



Aberdeen Greyhope Road Coastal Embankment

Risk Assessment

18 April 2017

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1 Introduction

1.1 Background and Scope

A site walkover survey was undertaken at the Greyhope Road coastal embankment site on the 23rd January 2017 by two engineering geologists. The aims of the walkover surveys were to:

- Identify visual evidence of historical instability on the site associated with landslides;
- Identify potentially unstable areas and assess the risks these pose to adjacent roads and pathways and users;
- Highlight areas which require management / remediation.

Figure 1.1: Indicative Site Boundary



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The information gathered during the site walkover has informed a quantitative risk assessment, to classify the overall condition of the embankment and prioritise remedial actions required, with numbers assigned to risk level, impact, priority.

The objectives of this report are to:

- Summarise the findings of the site walkover and describe the baseline condition of the embankment, including locations of instability.
- Present the results of a slope stability risk assessment for the embankment, highlighting where management or remediation actions are required.
- Provide a priority level for remedial actions.
- Make recommendations for any immediate actions required.
- Make recommendations for a proposed strategy for continual monitoring of the embankment by Aberdeen City Council staff.

The results of the site walkover are presented in Appendix A.

1.2 Sources of Information

The following sources of information summarised below have been used to compile this report and are summarised in Section 2.

- MML Greyhope Desk Study (Ref.1)
- A guide to managing coastal erosion in beach/dune systems, SNH (Ref. 2)

2 Site Walkover Summary

2.1 Site Walkover Results

A Site Walkover was completed by MML on 23rd January 2017. The results of the walkover are included in Appendix A.

The slopes in the north of the site are steep, generally between 45 and 70 degrees, and up to around 20m high. There are numerous current and historical slips along the slopes, typically shallow and acting within superficial deposits. The slips generally act from at or near the crest of the slope at the edge of Greyhope Road, and water piping is typically visible. Material from the slips has reached the footpath running around the coast at the base of the slopes. There are coastal defences in varying states of disrepair, along with breakwaters, along the shoreline. There is a drainage pipe coming out of the slope towards the north east that is causing scour.

As the slips tend to act at the crest of the slope, in places the road has been impacted, with ravelling of the road surface. Fences have been erected to prevent loading of the road edge. Additionally, fences have been erected on the road at the north west end of the site, west of the St Fittick's junction, where concrete blocks have been placed to stabilise an area experiencing undercutting and scour. The blocks appear unstable in places. There are sea defences in this area, comprising concrete revetment, in a state of collapse and have been covered in a layer of gabions, also in a state of disrepair.

The slopes in the east of the site at Greyhope Bay are typically 45 degrees and are experiencing instability at the toe, potentially due to wave action. Greyhope Road is set back from the crest of the slope in this area. Spoil consisting of brick, dressed stone and ceramic was observed on the beach, potentially associated with demolished cottages in the area. There is a drainage pipe coming out of the slope that is causing scour.

The slopes as they round the lighthouse promontory are steep, up to 70 degrees, and between 12 and 20m high. They are hummocky and composed of soil in the upper parts and rock in the lower, with rock outcrops visible along the shoreline. There have been recent slips in the area, one being on a saturated slope below the radar tower and one at the crest of the slope below the road, where fences have been erected.

The slopes in the south of the site are generally shallower than elsewhere on site, between 20 and 45 degrees, and with breaks in slope on bedrock. There are several historical structures and sea defences have been installed along this part of the shoreline, typically comprising concrete and masonry and in various states of disrepair. There is also a more recent revetment at the southernmost part of the site, with blocks having been plucked out by wave action.

A record geodatabase of each feature has been produced, including photographs, issued by CD. A plan showing the features at each site is included in Appendix A.

3 Slope Stability Risk Assessment Methodology

3.1 Strategy

Using published guidance (E. M. Lee and D. K. C. Jones, Landslide Risk Assessment, ICE 2014), the slopes have been assigned a category according to the level of risk to infrastructure and members of the public, by chainage groupings. The risk categories are from 1 to 5, with 1 being the lowest risk and 5 the highest.

This risk assessment method is quantitative, with the ratings based on engineering judgement. The risk assessment has been undertaken focusing on potential harm to users.

