professional institutions.

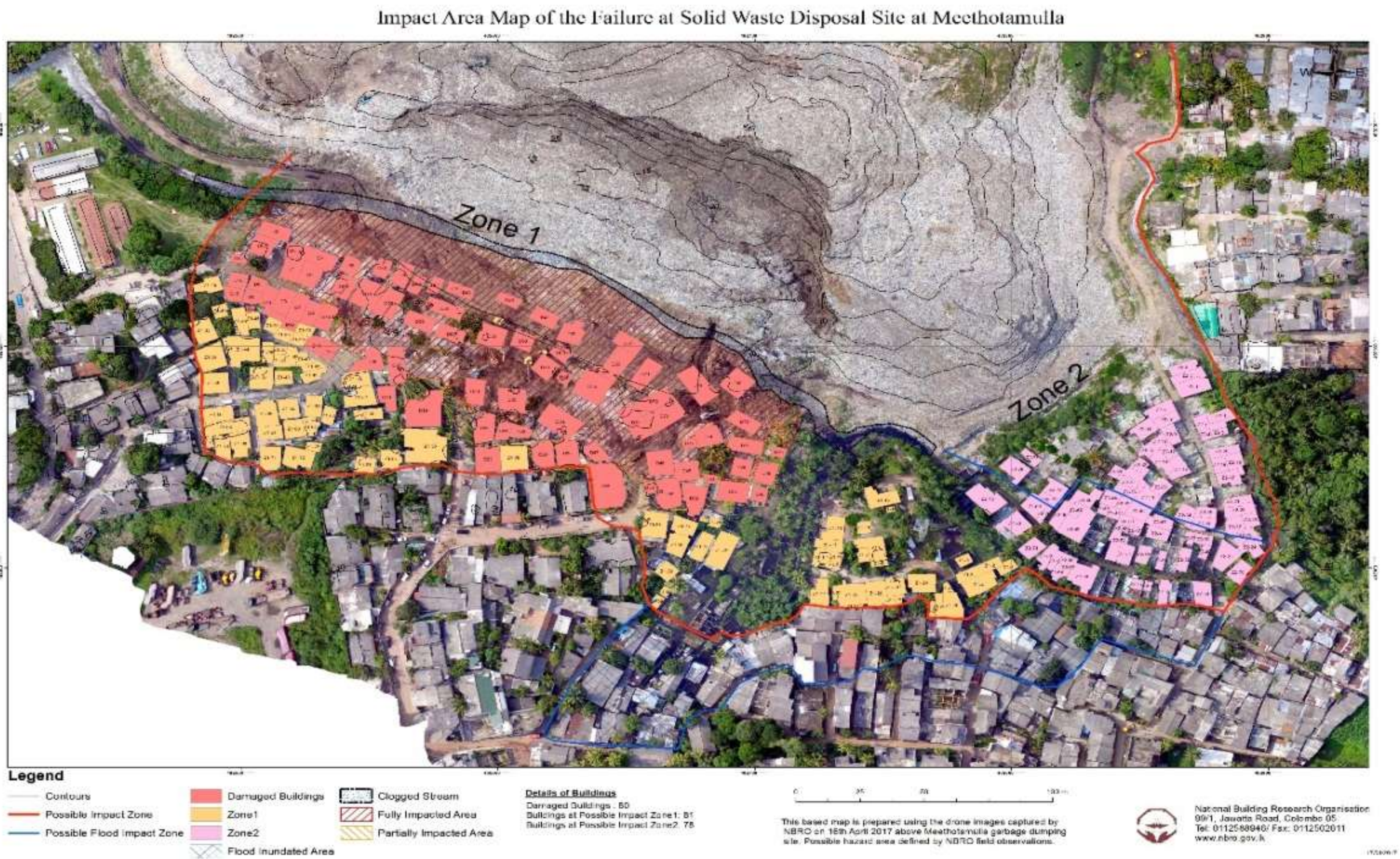


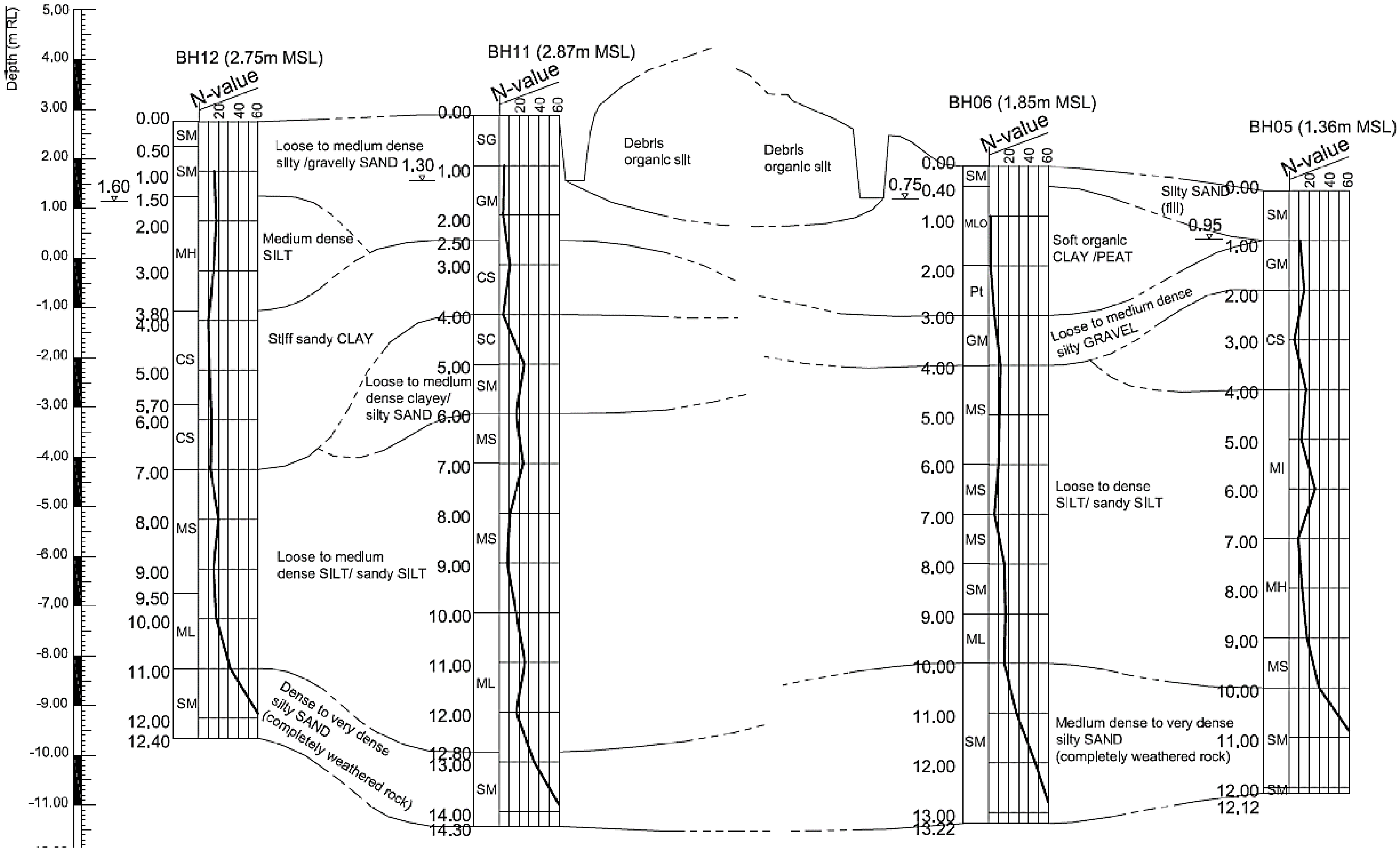
Figure 11: Impact area map of the failure at Waste fill site, Meethotamulla

9. REFERENCES

- D.P.Zekkos, J.D.Bray, E.Kavazanjian, N.Matasovic, E.Rathje, M.Riemer And K. H. Stokoe II, “Framework for the estimation of MSW Unit Weight profile,” proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium
- Gabr, M. A. and Valero, S. N., "Geotechnical Properties of Municipal Solid Waste," Geotechnical Testing Journal, GTJODJ, Vol. 18, No. 2, June 1995, pp. 241-251.
- Neil Dixon and D.Russell V.Jones, “Engineering properties of municipal solid waste”, Geotextiles and Geomembranes 23 (2005) 205–233.
- Nejan Huvaj-Sarihan and Timothy D. Stark., “Back-Analyses of Landfill Slope Failures,” 6th International Conference on Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16, 2008.
- S. Margherita di Pula, Cagliari, Italy; 3 - 7 October 2005 ©2005 by CISA, Environmental Sanitary Engineering Centre, Italy
- Timothy D. Stark, Nejan Huvaj-Sarihan & Guocheng Li, “Shear strength of municipal solid waste for stability analyses”, Environ Geol (2009) 57:1911–1923.
- Udeni P. Nawagamuwa and R.W.U. Nuwansiri, “Compaction Characteristics of Municipal solid Wastes at Open Dump Sites in Sri Lanka”, Geoenvironmental Engineering GSP 241 © ASCE 2014.
- Udeni P. Nawagamuwa, R. Rajeevan and W.U. Tharanga, “Study on the Strength Characteristics of MSW in Sri Lanka”, Research Gate Publications - Conference Paper, November 2015, DOI: 10.3208/jgssp.LKA-03
- U.P. Nawagamuwa and W.H.R.S. Dayarathne, “Slope Stability Analysis at Bloemendhal Open Dump Site in Sri Lanka”, World Landslide Forum 3.
- Yamawaki A, Omine K, Doi Y and Kawasaki M, “Slope Stability of Solid Waste Layers inside and outside of Japan”.

