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Witton Bluff Base Trail Environmental Feasibility and Design Concept Study

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Executive Summary

Connell Wagner, in conjunction with URS Australia (URS) and Environmental and Biodiversity Services (EBS), was commissioned by The City of Onkaparinga to prepare an Environmental Assessment and Site Concept Report for a proposed base trail at Witton Bluff, Port Noarlunga.

The report firstly examined the potential environmental impacts associated with the development of a shared trail at the base of the Bluff and then using the understanding of the environmental impacts, identified a preferred route alignment for the trail.

The following environmental issues were identified as being the most critical relating to the proposed base trail:

- Geotechnical Issues,
- Marine and Coastal Issues,
- Civil Engineering Issues,
- Social, Historical, Heritage and Cultural Issues; and
- Ecological Issues

Geotechnical issues were assessed for several possible path alignments. The geotechnical study concluded that trail alignments along the sloping cliff face or immediately adjacent to the cliff crest are not feasible options from a geotechnical perspective. The most viable option based on geotechnical and other considerations is an elevated boardwalk constructed of either timber or pre-cast concrete along the limestone wave cut platform at the base of the cliff. However, adequate set-backs from the edges of the limestone platform are recommended due to the risks associated with potential geotechnical instability of both the seaward edge of the platform and the cliff above the landward edge of the platform.

From a marine and coastal view point, it is recommended that the deck level should be at least RL 5.5 AHD. At the gap in the limestone platform caused by the embayment feature, pile supports to the deck would be driven down through the sand to bedrock or at least to well below the erosion zone if the bedrock is deep.

Further investigations relating to the drainage issues along the Esplanade are recommended due to what appears to be an inadequate drainage system. Damage to the platform as a result of the need to provide construction equipment access and the generation of spoil from the excavation of holes in the limestone platform surface for piers to support the new structure will require appropriate management during construction.

Opportunities exist for interpretative signage to be utilised to display the landscape, European and Aboriginal features and history of the Witton Bluff environment.

The impact on native vegetation is considered to be insignificant except where the proposed trail connects with the stairs at the southern end, which could impact on several large native shrubs.

The consultation report, *Foreshore Access Plan Stage 1:Christies Creek to Port Noarlunga, Enterprise Development Network (EDN) 2004* identified the results of surveys undertaken in response to several options for foreshore access within the area. The surveys indicate that the project has gained strong support from residents within the Council area.

The proposed base trail provides a much improved and more formal access solution along the base of Witton Bluff from a safety and environmental impact point of view. In summary, the potential for significant environmental impacts resulting from construction of a shared trail along the base of the Witton Bluff is considered to be minor. However, further environmental assessment will be required during the detailed design process and a construction environmental management plan (CEMP) will be required to ensure protection of the surrounding marine and cliff environments.

An investigation into the design of the proposed base trail concluded, after an assessment of the route alignment and other issues such as material durability, aesthetics, workability, weight, strength and fire resistance, that a timber boardwalk at the base of the cliff but elevated above the limestone wave cut platform would be the preferred form of construction.

An order of the cost of materials and construction for this particular design is estimated to be approximately $1,200,000 inclusive of professional fees, escalation and contingencies.

It is strongly recommended that the appropriate investigations be carried out to allow a preliminary design to be developed in conjunction with a cost consultant to provide detailed estimates of cost for the full length of the base trail including any stairs between the monument and the main trail.

1 Site Information

1.1 Context

Witton Bluff is located approximately 27 kilometres south south-west of the Adelaide CBD, and approximately 3 kilometres west of Noarlunga Centre.

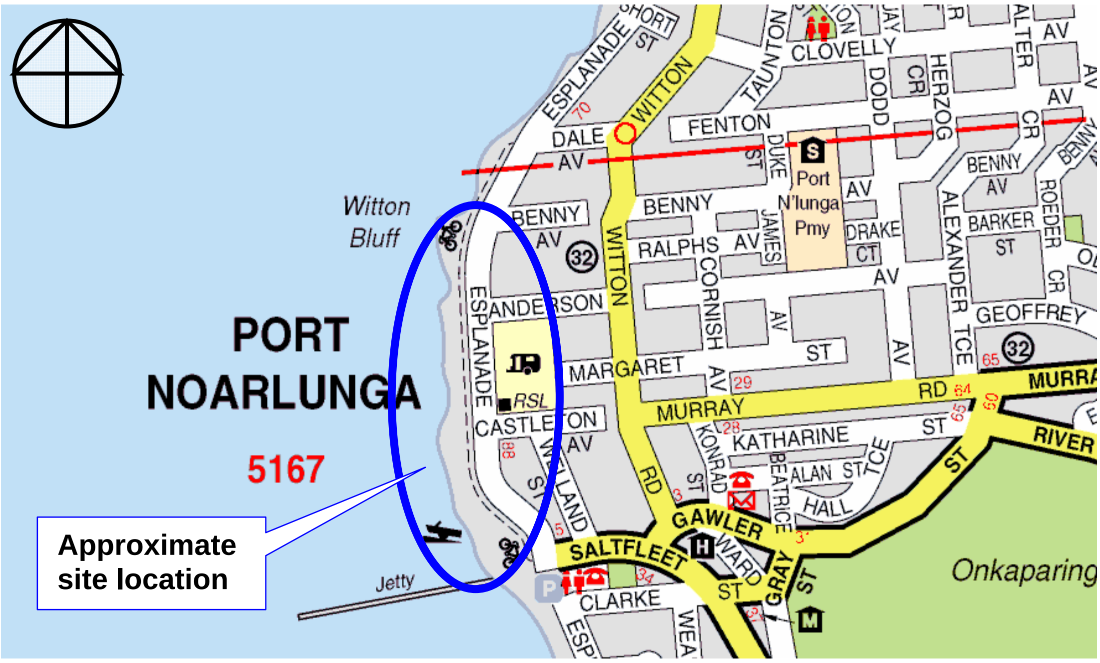
The site (the Bluff) enjoys a prime location surrounded by future residential development, a highly aesthetic foreshore and has strong linkages to nearby tourist and community issues. An existing shared path extends from Christies Beach to the Bluff but stops at a point where the limestone platforms commence.

The location of the proposed path is several hundred metres north of the Port Noarlunga jetty along a wave cut limestone platform at the base of a coastal cliff. The main objective of the proposed path is to provide a recreational trail along the section of beach where there is presently no formal access. The trail will provide for both pedestrian and cyclist access.

By nature of its location and accessibility, there are environmentally related issues surrounding the proposal, including:

- The landform and landscape of the limestone base platform and cliff above
- The nearby ecology, including vegetation (plant associations, species) and habitats, that may be affected by the construction of a trail
- The social, heritage and historical aspects of the location
- The marine and coastal development aspects of the trail
- Stormwater management, access tracks and paths

Figure 1 Location of Witton Bluff and proposed base trail



Source – UBD Adelaide

1.2 Site Inspection

An inspection of the site was undertaken on 22 March 2005 by environmental and engineering personnel from Connell Wagner, URS, EBS and City of Onkaparinga. Selected photographs taken during the visit have been included in Appendix B.

The site (the Bluff) consists of a narrow (in comparison to most metropolitan Adelaide foreshore beaches) beach, a striking cliff face and a limestone platform at the base of the cliff face.

Surrounding land use was noted to be:

- Predominantly residential to the east of the esplanade
- A boat ramp and jetty to the south of the proposed path
- A restaurant and car-parking facilities to the south of the jetty on the beach front
- A gravel path at the base of the cliffs to the north of the location of the proposed path and extending to Christies Beach

Figure 2 illustrates the location of the proposed trail, at the base of the cliffs. The preferred option is to locate the trail on the limestone platform at the base of the cliffs, however it must be noted that this limestone platform is discontinuous; therefore a combination of engineering, planning and environmental factors should be assessed to determine the most practicable trail location.