The following factors have been considered when assigning risk:

- Slope angle
- Consequence of failure
- Likelihood of failure
- Topography
- Groundwater
- Vegetative cover

Tables 1 and 2 demonstrate the ratings assigned to both likelihood of slope failure occurring and the consequences associated with failure.

The slopes have been assessed in terms of likelihood and consequence; these ratings are multiplied together to form a risk rating. The possible risk ratings are shown in the Risk Rating Matrix in Table 3, the ratings have been assigned a risk category from 1 to 5 indicated in Table 4. These risk categories inform prioritisation of any potential actions or remediation measures, with a High to Very High risk necessitating further investigation and a discussion of options / recommendations.

Table 1: Probability Ratings

Likelihood	Rating
Very unlikely	1
Unlikely	2
About as likely as not (Possible)	3
Likely	4
Very likely	5

Table 2: Consequence Ratings

Consequence	Rating
Minor: failed materials stop along the slope, no failure that would impact on infrastructure	1
Moderate: failed materials impact the foreshore, potential for failure to affect upslope footpaths	2
Serious: failure with debris/blocks reaching the foreshore, with the potential for damage to upslope footpaths / roads and injury to members of the public	3

Table 3: Risk Rating Matrix

		Likelihood				
		Very unlikely	Unlikely	Possible	Likely	Very Likely
Consequence		1	2	3	4	5
Minor: failed materials stop along the slope, no failure that would impact on infrastructure	1	1	2	3	4	5
Moderate: failed materials impact the foreshore, potential for failure to affect upslope footpaths	2	2	4	6	8	10
Serious: failure with debris/blocks reaching the foreshore, with the potential for damage to upslope footpaths / roads and injury to members of the public	3	3	6	9	12	15

Table 4: Risk Categories and Recommended Actions

Risk Category		Action
Very Low	1-2	None required
Low	3-4	None required
Moderate	5-6	Management required
High	7-10	Remediation required
Very High	11-15	Remediation required

↑ Increasing Risk ↓

4 Slope Stability Risk Assessment Results

4.1 Risk Assessment Results

The results of the slope stability risk assessment are included in Table 5.

A prioritisation level has been applied to those areas requiring action (moderate to very high risk) of between 1 (highest priority) and 3 (lowest priority).

Table 5: Greyhope Road Slope Stability Risk Assessment

Chainage (m)	Description	Grid Reference (centre)	Associated Features (Appendix A)	Consequence Rating	Likelihood Rating	Risk Rating	Risk Category	Prioritisation
0 to 100	This area has short (1-4m) slopes with a masonry / rock sea defence on the beach, below Greyhope Road. It is considered possible that the sea defence could fail, impacting on the road.	NJ 9562 0542	43, 92	3	3	12	High	2
100 to 160	This area has been previously remediated using interlocking concrete blocks to stabilise a 4m high slope below Greyhope Road subject to undercutting, potentially due to scour. The concrete blocks appear unstable in places and could fail, affecting the road at the crest and falling onto the foreshore.	NJ 9574 0542	93, 94	3	4	12	Very High	1
160 to 200	Gabion baskets have been installed on top of an historical collapsed sea defence. These baskets are in poor condition, being collapsed / burst throughout. The gabions are directly below Greyhope Road and evidence of slope instability can be seen between the gabions and road.	NJ 9577 0543	51, 95	3	3	9	High	1
200 to 500	There are numerous recent slips across this area on 60 to 70 degree soil slopes. The slips often originate from the edge Greyhope Road at the crest of the slope, with sub vertical back scarps. Fences have been erected to protect the road edge. The slope is typically 7m high with between 15 and 60m ³ failed material from slips. It is considered that slope is very likely to continue to fail, due to the	NJ 9591 0549	1, 2, 63, 5, 65, 66, 67	3	5	15	Very High	1