Annexure -1

Sub Soil Profile



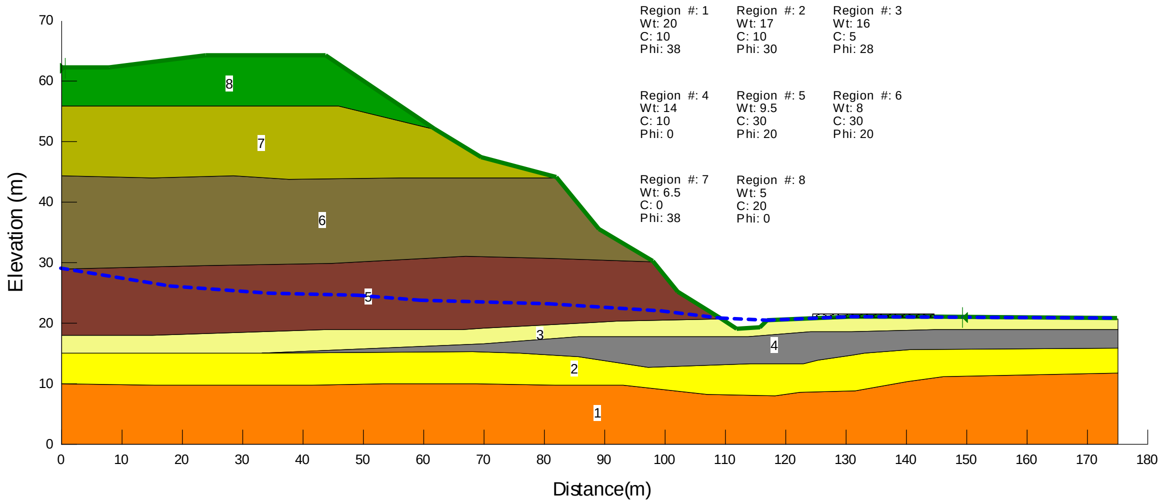
***Annexure I**: Subsoil profile drawn from the geotechnical investigations done in 2012/2013 at Meethotamulla waste fill site*