Figure 2 Aerial view of the location of the proposed base trail

Source – (DEH) Coast Protection Branch

1.3 Zoning

The location of the proposed base trail is within a Coastal Zone. There is a parcel of land at the top of the cliffs and east of the Esplanade zoned as Tourist Accommodation and a Town Centre Zone to the east of the jetty. All other nearby surrounding land use is Residential.

This type of development, a base trail, within a Coastal Zone is neither complying nor non-complying according to Onkaparinga City Council Development Plan (17 March 2005) and will therefore be considered on merit upon the lodgement of a Development Application.

1.4 Related Information

A document produced by City of Onkaparinga titled *Foreshore Access Plan: Christie Creek to Port Noarlunga* reported that a survey relating to Witton Bluff Base Trail received “91% community agreement.” Also, of the 499 people who responded to the Council survey, which represented a response rate of 16.1%, 92% of respondents agreed to the following question: “Should the Foreshore be upgraded?”

Key issues identified in regards to the Base Trail in this report included:

- cliff stability and possible damage
- environmentally sustainable design and environmental impacts

This survey addressed what the local community desire for “their” local foreshore. Hence, these survey results indicate that the Witton Bluff Base Trail poses a low social risk in terms of public acceptance.

Figure 3 -Study Area

2 Consultation

The following stakeholders were consulted during the compilation of this report:

- Onkaparinga Council were the key stakeholder and client for the project. Therefore direct and regular consultation was important to deliver an outcome relevant to Council's objectives. Meetings were held on 5 April and 15 April 2005 with staff from Connell Wagner, Council and various other organisations to deliver a report which endeavours to assess all environmental aspects of the project that will impact on the design or construction of the trail.

- Mr Mike Cooney of Transport SA (TSA) was contacted on 18 April 2005 to ensure that the proposal will not have any negative implications for TSA. Mr Cooney had no issues related to the proposal as the trail and its construction will not impact on TSA infrastructure.

- Ms Jennifer Deans of the Coast and Marine Branch was present at the meeting held on 5 April 2005 with Connell Wagner and URS. Ms Deans noted that the Coast Protection Board Policy document should be assessed.

- Jack Nicoloau, Manager of Crown Lands SA has been contacted with regards to the potential implications of the base trail. Crown Lands advised that prior to the detailed design and construction of any development along the coastline, Crown Lands will require information to assist it in its assessment of the development and referral to the Crown Solicitor from whom Crown Lands will seek advice as to the status of any native title claim over the area. This in turn will determine the extent of any notification to be sent to original land owners.

- The National Native Title Tribunal conducted a search under the following list of databases in the area of Port Noarlunga: Schedule of Applications, Register of Native Title Claims, Register of Indigeneous Land Use Agreements and Notified Indigeneous Land Use Agreements. The search identified that Port Noarlunga falls under the Native Title Application SC00/001 – S6001/00 Kaurna Peoples Native Title Claim, which covers an area of 8,160km^2.

- SA Department for Aboriginal Affairs and Reconciliation were contacted via facsimile on 11 April 2005 to determine whether there are any sites of Aboriginal heritage significance within the locality of Witton Bluff. A response was received by post on 21 April 2005, which advised that "the Central Archive, which includes the Register of Aboriginal Sites and Objects ("the Register"), administered by the Department for Aboriginal Affairs and Reconciliation (DAARE), has no entries for Aboriginal sites within the area described in your correspondence."

- The President, Mr Michael Rose, of Port Noarlunga Surf Life Saving Club was contacted on 18 April 2005 to discuss the affect the proposed trail would have on the Life Saving Club. Mr Rose welcomed the proposal for a base trail at Witton Bluff and said that there were no negative implications for the Life Saving Club.

- Mr Gary Pike of The Office for Recreation and Sport was contacted via telephone in July 2005 for the purpose of informing the department of the proposed base trail and asking for any feedback they may have. Mr Pike's comments, based upon the informing Mr Pike of the proposal via the telephone, was that the trail was a 'good idea' and the 'linkage would be beneficial.' Mr Pike stated that he would be available to view the Draft Environmental Feasibility and Design Concept Study report to provide comment if required.

In addition to contacting the above stakeholders, the City of Onkaparinga was also consulted during the feasibility and design stage. Members of the project team conducted a focus group workshop on

24 May 2005 for City of Onkaparinga staff involved in the engineering and planning and environmental teams. The workshop involved a visual overview of the project followed by a discussion session.

3 Environmental Assessment

The environmental assessment, which involved conducting background research, a site inspection and consulting with relevant stakeholders has been divided into five main areas:

- Geotechnical Issues,
- Marine and Coastal Issues,
- Civil Engineering Issues,
- Social, Historical, Heritage and Cultural Issues; and
- Ecological Issues

3.1 Geotechnical Issues

A separate report has been prepared by URS that addresses the geotechnical issues associated with the proposed trail. Therefore, only a summary of the geotechnical assessment is presented in this main report, and the reader is referred to the URS report in **Appendix A** for further information on geotechnical issues.

3.1.1 Review of Existing Data

The main sources of geotechnical information relating to the study site are contained in the following documents, which have been reviewed as part of this study.

- Golder Associates "Coastal Cliff Stability Geotechnical Investigation". Report prepared for City of Onkaparinga, May 2001.

- URS Australia "Detailed Cliff Stability Investigations, Stage 2 Report, Risk Assessment and Risk Management Strategy for Site Areas A to I". Preliminary draft report prepared for City of Onkaparinga, January 2004.

In addition, the further assessment of the Port Noarlunga to Witton Bluff (South) site that URS has undertaken for Stage 3 of the detailed cliff stability investigations consultancy for Council was also reviewed.

The cliff over the length of the Witton Bluff Base Trail comprises a hard limestone base platform that supports a sloping face formed of clay and sand units over weak limestone. The hard limestone base platform is subject to long term erosion by wave action, resulting in the slow development of caves and overhangs along parts of the limestone base platform. The weaker units above the base platform are subject to extensive and ongoing gully erosion, leading to over-steepening and slumping of soil on the sloping face, and hence undermining and rock falls of the calcrete present near the cliff crest.

3.2 Geological Hazards

Based on the results of geological field mapping for the site, URS identified the following geological hazards associated with the cliff in the study area and the current pattern of land use:

1. Rock falls from the limestone platform at the beach. Three areas (one cave and two blocks) were observed that will fall at some time in the future. The falls will be up to 5 m^3 in size. Currently, people sit under these caves and overhangs. The hazard impact is on public safety only. If these overhangs are removed then this hazard can be downgraded.

2. Runoff and foot traffic erosion and subsequent slumping/debris flow in soil units. This hazard is occurring now. Slumps would be relatively small (up to 3-4 m^3 in size) and would only impact on people directly under a slump if they were on the informal walking tracks on the slope. Therefore, there is low exposure to this hazard. The main consequence of this hazard is slope regression back towards the road where the road is already being affected. There is the potential for an undercut slump to take out the road edge and to impact on the road users on

the southern three quarters of the road length where the cliff edge is 0-5 metres from the road. As a short term risk reduction, the two areas primarily affected (road cracking near the lookout, and the existing monument) could be treated by placing fill and vegetation. The risk could then be downgraded. However in the longer term the whole slope must be addressed or this mechanism will recur. North of the study site, there is a buffer of approximately 7-10 metres between the cliff edge and the road. However, people can access the area directly below the slope due to the informal walking tracks present on the slope. Therefore, although the road is less likely to be impacted, public safety is an issue. This is also where the impacts of the pigeons are greatest.

3. Mechanism 2 above, which undercuts the surface calcrete and creates an unstable edge. People have been observed walking and siting on the cliff edge, which could collapse at any time. Falls would be small and not impact on infrastructure; however they could impact on people near the edge. Fences and signs warn of the danger and these should be maintained and, if appropriate, their coverage should be expanded (this has since been done). Any falling blocks would be unlikely to reach the beach due to the geometry of the slope, and therefore such rock falls would not present a significant danger to beach users.