	steepness of the slopes and soil pipes seen within the topsoil in the back scarps. This would have a significant impact on the road.							
500 to 650	There are several historical slips in this area, characterised by vegetated slopes with a break in slope where material has been deposited (35m ³ at Ch600). Slopes are typically 8m high and 45 to 55 degrees. There is a small retaining wall at the toe of the slope. It is considered possible that this area could fail in the future, potentially affecting the road at the crest, as well as footpath below.	NJ 9612 0562	68, 69, 70, 13, 14, 16, 72	3	3	9	High	1
650 to 950	There are numerous recent and historical slips present across this area. Slopes are between 8 and 20m high, typically 50 degrees and occasionally wet, with soil pipes and springs. Between approx. 25 to 120m ³ failed material in slips. Several of the slips originate from just below the road, with fences erected to protect the edge, and have deposited material onto the footpath below. Additionally, scour has occurred below a drainage pipe. It is considered likely this area will continue to fail, potentially further affecting the road and footpath.	NJ 9629 0567	73, 74 16, 21, 22, 23, 75, 76, 77, 78, 27, 79, 28, 80, 29, 81, 30, 31	3	5	15	Very High	1
950 to 1200	The slopes in this area are comprised of soil in the upper parts and rock in the lower. There is recent and historic instability on the slopes between Greyhope Road and footpath mid slope, as well as between the mid slope footpath and footpath at the toe of the slope. Slips of up to	NJ 9660 0574	32, 82, 33, 34, 83, 84, 85, 86, 37, 87	3	3	9	High	1

		15m ³ material. The upper slope is typically 4m high. There is scour/instability due to a water pipe within the slope. It is considered likely that the slope will continue to fail, potentially affecting the footpaths and road.							
1200 to 1600		A soil slip has occurred at the toe of a slope; however, the majority of the slopes appear stable. The road is set back from the crest of the slope and is considered to be at low risk. There is spoil on the beach, potentially associated with demolished cottages. Any further instability may potentially affect informal footpaths at the crest of the slope.	NJ 9686 0550	88, 38, 40, 89, 91	1	3	3	Low	-
1600		There is a pipe with scour occurring within the slope. This is below the road and it is considered that this could affect the road if the scour continues.	NJ 9697 0542	90	3	3	9	High	2
1600 to 1800		The slope in this area are hummocky and formed of soil and rock. The slopes appear generally stable. The road is set back in this area and is considered to be at low risk.	NJ 9705 0542	96	2	2	4	Low	-
1800		There have been some recent slips in soil material on the 12m high slope below a radar tower, with water visible in the failed areas and approx. 80m ³ volume of material failed. Concrete is visible in the deposited material at the toe of the slope. The road is set back in this area; however, as the slopes are likely to continue to fail and there are structures above it would be considered prudent to monitor movement.	NJ 9719 0543	54, 55, 97	2	4	8	High	2

1800 2000	to	The slopes in this area appear to be generally stable and are formed of soil in the upper parts and rock in the lower, with outcrops visible. There are some minor slips of soil material on rock visible below a foghorn. There is an outfall building and sea defences present. The road is set back in this area and is considered to be at low risk.	NJ 9724 0536	9	2	2	4	Low	-
2000 2100	to	A slip has occurred within soil on a 10m high, 20 to 35 degree slope directly below the road, with approx.. 8m ³ material. The slip appears to have been caused by surface / near surface water. Temporary barriers have been erected at the side of the road. It is considered that this slip could deteriorate, potentially affecting the road above.	NJ 9717 0522	99, 100	3	4	12	Very High	1
2100 2600	to	The slopes in this area appear to be generally stable and are formed of soil in the upper parts and rock in the lower, with outcrops visible. There are concrete and masonry sea defences and some ruined buildings at the toe. The road is at the crest of the slope; however, the lack of apparent historical instability suggests this area is low risk to infrastructure.	NJ 9688 0508	59, 102, 60, 61, 103	2	2	4	Low	-
2600		There has been damage to the revetment defences, with blocks having been plucked out. This should be repaired to prevent further damage.	NJ 9663 0499	62, 104	2	3	6	Moderate	2

4.2 Recommendations

It is recommended that potential mitigation and remedial measures are considered for those high and very high risk areas to prevent damage to infrastructure. Management and monitoring measures are considered to mitigate potential risk for the identified moderate risk areas.