Annexure -2

Stability Analysis Results

(a) At the time of failure

Section A-A



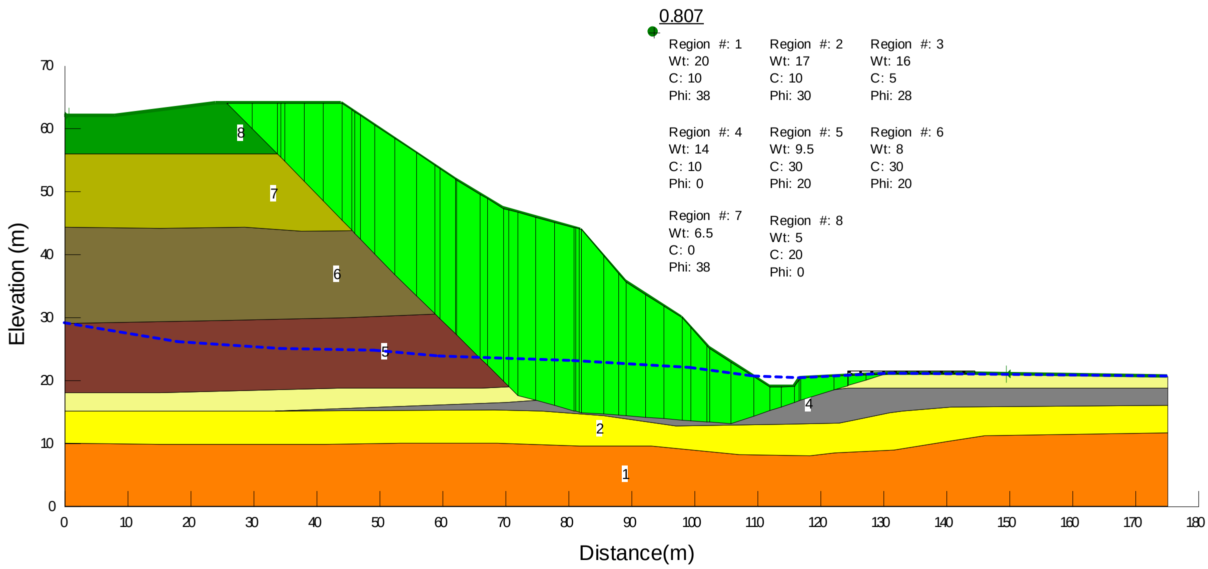
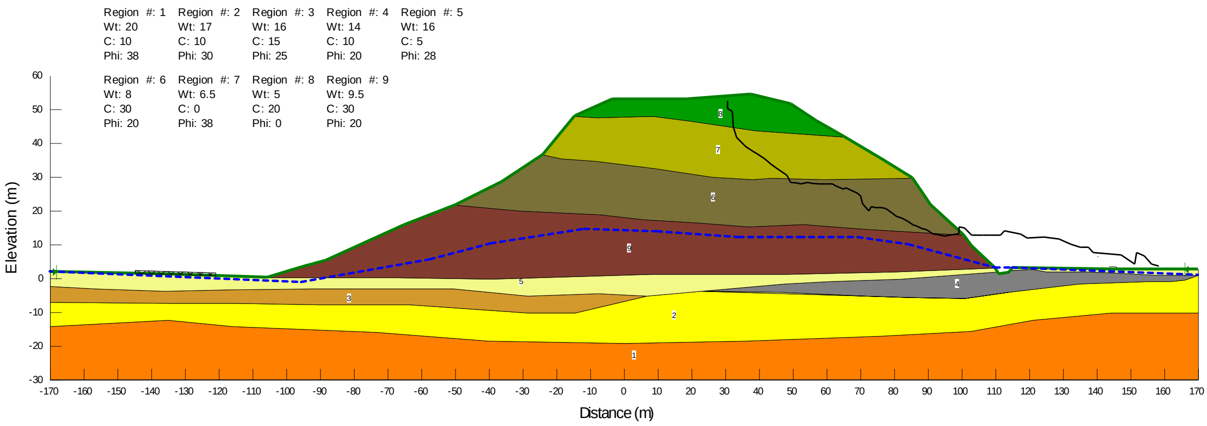


***Figure II**: Stability analysis for section A-A*

Section B-B RHS (failed area)



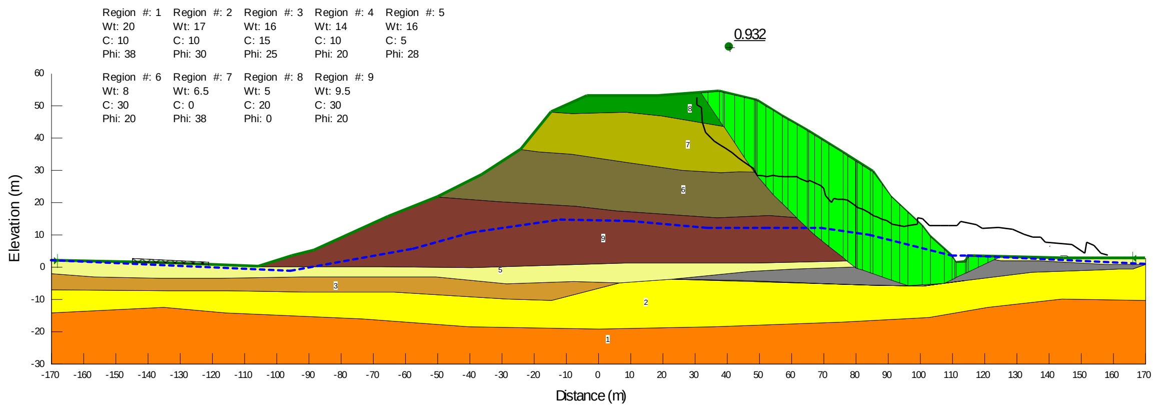
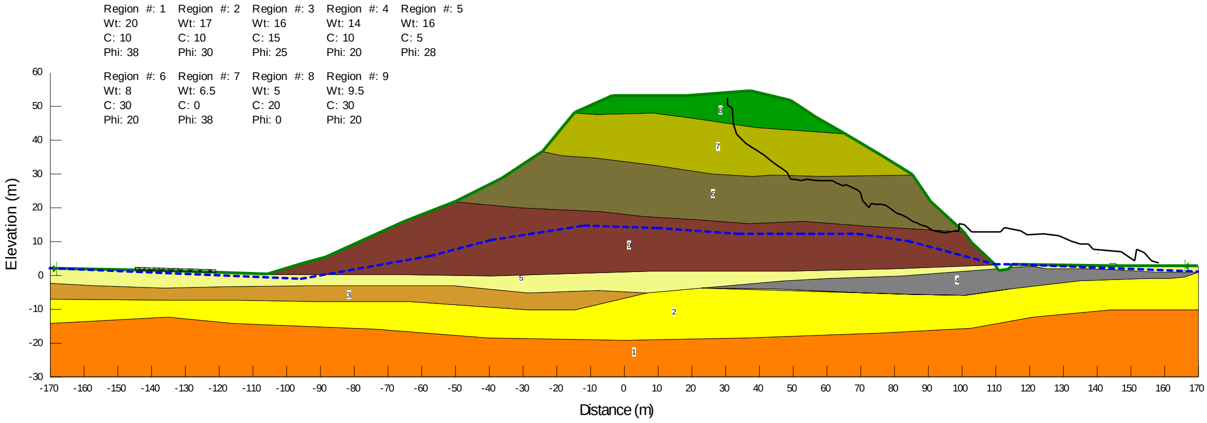