4. In the steep section of cliff north of the study area where the revetment has been placed, erosion of the sand beds by water and pigeons can lead to slumps and rock falls of up to several cubic metres. This is currently occurring.

3.3 Results of Risk Assessment

Golder and URS both concluded that the length of coastal cliff from Port Noarlunga to Witton Bluff (south), that includes the study site for the proposed base trail, is a relatively risky site compared to other lengths of coastal cliffs within the City of Onkaparinga's catchment. This is because of the following factors:

- The presence of caves and overhangs in the limestone platform at the base of the cliff which, should they collapse, will collapse rapidly and without warning.
- The presence of a relatively busy roadway (The Esplanade) and associated infrastructure adjacent to the crest of an unstable cliff face along the majority of the site length.
- The relative popularity of this stretch of the coast with beach users.

3.4 Geotechnical Assessment of Proposed Base Trail

The geotechnical hazards outlined above pose a potential risk to path infrastructure and path users, in the form of potential undermining and collapse of path support systems founded on unstable cliff material, and/or physical impacts from landsliding of unstable cliff material above the path level.

Based on the existing geotechnical information that was reviewed in the previous section and on the results of the site inspection undertaken by the project team on 22 March 2005, a geotechnical assessment of the proposed base trail has been undertaken and the results are summarised below.

3.4.1 Alignment Options

There are five possible alignments for the proposed Witton Bluff Base Trail:

1. Along the crest of the cliff
2. Across the gullied slope between the limestone base platform and the cliff crest
3. Along the limestone base platform
4. Along reclaimed land formed by constructing a fill embankment protected by a rock revetment and located immediately seaward of the face of the limestone base platform

5. Some combination of the foregoing four options.

Option 1 – Along Cliff Crest

A trail that is located along the cliff crest will be founded on or near a part of the cliff face that is geotechnically unstable. This is because the upper part of the cliff face is subject to ongoing recession due to erosion processes, which leads to over-steepening and slumping of the weak soils that form the majority of the upper part of the cliff face, and which also leads to undermining and falls of the thin calcrete cap rock near the crest level. This poses a risk to path users as well as the path infrastructure itself, because of the potential for eventual undermining and collapse of the path support system.

For these reasons, a trail along the cliff crest is only considered to be a feasible option from a geotechnical perspective if it is set back landward from the cliff crest. However, since this will likely require the trail alignment to intrude on the current width of the Esplanade, the current width of the Esplanade would need to be reduced. Since this may have a significant adverse effect on traffic, access and parking along the Esplanade, a trail along the cliff crest is unlikely to be the preferred option on environmental grounds.

Option 2 – Across Gullied Slope of Cliff

The sloping part of the cliff face is geotechnically unstable. The face is comprised of sands, clays and soft limestone that are relatively weak and are subject to ongoing gully erosion, over steepening and slumping. Any embankment fill or boardwalk column footings that were constructed on the sloping cliff face to support a trail would also be adversely affected by these cliff instability processes. This poses a risk to path users as well as the path infrastructure itself, because of the potential for eventual undermining and collapse of the path support system. There is also a risk that path users and path infrastructure will be impacted by gully erosion, soil slumps and calcrete cap rock falls from the slope above the path.

For these reasons, a trail across the gullied cliff slope is not considered to be a feasible option from a geotechnical perspective.

Option 3 – Along Limestone Base Platform

The limestone base platform presents an obvious corridor for a path, because it is relatively planar and flat, and a path along the limestone base platform would truly be a “base trail”. From a geotechnical perspective, it is desirable for the horizontal alignment of the path to run along the middle of the limestone base platform, rather than at the seaward edge of the platform or at the landward edge of the platform.

At the seaward edge of the platform, there is a risk of collapse of the limestone at a number of locations where caves and overhangs have developed. Although cave and overhand development is a slow process, when collapse does eventually occur failure is rapid and without prior warning. This poses a risk to the path infrastructure and path users.

Another reason for setting the path back from the seaward edge of the limestone platform is that spray from waves hitting the vertical face of the limestone platform will be a little less if the path alignment is set back from the edge. At the landward edge of the platform, there is a risk that path users and path infrastructure will be impacted by gully erosion, soil slumps and rock falls from the significant height of steep slope above the path.

For these reasons, a buffer of several metres between each of the path edges and each of the limestone platform edges is desirable. The actual buffer at a given location will depend on, among other things, the geotechnical risk at that particular location along the path. A smaller seaward buffer may be acceptable if the limestone platform at the location in question has no cave or overhang development, and a smaller landward buffer may be acceptable if the slope above the limestone platform at the location in question is smaller in height, shallower in slope or shows less sign of instability. Since the limestone platform itself is geotechnically stable apart from its seaward edge, the platform will form a suitable foundation for either a pavement path or a suspended boardwalk path.

There are several locations along the length of the site where appropriate buffer distances will not be able to be met. The most obvious example of this is over the width of the embayment feature north of Castleton Avenue, where the limestone platform has been completely eroded by wave action. In order to provide a link between the northern limestone platform and the southern limestone platform, a boardwalk form of path acting as a bridge will be necessary over the width of the embayment, supported by piles driven into the beach below. Alternatively, a fill embankment founded on the beach and protected by a rock revetment could provide the link between the northern and southern platforms. Another location where the buffer distances cannot be achieved is at the large gully feature in the limestone platform south of Castleton Avenue. This would require infilling with rock to support a pavement path, or suspension of a boardwalk path over the width of the gully, with the boardwalk supported by driven piles founded on the rock underlying the beach sand.

The path will need to be set at a level of at least +5.5 m AHD to protect it from tidal inundation or significant wave spray. Although this will be straightforward for the northern limestone platform where the platform level is already adequate or nearly so, it will be more difficult for the southern limestone platform. It will be easier to construct a suspended boardwalk path over the southern limestone platform by progressively increasing the supporting column height with increasing distance southward, than it will be to construct a pavement path by progressively increasing the height of a supporting fill embankment with increasing distance southward.

Given all of the foregoing, a trail along the limestone base platform is considered to be not only a feasible option but also a preferred option from a geotechnical perspective. The same conclusion is also likely from an overall environmental impact perspective.

Option 4 - Along Reclaimed Land

This option would involve reclamation of a strip of beach or sea immediately in front of the limestone base platform to provide a corridor for the path. This would involve construction of an armour protective layer on the seaward face of the reclaimed land, with the reclaimed land itself formed by filling between the armour layer and the limestone platform. The end product would effectively be a southwards extension of the existing rock revetted and filled area that extends northwards towards the point of Witton Bluff from the northern end of the Witton Bluff Base Trail project site.

The coastal cliff would not present any geotechnical risks to a path formed along reclaimed land or to users of such a path, provided that the path had a suitable seaward buffer distance from the locations of any caves and overhangs in the adjacent limestone platform that might otherwise result in impacts should such caves and overhangs collapse. It would be necessary to ensure that the design of the reclaimed land had an adequate factor of safety against slope instability, and that the rock armour design was robust enough and the finished level of the reclaimed land was high enough to minimise the potential for erosion by tidal inundation, wave action or sea spray.

Based on the above considerations, a trail along reclaimed land seaward of the limestone base platform is considered to be not only a feasible option but also a preferred option from a geotechnical perspective. However, this option is unlikely to be a feasible option from either an environmental impact perspective or from a cost perspective.

Option 5 – Some Combination of Options 1-4

From a geotechnical perspective, any trail option that involved location of a significant length of the path on the unstable sloping face of the cliff is considered infeasible. This rules out any combination option involving Option 1 and/or Option 2. The only combination option considered geotechnically feasible is then Option 3 combined with Option 4.