It is understood that Greyhope Road from the Lighthouse (Ch1900) to the junction with St Fittick's Road (Ch2750) is to be closed and widened as part of works associated with the development of Nigg Bay. This requires all traffic to use the road to the north, where instability has already impacted on road suitability / usage.

It is not known how the Contractor for the road widening works proposes to mitigate landslide risk, given landslides have occurred in this area.

4.2.1 Immediate Actions

Immediate actions that may be undertaken at the site include setting up fixed monitoring points on the slope and road along the northern slopes to monitor movement. This is considered to be a significant risk and it is recommended that visual inspection is undertaken regularly i.e. every two weeks and after periods of extended rainfall. Particularly as it is now the only access to Torry Battery and the lighthouses

This intensive monitoring will allow the slopes and Greyhope Road to be properly assessed and managed while a hard engineering solution is considered. Additionally, it may help an informed decision to be made as to the nature and extent of remedial works.

4.2.2 Proposed Strategy for Continual Monitoring

As well as the intensive monitoring along the northern slopes, it is considered that fixed monitoring points could be installed at various locations along the crest and face of the slopes around the site to monitor for movement, checked either by traditional topographic survey methods or by aerial photogrammetry / point cloud survey, at regular intervals.

ACC may also wish to undertake a visual inspection at regular intervals to identify any slope changes, based on the photographs provided by MML and any subsequent ACC visits, as well as after any periods of extended heavy rainfall when slope instability is more likely.

5 References

1. MML Desk Study, 378926 Donmouth Phase I Desk Study, Rev B, March 2017
2. SNH, 'A guide to managing coastal erosion in beach/dune systems', dated October 2000.
[online- <http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/index.shtml>]

A. Site Walkover Results

Figure A: Site Walkover Results



Location Map

Key to Symbols

- Current Instability
- Historic Instability
- Observation
- Structure
- + Chainage (m)
- ▭ Site Boundary

Reference Drawings

Rev	Date	Drawn	Description	SEY	AM
A	17/02/2017	KY	Draft for Comment	SEY	AM

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Title

Aberdeen Coastal Embankments
Grehope Road
Site Walkover Results

Designed	K Young	Eng Check	S Eyers Young
Drawn	K Young	Coordination	K Young
GIS Check	J Irons	Approved	A Martin
Scale at A1	Status	Rev	Security
1:2,500	DRA	A	STD

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Table A: Site Walkover Features