***Figure III**: Stability analysis for section B-B RHS*

Section B-B LHS (direct opposite to failed area)



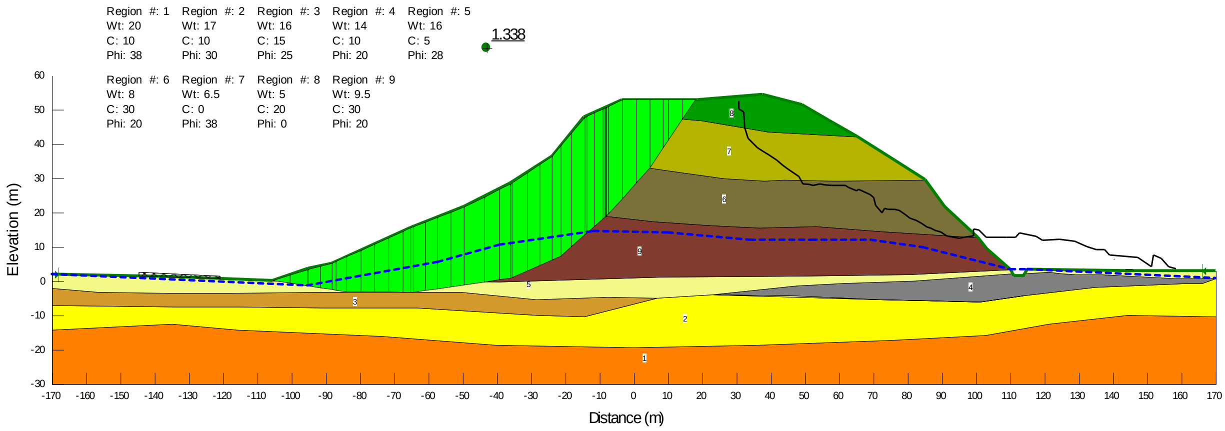
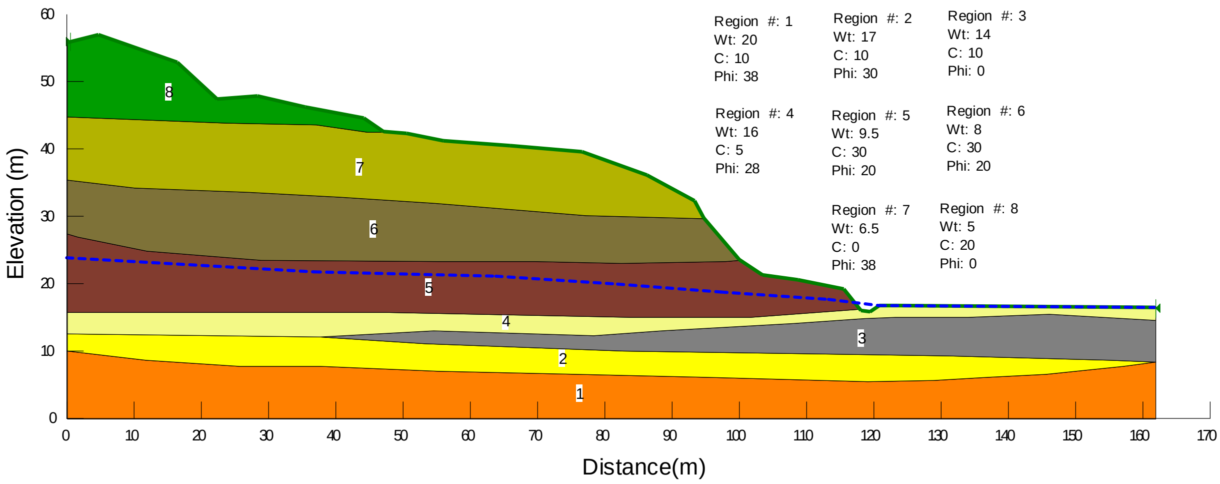