From a cost and environmental perspective, Option 3 would need to be the dominant option in the combination. A possible combination of Option 3 and Option 4 may involve constructing the path on the limestone base platforms wherever there is sufficient lateral buffer distance between the path edges and the platform edges for this to be feasible. Where there is insufficient buffer, armour protected fill reclamation could be undertaken, such as over the width of the embayment and over the gullied pinch point a little south of the embayment. In each case, the reclamation would replace a suspended board walk structure with supports piled into the beach.

Such a combination of Options 3 and 4 would have essentially the same geotechnical considerations as Option 3 and hence be not only a feasible option but also a preferred option geotechnically. However, environmentally it will not be as attractive as Option 3, because of the various construction phase impacts and post construction visual impacts associated with the locations of reclamation.

3.4.2 Main Findings

Based on the outcomes of the alignment options review for the proposed trail, and on a review of the potential forms of path (pavement type path or boardwalk type path) and of end and intermediate path connections, the main findings of the geotechnical assessment are as follows.

The geotechnical risks summarised above mean that it is infeasible for the proposed path to be located on the unstable sloping face of the cliff above the limestone base platform. Although it is geotechnically feasible for the path to be located landward of the cliff crest or along a rock armour protected reclaimed strip of land immediately seaward of the limestone base platform, the preferred option for alignment of the path is along the limestone base platform, based on geotechnical considerations combined with environmental impact and cost considerations.

The preferred position of the path over the width of the limestone base platform is approximately along the middle of the platform, so as to minimise geotechnical risk associated with potential collapse of caves and overhangs that are present at some locations on the seaward edge of the limestone base platform, while also minimising geotechnical risk associated with gully erosion, soil slumping and rock falls from the unstable sloping cliff face above the landward edge of the limestone base platform.

Based on an assessment of the geotechnical risks to path infrastructure and path users, and on other engineering and environmental considerations, a boardwalk form of path is preferred to a pavement form of path.

Special consideration will be required at locations where the path cannot be supported by the limestone platform because the platform is too narrow or is absent altogether, most notably over the width of the embayment feature. For a suspended boardwalk form of path, the path at such locations would act as a bridge and be supported by piles driven through the beach sand and founded on the underlying rock.

The connection from the northern end of the Witton Bluff Base Trail to the existing path to the north could be formed by a boardwalk that ramps down from the northern edge of the limestone base platform to the reclaimed land below.

The connection from the southern end of the Witton Bluff Base Trail to the Port Noarlunga Esplanade could be formed either by taking the path around the seaward face of the limestone point present at the southern end of the limestone base platform, or by taking the path over the ridge landward of the limestone point. The latter option is preferred from a geotechnical perspective, because it avoids wave erosion and load impacts on the path support structure.

Intermediate connections from a Witton Bluff Base Trail path level on top of the limestone base platform down to the beach level are possible but are not favoured because they will be subjected to significant wave action that may damage or even destroy the connections during storm events.

3.4.3 Recommendations

Based on the geotechnical assessment findings, it is recommended that:

- The Witton Bluff Base Trail should run along the top of the limestone base platform, and be aligned with the approximate middle of the limestone base platform width.
- A boardwalk form of path should be adopted rather than a pavement form of path.
- The foregoing outline concept for the Witton Bluff Base Trail should be taken to the next stage of design development and environmental assessment, given the geotechnical feasibility of the path concept that has been demonstrated in the current report.

Figure 4 – Geotechnical considerations

3.5 Marine and Coastal Issues

3.5.1 Design Criteria

The design of the base trail must conform to the standards and criteria contained in Regulatory Authority publications such as the Coast Protection Board's Policy Document which addresses marine issues and Austroads Part 14 which covers shared pedestrian and cycle paths.

3.5.2 Coastal marine effects

The proposed route for the path follows a limestone wave cut platform that slopes gradually from about RL 7 AHD at the northern end of the site to about RL 2 AHD at the southern end. There is a gap in the platform in its mid-section.

Immediately to the north of the site a rock revetment has been constructed to RL 5.0 AHD. This is the level that has been determined by the Coast Protection Board as being the appropriate height for coastal protection works in this location. It was determined following wave run-up damage to some sections of the seawall that had been previously constructed. The damage has since been repaired. Any path constructed on the limestone platforms would need to be at least at RL 5.5 AHD or designed to withstand wave forces.

It was also evident at the site inspection that the platforms were regularly covered with water, as there did not appear to be any scree on them washed down from the highly erodible soils above the platforms. This water would predominantly be seawater carried up onto the platforms as sea spray at the northern end and as overtopping and spray at the southern end. Any path built on top of the platforms would therefore have to be able to handle significant volumes of water runoff fairly frequently. This runoff may also have a relatively high sediment load as it cleaned any material eroded from the cliffs off the platforms. It would therefore be desirable that any path allows free drainage of the area.

3.5.3 Path Construction

There are a number of methods for the construction of shared paths but is clear that an elevated board walk would best satisfy the site conditions. There are many examples of elevated boardwalks along coastal areas of South Australia.

The boardwalk would be constructed on piles socketed into the limestone platforms with a deck level at least RL 5.5 AHD. At the gap in the limestone platforms the piles would be taken down through the sand to bedrock or at least to well below the erosion zone if the bedrock is deep. The deck would therefore be above the wave runup level and being elevated would maintain free drainage of the platforms.

The boardwalk deck could be constructed of either timber or precast concrete. Both forms of construction have been used on Granite Island, Victor Harbor.

The path should be constructed clear of the seaward edge of the limestone platforms and clear of the eroding cliff faces. The platforms are generally wide enough to satisfy both criteria.

3.5.4 Design Standards

The design standards should comply with Austroads Part 14 Cycles and AS 1428.1 *Design for Access and Mobility.*

Section 6 of Austroads Part 14 covers the requirements for shared use pedestrian and cycle paths. The recommended minimum width of paths for shared recreational use is 3.0 m. It is recommended that frequent layouts be constructed to enable users to stop to rest and admire the views clear of the path.

A nominal design speed for cyclists of 20 km/hr is recommended. This is less than the preferred design speed but is considered more appropriate for the boardwalk configuration. The radius of curves in the path could therefore be as low as 10 metres.

The gradients should meet or improve on the minimum standards for disabled access. AS 1428.1 specifically refers to building works but its recommendations on gradients are widely adopted for general use. Landings should be provided at the following intervals:

- 25 m for a grade of 1 in 33 for a rise of 0.75 m without handrails or 33 m for a rise of 1.0 m with handrails
- 15 m for a grade of 1 in 20 for a rise of 0.75 m without handrails or 20 m for a rise of 1.0 m with handrails
- 9 m for a grade of 1 in 14 for a rise of 0.64 m
- 1.5 m for a grade of 1 in 8 for a rise of 0.19 m.

Grades flatter than of 1 in 33 do not require landings. Landings should be at least 1.2 m long and no steeper than 1 in 40.

3.5.5 Barriers

Barriers will be required on both sides of the elevated walkway. To suit cyclists the barriers should be between 1.2 m and 1.4 m high. For child safety the panels between posts should be a full barrier type fence or balustrade. The barriers could be constructed of timber, steel (preferably stainless) or marine grade aluminium or a combination of these materials.

3.5.6 Pavement Surfaces

The pavement surface should be smooth and with small joint widths at right angles to the direction of travel. It is assumed that access for light maintenance vehicles will be required.

Timber construction would need to be from high durability grade timbers using stainless steel grade 316 fixings. Attention will need to be given to the surfaces which could become slippery when wet. The publication *Boardwalk Design Guide* gives recommendations on the design of timber boardwalks.