Number	Classification	Feature	Description	Comment
1	Current Instability	Start of extensive instability	Translational slip with road at the crest of slope	No slip material accumulations, 6.4m high, 15m ³ material, slope angle 60 to 70. Materials topsoil over clay bound sand.
2	Current Instability	View of slip	See 1	
5	Current Instability	View of slip	Slip undercutting the edge of the road, 0.5m backscarp, 8m high slope, approx.20m ³ material	Materials topsoil over clayey sand
13	Historic Instability	Historic slip	Beneath road, 7m wide, 7.4m high slope, 0.7m backscarp, 35m ³ deposited material	
14	Observation	View of slopes		
16	Historic Instability	East of rocket house	Potential historic slip, fully vegetated, break in slope	
17	Observation	View of water edge	Looking west	
18	Observation	View of water edge	Looking east	
21	Current Instability	Recent slip	Possible slight over hang. 7.9m high back scarp 1.7m 9m wide, approx. 120m ³	thin topsoil over very clayey soil with cobbles and boulders.
22	Current Instability	Recent slip	Natural slope 50 degrees, slip is over hanging. See 21	
23	Observation	Slope	View looking east	
27	Current Instability	Recent slip	View from base of 79	
28	Current Instability	Slip features historic and recent	View from base of 79	
29	Observation	Coastal defence		
30	Observation	Faulted rock	Faulted rock at shoreline	
31	Current Instability	Recent slip	Approx. 100m ³ material	9.2m high. soil pipes. 2.5m back scarp. top soil sand and very sandy clay
32	Historic Instability	Historic slip	Fully vegetated potential historic slip	
33	Historic Instability	View of slope	See 32	
34	Observation	view of slope		
37	Historic Instability	Historic slip between road and path	3 to 4m high slip, 0.5m backscarp, approx. 9m ³ material	3 to 4m high, flat area beneath to path
38	Current Instability	Slip	Up to 4m high slip face. Demolition rubble on beach	No receptor and flat land above with no land use
40	Observation	Vegetated Slope	Looking north	
42	Observation	Slopes	Photo to the east	
43	Observation	Manmade slope	Small slope in front of SEPA building	Condition ok
51	Observation	Poorly vegetated slope		
54	Current Instability	Slip of soils	12m high slope with superficial slips, up to 10m wide at base, approx. 80m ³ material, damp, radar tower above	Old and recent slips. 12m high. Slips superficial. Concrete at the base in blocks.
55	Current Instability	Slip of soils	See 54	
59	Observation	Slopes and ruined building	Photos looking east and west	
60	Structure	Retaining feature in slope		
61	Observation	Seawall/defences		
62	Current Instability	Damage of sea wall		
63	Current Instability	View of Slip	Scarp from slip at road edge. 60-70 deg and sub vert. See 5	300mm topsoil over clayey sand.
65	Current Instability	Slip	Directly beneath road, 1.2 m backscarp, 7m high with runout of deposited material, approx. 40m ³	
66	Current Instability	Surface Slip	6.3m high with 1.9m exposed backscarp, 5m wide, approx. 60m ³ , continues round corner	Materials v. clayey sand, debris at base, within last year
67	Current Instability	Slip	Slumped materials visible, translational. See 66	Adjacent to public footpath
68	Observation	Concrete rock protection		
69	Observation	Retaining Wall	8.6m high slope, 1m high wall, 45 to 55 degrees	
70	Observation	Plucked stone from sea defence		
72	Historic Instability	Rocket house	Break in slope, potential historic slip, fully vegetated	
73	Current Instability	Slip	1-2 m high ret. wall	
74	Current Instability	Fresh slip	See 21. 7.9 high, 1.7m high backscarp, 9m wide, soil pipes, wet surface, 50 deg slope, overhanging scarp	
75	Observation	Steep slope	View looking west	
76	Current Instability	Slip	21.5m high, 7m slip, 0.5m backscarp, approx. 75m ³	

Number	Classification	Feature	Description	Comment
77	Historic Instability	Historic slip	See 77	
78	Historic Instability	Spring and historic slip	Fully vegetated, from mid slope, 5m high, 10m wide, approx. 25m ³	
79	Current Instability	Slip	9.1 m high slope, 5m wide scarp, approx. 50m ³ material, at edge of road	
80	Observation	Coastal defences and breakwater		
81	Current Instability	Slip	See 31, overhanging, toe wall hidden under material	Distance from road
82	Structure	Pipe	Instability below pipe due to scour	
83	Observation	View of slope	Looking west and south	
84	Observation	Rock	16m high slope	
85	Current Instability	Instability below path	5m high, 5m wide, 0.6m backscarp, approx. 15m ³ material	
86	Historic Instability	Historic slip	See 86	
87	Observation	View of slope		
88	Current Instability	Slip	See 38	
89	Observation	Photo north and south		
90	Structure	Pipe		
91	Observation	Hummocky slope		
92	Current Instability	Remediation of outfalls	4m high slope, concrete interlocking blocks	In poor condition and requires addressing
93	Current Instability	Concrete slope with damage	Underscour/plucking evident	
94	Current Instability	Start of gabions	Condition poor, 4 gabions high, coated wire	Photos looking west, south and east
95	Current Instability	End of gabions	Condition poor	Photos looking south, west, east and showing gabion damage
96	Historic Instability	Historic Slip		
97	Current Instability	Slip	See 54	
98	Historic Instability	Small slips below foghorn		
99	Current Instability	Slip	See 100	Water
100	Current Instability	Slip	1-1.5m high backscarp, 2m high 3m wide, approx. 8m ³ material deposition, 10m high slope, halfway down slope, 5-6m wide, directly under road	Superficial slip on rock
102	Observation	Slopes and ruined building		
103	Structure	Retaining feature in slope		
104	Observation	Sea wall/ defences	Photos looking east and west	No slip material accumulations, 6.4m high, slope angle 60 to 70. Materials topsoil over clay bound sand