***Figure IV**: Stability analysis for section B-B LHS*

Section C-C



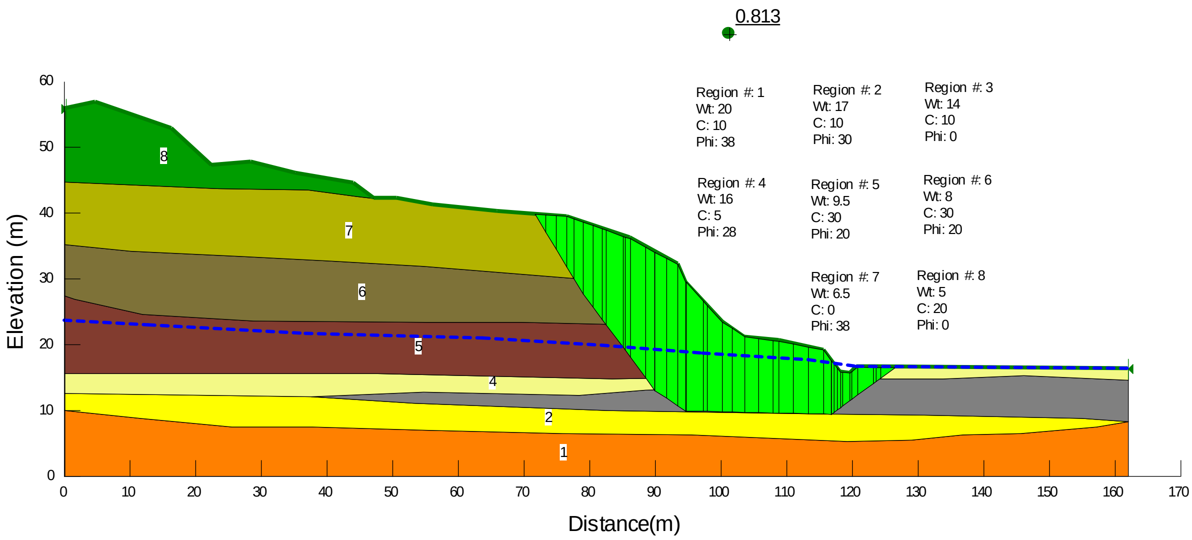
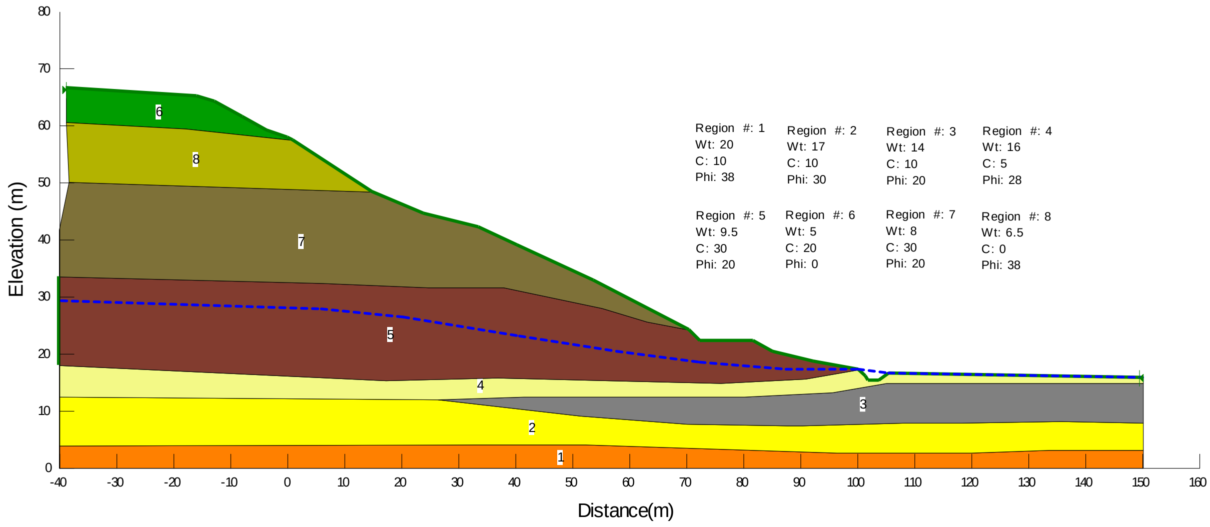