Figure 5 – Marine Interface

Photo source: MapLand, Department for Environment and Heritage

3.6 Civil Engineering Issues

3.6.1 Stormwater -Esplanade Drainage

The Esplanade kerb gutters extend from the top of Witton Bluff toward the south, to side entry pits approximately in line with the boat ramp. This is a long distance at a steep gradient resulting in large volumes of fast-flowing stormwater travelling down the gutters during rainfall events. A number of traffic-calming devices have been constructed on The Esplanade extending into the carriageway from near the edge of the gutter.

There is soil erosion north of the memorial, where the footpath is partially undercut. This may have been caused by the gutters overtopping due to constrictions to the gutter flow or debris, and the excess water flowing over the narrow footpath and down the embankment.

Means to prevent water from the roadside flowing over the embankment should be investigated.

3.6.2 Stormwater - Base Trail Drainage

Stormwater runoff from the cliffs above the limestone platforms flows over the platforms largely unimpeded on to the beach. Although gullying of the cliffs is evident in some locations, it appears that generally the flow over the platforms 'spreads out' and flows across the platforms as sheet flow.

The implication for the new base trail is that it should not impede the flow of stormwater runoff over the platforms. This could be achieved by constructing a path flush with the existing surface levels, allowing runoff to flow over it, but the most appropriate way of minimising impacts on stormwater flow is to elevate the new base trail above the platform level (e.g. as an elevated boardwalk).

3.6.3 Construction

With the cliffs above the limestone platforms considered generally unsuitable for the new base trail route for geotechnical reasons, the majority of the construction would be on the limestone platforms and over the beach, as well as some works on the more stable cliff area between the boat ramp and the lower limestone platform.

The primary impacts of construction would be likely to be the generation of minor amounts of spoil, from the excavation of holes for piers for the new structure between the boat ramp and the lower platform, along the limestone platforms, and along the beach in the embayment between the two platforms.

It is anticipated that the spoil could be adequately managed by:

- Undertaking construction on the beach only 'in the dry' and undertaking the drilling and pier installation in one operation or by driving the piles into the beach.
- Drilling on the limestone platforms only during appropriate tidal conditions, and ensuring that all limestone cuttings are captured and disposed off site.
- Using appropriate spoil removal methods when drilling in the area between the boat ramp and the lower platform, as well as working only in dry weather.

3.7 Social, Historical, Heritage and Cultural Issues

3.7.1 Social

A sensitive location such as a foreshore will attract community attention. At present, the cliffs and beach at Witton Bluff remain virtually untouched since European settlement. The proposed base trail will have minimal impact environmentally; however design and construction of the structure will need to be cognisant of the existing environment in terms of its aesthetic values.

There is an existing walking/bike riding trail that runs along the top of the cliffs which in its present state is considered a dangerous route for pedestrians due to the traffic along the Esplanade. The option to construct a trail along the base of the cliffs will provide a more pedestrian friendly option for recreational walkers and bike riders. The trail will most likely attract more tourists to the immediate area, thus providing economic benefits for local businesses.

Providing safe access for visitors to the area will be one of the major positive outcomes of constructing the base trail. The path at the northern end of the limestone platform suddenly terminates and pedestrians are forced to either climb onto the limestone shelf or down the rock revetment if they desire to continue in a southerly direction. Both of these options present the risk of injury, hence the current situation presents a liability risk to Council.

3.7.2 Historical and Heritage

3.7.2.1 European and Landscape History

Witton Bluff took its name from the wreck of the brigantine David Witton that was wrecked nearby in 1839 (REF: http://www.postcards.sa.com.au/features/pt_noarlunga.html).

One of the key features of Witton Bluff was an isolated free-standing piece of land off shore, which was referred to as Table Rock. Table Rock, which acquired its name due to its square flat top, was approximately 50 metres from the cliff face, ten metres long and ten metres high. This notable landmark which existed north of the Port Noarlunga jetty between Port Noarlunga and Christies beach was believed to have collapsed in 1912.

The site inspection identified drill holes on the limestone platform, which have since been identified as supports for the platform of a beach shelter. The shelter is estimated to be 100 m^2 and was supported by posts mounted in the platform based upon the photograph illustrated in *Port Noarlunga: An endearing Coastal Town* (P. 50). These structures were present in the early 1900s and utilised by locals for recreational purposes.

These key historical features, table rock and the beach shelter, should be acknowledged from a historical standpoint when designing the base trail. These landmarks should be signposted with descriptions and photographs on information boards along the trail, adding an element of historical bearing to the surrounding environment.

3.7.2.2 Aboriginal Heritage

A search for heritage listed place was conducted using the Australian Heritage Places Inventory search function on the government web site. The search incorporated all heritage listed places, of state and national significance, in Onkaparinga; however there were found to be no sites, at the time of the search (11th April 2005) that will be affected by the construction of a base trial at the proposed location.

3.7.3 Cultural

The Kaurna people occupied parts of the Adelaide Plains prior to European settlement. The Kaurna people were made up of independent groups living within their own lands but who came together for trade, social, ceremonial and religious reasons.

In recognition of the cultural aspects construction may have on this part of the Adelaide coast line a search request has been made to The South Australian Department for Aboriginal Affairs and Reconciliation (DAARE) for any sites of aboriginal significance.

It is also important to recognise the opportunities in developing this trail that highlight the cultural heritage significance of the area. The Kaurna's relationship with the Witton Bluff coastline, extending through to the Witton Centre can be acknowledged through interpretative opportunities along any new trail or associated with any enhancements of the historic monument.

3.7.4 EPBC Search

An EPBC web search has indicated that no threatened ecological communities, World Heritage Areas, National Heritage Places, Ramsar Sites or Threatened Ecological Communities exist within the proposed location of the base trail. The search flagged a number of bird, fish and mammal species associated with the marine environment. Some migratory birds, whale, dolphin and shark species were also flagged. The Port Noarlunga Reef Aquatic Reserve and the Onkaparinga Recreation Park were also flagged by the search. The Historic, Indigenous and Natural search results identified are not relative to the location of the base trail. It should be noted that the search area may be able to be refined further. It is recommended these EPBC matters be investigated further prior to construction of a base trail at Witton Bluff. The EPBC Act Protected Matters Report for the area within City of Onkaparinga has been attached as Appendix D.

Figure 6 – Historical Features of Marine environment

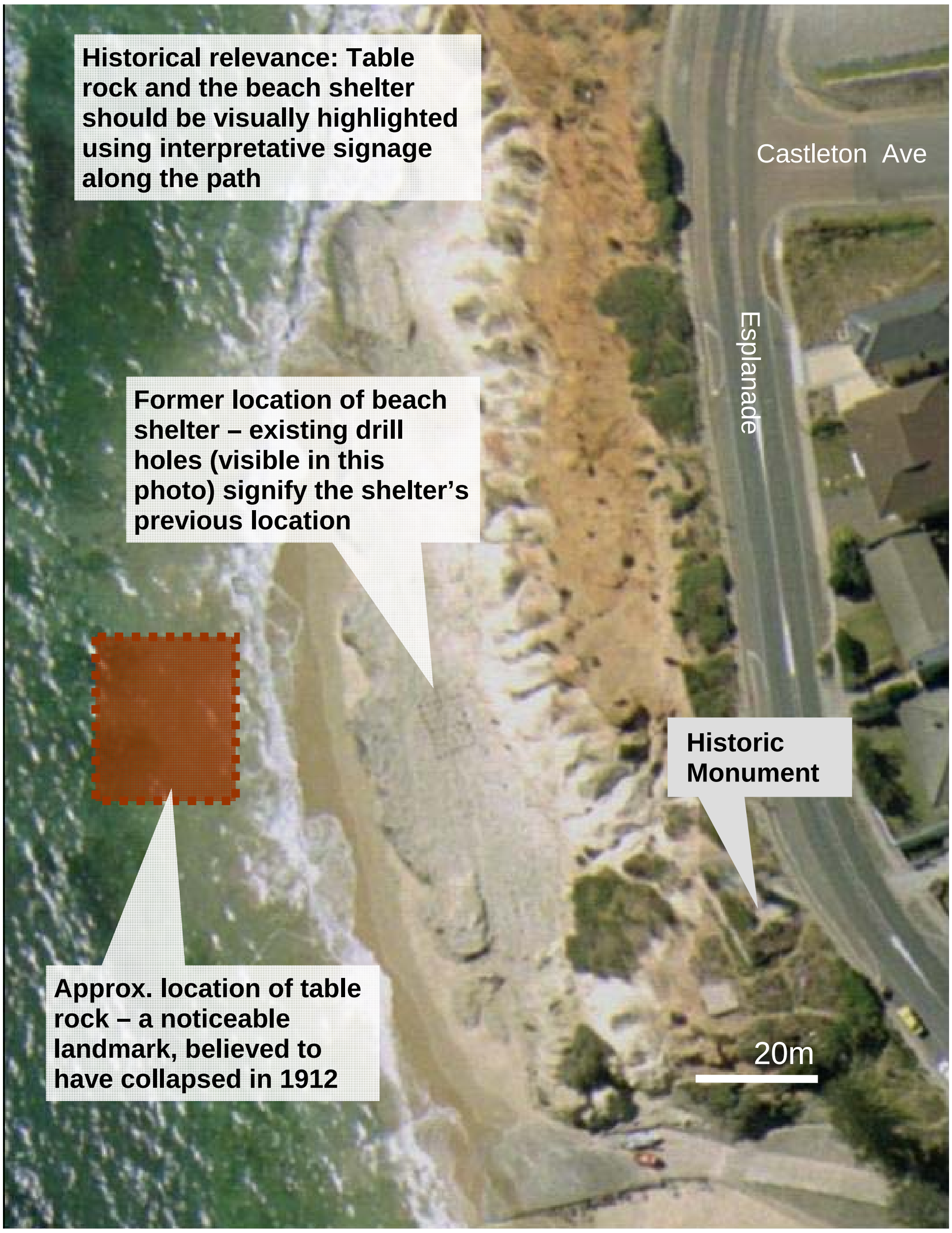


Photo source: MapLand, Department for Environment and Heritage

3.8 Ecological Issues

The following report (Section 3.8) has been prepared by EBS in relation to the ecological impacts associated with constructing a base trail at Witton Bluff including a site inspection, which identified the species present in the immediate area and the disturbance impacts and threats to flora. Key management issues have been identified in Section 3.8.4, which should be investigated further prior to construction.

The ecological report below is based on a site inspection carried out by EBS personnel on 22 March 2005.

3.8.1 Description of Native Vegetation

3.8.1.1 Proposed Trail Area

During the site visit no native vegetation was observed between the northern end of the proposed trail until it meets the stairs at the southern end of the trail. At this point there are several large native shrubs of *Nitraria billardierei* (Nitre-bush) and *Myoporum insulare* (Common Boobialla), some of which are covered with the native climber *Muehlenbeckia gunnii* (Coastal Climbing Lignum). The understorey in this area is dominated by weeds, the most common being Gazania (*Gazania linearis*), Rodondo Creeper (*Drosanthemum candens*) and Hare's Tail Grass (*Lagurus ovatus*). It is likely that the only vegetation that will be impacted upon (as per the proposed trail location)is the area dominated by introduced weed species.

3.8.1.2 Cliff Face

Above the proposed trail area, there is an area of native vegetation on the top half of the cliffs, on the cliff face, which is considered to be in moderate condition. The vegetation in this area is a *Myoporum insulare* (Common Boobialla), *Nitraria billardierei* (Nitre-bush), *Scaevola crassifolia* (Cushion Fanflower) and *Rhagodia candolleana ssp. candolleana* (Sea-berry Saltbush) Open Shrubland. The understorey species consists of a mixture of introduced and native species. The native species included *Atriplex paludosa ssp. cordata* (Marsh Saltbush), *Disphyma crassifolium ssp. clavellatum* (Round-leaf Pigface), *Maireana oppositifolia* (Salt Bluebush) and *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush). The common introduced species in this association included Gazania (*Gazania linearis*), Hare's Tail Grass (*Lagurus ovatus*), Sea-lavender (*Limonium companyonis*) and Great Brome (*Bromus diandrus*).

3.8.2 Species Abundance and Significance of Vegetation

3.8.2.1 Proposed Trail Area

No native plant species were recorded within the proposed trail area except around the stairs at the southern end of the trail. This small area contained approximately three indigenous species and three exotic species. The diversity of flora species within this area is considered to be very low and is not considered to be significant native vegetation.

3.8.2.2 Cliff Face

A total of 48 flora species were recorded at the Witton Bluff site, comprising 25 indigenous species and 23 exotic species, which is considered to be a moderate number. The majority of these species were recorded in the cliff face area and not in the proposed trail area. It is likely that the number of species observed is an underestimation due to time constraints and the season in which the survey was undertaken.

The vegetation in this area is considered to be significant native vegetation that is worthy of protection and restoration. It is considered significant because it;

- is an intact remnant of native vegetation,
- occurs in an area that has been heavily cleared and highly impacted on by human activities;
- would offer an area of habitat for native reptiles and birds

3.8.3 Flora Species of Conservation Significance

3.8.3.1 Proposed Trail Area

No species of national, state or regional conservation significance were observed within the proposed trail area.

3.8.3.2 Cliff Face

No species of national or state conservation significance were observed within the proposed trail area. However, four species of regional conservation significance were recorded. They are detailed in the following table:

Scientific Name	Common Name	Conservation Status		
		AUS	SA	SL
Alyxia buxifolia	Sea Box			R
Samolus repens	Creeping Brookweed			U
Scaevola crassifolia	Cushion Fanflower			R
Zygophyllum billardierei	Coast Twinleaf			R

AUS = Australia, SA = South Australia, SL = Southern Lofty Botanical Region

Conservation Ratings

X = Presumed extinct; not recorded for more than 50 years
E = Endangered; rare and in danger of becoming extinct
V = Vulnerable; rare and at risk from potential threats in the long term
T = Threatened; rare and likely to become either endangered or vulnerable
R = Rare; having a low overall frequency, confined to a restricted ranged or scattered sparsely over a wider area
U = Uncommon; less common species but not rare

N.B.
There may be other native species present in this area, that were not found during this survey due to the time of the year it was undertaken and the brief time taken to carry out the survey. If a survey was carried out during winter or spring more native species (and weed species), such as herbs or lilies may be present. Consequently species abundance is likely to be an underestimate, and other flora species of conservation significance may occur within the area.

3.8.4 Summary of Impact on Native Vegetation

The proposed location of the trail is at the base of the cliff at Witton Bluff, Port Noarlunga. The majority of this area contains little native vegetation and the impact on native vegetation in this area is considered to be insignificant. The main area containing native vegetation is located at the southern end of the proposed trail where the trail will connect to the stairs. At this point there may be an impact on several large native shrubs, which may require some trimming, but should not require removal. The understorey vegetation in this area is dominated by weed species, and therefore the proposed development will have a negligible impact on native flora.

Any construction works associated with the proposed trail should avoid the areas on the cliff face, as it contains significant native vegetation.

3.8.5 Revegetation Species List

If revegetation works are required or proposed as part of the Witton Bluff Base Trail, the following species are recommended:

- *Acacia longifolia var. sophorae* (Coastal Wattle)
- *Alyxia buxifolia* (Sea Box)
- *Atriplex cinerea* (Coast Saltbush)
- *Atriplex paludosa ssp. cordata* (Marsh Saltbush)
- *Carpobrotus rossii* (Native Pigface)
- *Dianella revoluta var. revoluta* (Black-anther Flax-lily)
- *Disphyma crassifolium ssp. clavellatum* (Round-leaf Pigface)
- *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush)
- *Isolepis nodosa* (Knobby Club-rush)
- *Maireana oppositifolia* (Salt Bluebush)
- *Myoporum insulare* (Common Boobialla)
- *Olearia axillaris* (Coast Daisy-bush)
- *Rhagodia candolleana ssp. candolleana* (Sea-berry Saltbush)
- *Scaevola crassifolia* (Cushion Fanflower)

Refer to Appendix C for Witton Bluff species list.