***Figure V**: Stability analysis for section C-C*

Section D-D



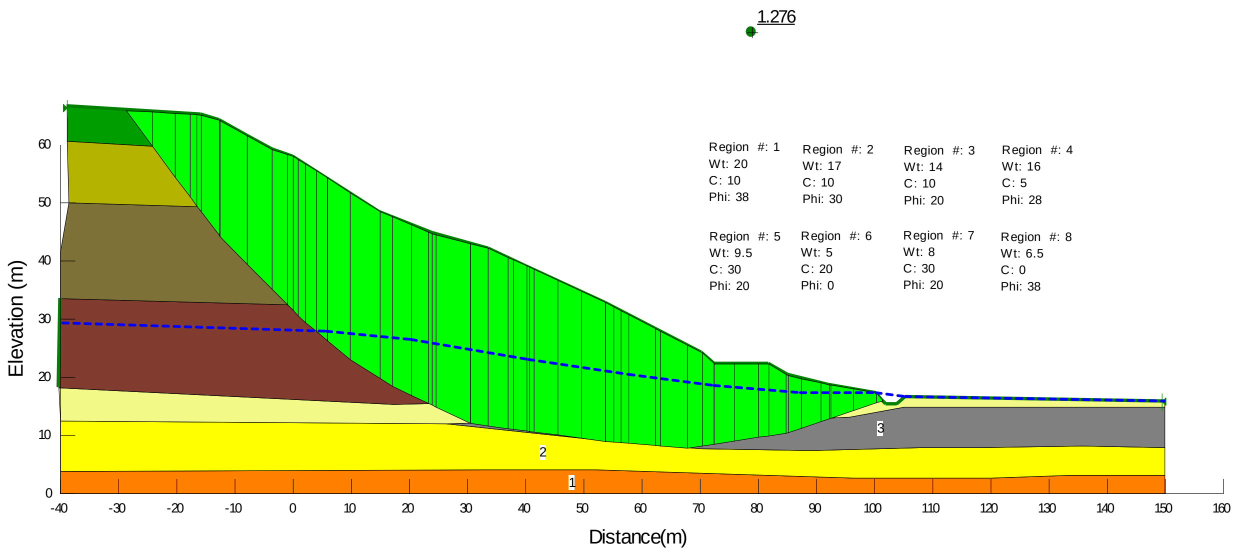
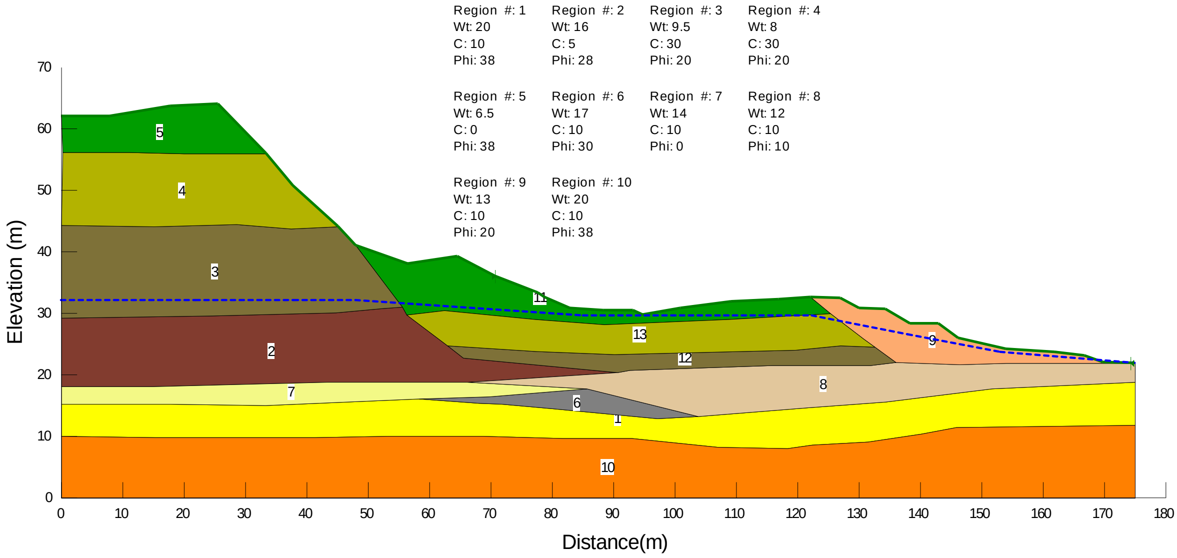