4 Risk Analysis

This section is Connell Wagner's interpretation of the risks associated with a base trail at Witton Bluff. Council are advised to undertake their own detailed risk analysis and risk management strategy in conjunction with its insurer.

Outlined below are some of the major issues and risks relevant to the Study as identified from the site inspection and discussions with various stakeholders. To summarise these risks and the potential mitigative actions, a Risk Management Schedule has been prepared, and is provided as Table 3. Monitoring procedures to manage these risks have also been prescribed. It will be the responsibility of City of Onkaparinga to undertake the monitoring, and advise and seek assistance of relevant agencies as necessary.

Residual risk is expressed as likelihood and consequence, in accordance with the Australia/New Zealand Risk Management Standard (AS/NZS 4360-1999: Risk Management) as displayed in Tables 1 and 2. The detailed descriptions that are provided in Table 1 have been adapted to suit this particular project. Table 2 provides the qualitative measures of risk as the product of consequence (or impact) and likelihood, as detailed in the Standard.

Table 1 Likelihood and Consequences: definitions and ratings

Qualitative measures of consequence or impact			Qualitative measures of likelihood		
Level	Descriptor	Detailed description	Level	Descriptor	Detailed description
1	Insignificant	Very low significance	A	Almost certain	The event is expected to occur in most circumstances
2	Minor	Consequences can be readily absorbed but management effort is still required to minimise impacts	B	Likely	The event will probably occur in most circumstances
3	Moderate	Significant event that can be managed under normal operating procedures	C	Possible	The event might occur at some time
4	Major	Critical event, which with proper management, will be endured	D	Unlikely	The event could occur at some time
5	Catastrophic	Disaster, extensive loss of flora fauna, property or human life	E	Rare	The event may occur only in exceptional circumstances

Table 2 Qualitative risk analysis matrix

Consequences					
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (almost certain)	H	H	E	E	E
B (likely)	M	H	H	E	E
C (possible)	L	M	H	E	E
D (unlikely)	L	L	M	H	E
E (rare)	L	L	M	H	H

Legend
E: extreme risk; immediate action required
H: high risk; senior management attention needed
M: moderate risk; management responsibility must be specified
L: low risk; manage by routine procedures

Table 3 Risk Management Schedule

Issue	Related Issues	Risk Event	Environmental consequences	Impact / Consequences (see Table 1)	Likelihood (see Table 2)	Risk Rating	Mitigative Actions	Residual Risk	Monitoring	Partnerships#
Geotechnical	Cliff and limestone platform instability	High impact but low likelihood instability hazard such as cave or overhang collapse, or large soil slump	Human harm or death, and moderate to major damage to path infrastructure	Catastrophic (5)	Unlikely (D)	Extreme	a) Path set back sufficiently from seaward edge of limestone platform and from cliff base to avoid or reduce impact of instability b) Barriers provided on sides of path to control access on to the limestone platform and provide protection to path users against impacts from falls or slumps of cliff face material above path c) Signage on each side of the path to warn path and beach users of the instability hazards and hence the risk of accessing the limestone platform other than along the path	Moderate Unlikely Moderate	Visual inspections and regular (annual) site inspections by a geotechnical engineer to assess the risk associated with cliff stability	Engineer
Marine and Coastal	Wave Action	Storm	Possibility of water sweeping humans off the trail and cause human harm or death	Catastrophic (5)	Rare (E)	High	a) Construct walkway above high water levels. b) Provide balustrade fencing (designed to Australian Standards specifications) for safety purposes. c) Install appropriate signage to warn trail users of the risks associated with accessing the trail during storm events. d) Close walkway during extreme storm events.	Risk removed	No formal monitoring required. Signage will inform users of the associated risks of using the path during storm events. Regular maintenance inspections of the trail will be required to maintain adequate safety standards. Inspection and repairs if maintenance required after severe storms	Engineer
			Damage to the walkway due to debris carried by waves impacting on walkway and handrails.	Moderate (3)	Likely(B)	High		Minor Unlikely Low		
	Very High Tides (usually associated with severe storms)	Flooding	Water rising over walkway.	Insignificant (1)	Unlikely (E)	Low		Insignificant Rare Low		
Civil Engineering	Stormwater	Increase in pollution during construction	Endangering marine life	Moderate (3)	Unlikely (D)	Minor	a) Construction of the path during dry conditions to reduce risk of stormwater collecting any construction debris b) If any additional stormwater works is necessary, appropriate pollution prevention devices should be installed (eg GPTs)	Minor Unlikely Low	Construction work should occur during fine weather conditions. Interpretative signage displaying information about local marine life coupled with bins and stormwater pollution collection devices placed along the trail should be sufficient to avoid excessive pollution entering the ocean.	Construction company, Base trail design engineer
		Increase in pollution after construction	Endangering marine life	Moderate(3)	Possible (C)	High	a) Bins placed along the trail to collect user litter	Minor Possible Moderate		
		Erosion	Exacerbated gullying and tunnel erosion due to trail impediment	Minor (2)	Possible (C)	Moderate	Trail elevation to allow stormwater to pass underneath the trail, thereby nullifying any additional erosion	Minor Possible Moderate	Monitor and address any erosion created by the trail. Appropriate design should mitigate the possibility of erosion onset.	Engineer
Social, Historical, Heritage and Cultural Issues	Historical infrastructure	Construction or post construction impacts	Loss of historical infrastructure	Major (4)	Rare (E)	High	Conduct appropriate heritage searches (refer Section 3) to avoid any construction interruptions	Minor Rare Low	Conduct an internet search of Australian Heritage Places Inventory. On-going monitoring is not considered necessary.	Planner / Engineer
	Archaeological (Giant Penguin fossils)	Construction impact	Damage or loss of historical natural feature	Moderate (3)	Unlikely (D)	Medium	Recognition of possible event in Environmental Management Plan. Monitor during construction. Stop work immediately and notify the South Australian Museum	Minor Rare Low	Monitoring during construction	Construction contractor, South Australian Museum
	Social	Social opposition	Construction hold	Moderate (3)	Possible (C)	Medium	Conduct appropriate public notification measures to avoid any construction interruptions	Moderate Unlikely Minor	Social concerns must be taken into consideration by Council may be applied to the design of the trail	Planner
	Cultural	Cultural artefacts found during or post construction	Construction hold	Major (4)	Rare (E)	High	Construction company must be aware to notify Council if any items of Aboriginal significance are discovered. Employ the use of 'Heritage Monitors' to progressively watch-over the construction of the base trail.	Minor Rare Low	No on-going maintenance required	Department of Aboriginal Affairs and Reconciliation (DAARE), Kaurna Group
		Cultural opposition	Construction hold	Major (4)	Unlikely (D)	High	Conduct appropriate Aboriginal heritage searches (refer Section 3) to avoid any construction interruptions	Minor Unlikely Low	Appropriate cultural searches (through DAARE) are appropriate prior to the construction phase	DAARE, Kaurna Group
Ecological	Native Flora	Significant disturbance of native vegetation during construction	Significant reduction of threatened native vegetation	Moderate (3)	Unlikely (D)	Medium	There was little native vegetation identified during the site inspection at the location of the proposed trail.	Insignificant Unlikely Low	Construction company should be informed of native vegetation issues and will need to refer to an environmental management plan	Construction company
		Significant disturbance of native vegetation post construction	Reduction of threatened native vegetation	Moderate (3)	Unlikely (D)	Medium	No action required. It is anticipated that a formal trail will reduce the impact on native vegetation due to the reduction of traffic on informal tracks.	Moderate Unlikely Medium	Not required	