***Figure VI**: Stability analysis for section D-D*

(b) After short term counter measures

<u>Section A-A</u>



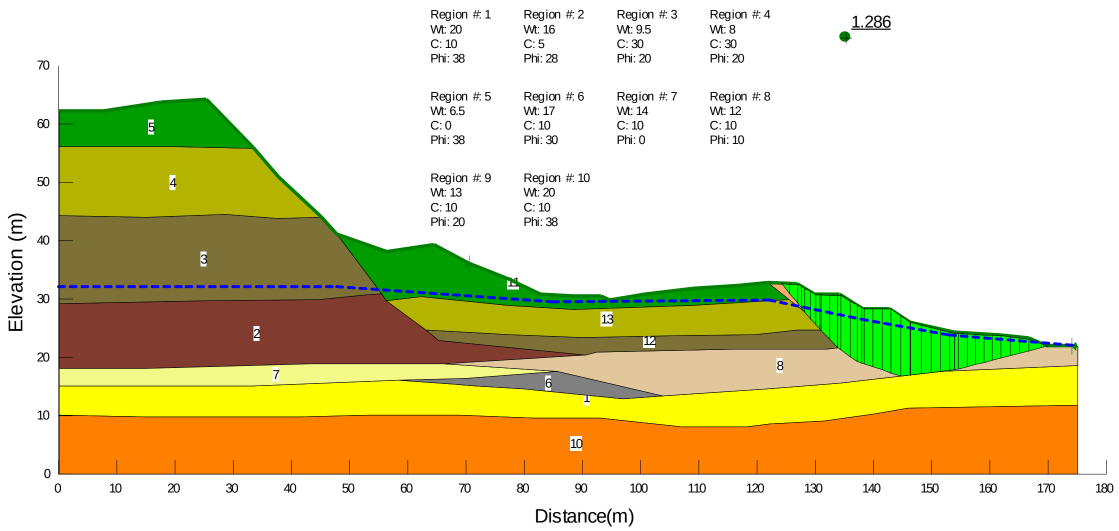
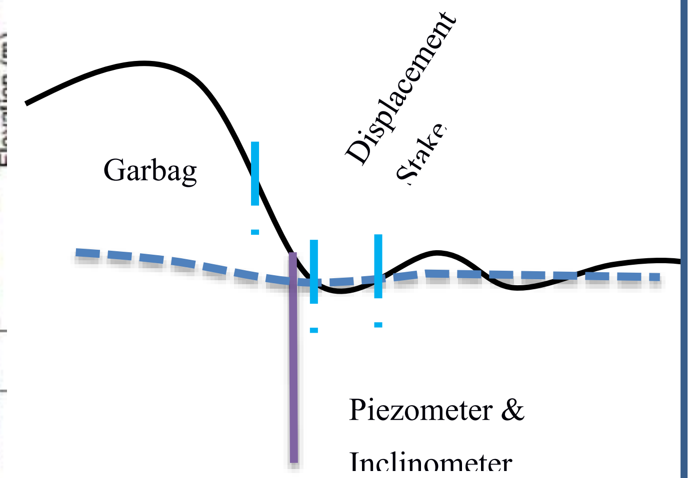


***Figure VII**: Stability analysis for section A-A – Current situation*

Annexure -3

Instrumentation Plan for Meethotamulla Waste Fill



Typical Section for instrumentation

Legend

Piezometer

Inclinometer

Displacement Stakes*

*Displacement stakes should be installed along the axis as shown in the typical section

Annexure -4

List of NBRO Officers /Technical Experts

List of NBRO Officers /Technical Experts

Name	Designation	Area of expertise
Eng. (Dr.) W A Karunawardena	Director General	Geotechnical Engineering
R M S Bandara	Director – Landslide Research and Risk Management Division	Geology, Landslide Risk Management
K N Bandara	Director – Geotechnical Engineering Division	Engineering Geology, Slope Stability
K C Sugathapala	Director – Human Settlements Planning and Training Division	Town and Country Planning
Dr. Pathmakumara Jayasinghe	Senior Geologist	Geology
L Indrathilaka	Senior Geologist	Geology
S Wimalaweera	Senior Geologist	Geology
K A D S B Jayatilaka	Scientist	Town and Country Planning
P M C J Paliskara	Scientist	Town and Country Planning
S H S Jayakody	Scientist	Civil Engineering
G D W N Galhena	Scientist	Civil Engineering