Issue	Related Issues	Risk Event	Environmental consequences	Impact / Consequences (see Table 1)	Likelihood (see Table 2)	Risk Rating	Mitigative Actions	Residual Risk	Monitoring	Partnerships#
		Increased numbers of flora pest species	Increased pest species/numbers possibly linked with a reduction in native flora	Minor (2)	Unlikely (D)	Low	Utilise native vegetation planting and pest flora control measures in the immediate area.	Minor Unlikely Low	The success of the vegetation programs will need to be monitored and assessed. Monitoring schedules and actions will depend upon the outcomes of the vegetation assessment	Friends Groups
	Native Fauna	Affecting native fauna populations(land)	Reduction of native fauna (land) in the immediate area	Moderate (3)	Rare (E)	Medium	Reduce the human impact on the fauna habitats. A formal path should discourage users to enter fauna habitats	Minor Unlikely Low	Not required	
		Affecting native fauna populations(marine)	Reduction of native fauna (marine) in the immediate area	Moderate (3)	Rare (E)	Medium	Pollution will need to be managed. Stormwater and litter are the major forms of pollution to affect marine life and these issues have been addressed elsewhere in this table	Minor Unlikely Low	Not required	
		Uncovering fossilised fauna (eg Giant Penguins) during construction	Destruction of historical values	Minor (2)	Rare (E)	Low	Inform construction contractors of the possibility of encountering fossils.	Minor Rare Low	Not Required	Construction contractor

It is implied that City of Onkaparinga will be a partner in all actions

5 Route Identification

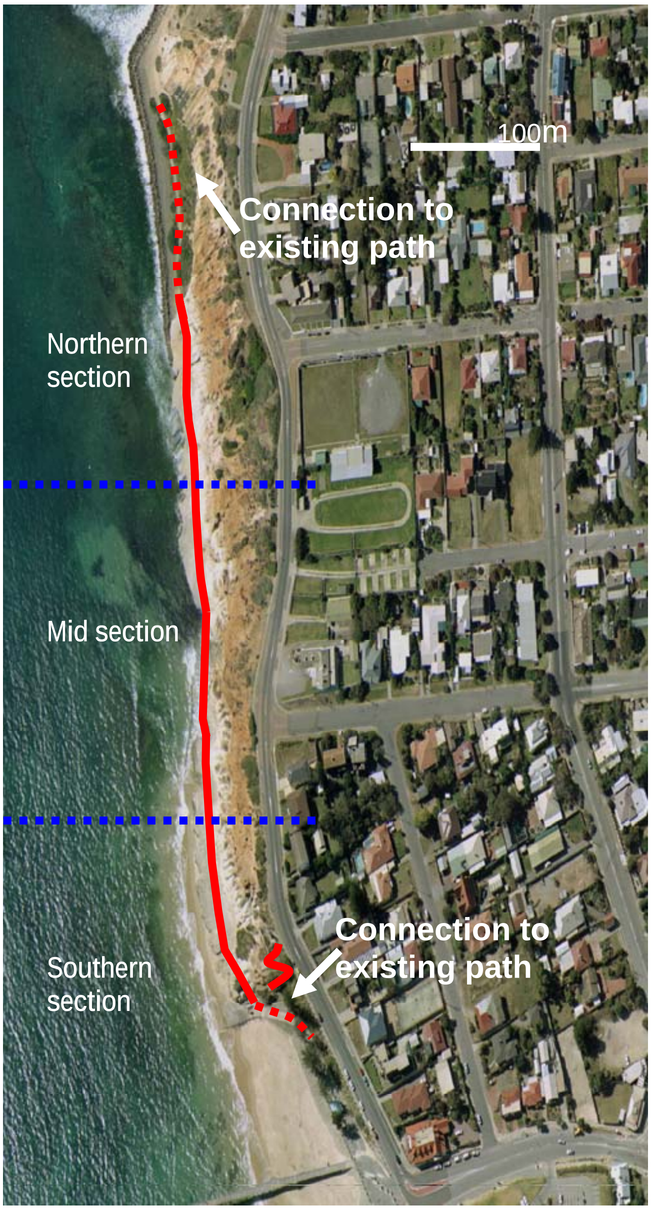
The preferred alignment of the proposed boardwalk has been based on environmental, geotechnical and civil issues detailed in **Section 3**. Specifically, the route alignment options identified in **Section 3.4** in reference to geological conditions and siting provides a strong basis for the selection of the preferred route.

This section identifies the route alignment over three stages. The route can best be described as being divided into three main areas as seen in **Figure 7**:

- northern section
- mid section
- southern section

Figure 7 – Route Alignment (3 stages)

Photo source: MapLand, Department for Environment and Heritage



Each area has a specific role with respect to linkages and the form of construction of the trail.

The **northern section** provides the critical connection to the existing path to the north. A graded ramp is recommended to link the northern limestone platform to the gravel path and will provide a distinctive physical change to the shared path experience through the increase in height and path form.

The **mid section** will feature a bridged form of the boardwalk making it a spectacular feature of the boardwalk at high tide and providing a design feature that emphasises the connectivity value of the boardwalk between the north and south limestone platforms.

The **southern section** will extend over the point and through to the existing pedestrian boulevard leading up to the Witton Centre. A graded ramp is recommended here to ensure adequate access for cyclists and wheelchair access.

The southern section also comprises additional detail (2 options as shown in **Figures 8 and 9**) with regards to the access between the boardwalk and the historic monument in recognition of the important interpretative link between the trail and the heritage of the area. Achieving an access arrangement that minimises impact on the cliff face here is extremely important. The absence of quality vegetation on the cliff allows for minimal environmental impact.

The following images were prepared in response to the need to clearly demonstrate the accessibility issues between the base trail and the historic monument. From the road, the monument provides a drawcard to passers by with the lure of a highly advantageous viewpoint over the coastal area. Connecting the monument to the boardwalk via safe passage will generate greater user potential for the boardwalk particularly for those unaware of the boardwalk such as tourists. Further analysis of cliff stability where stairs are proposed is recommended prior to construction.

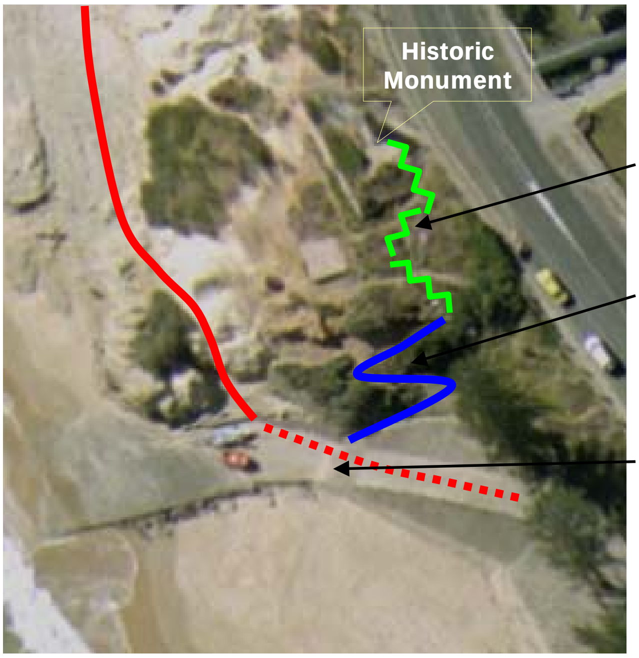


Figure 8 – Southern Section Access (Option 1)

Figure 8 demonstrates access to the monument via the previously constructed ramp with the addition of formalised stairs to complete the journey.

This Option relies completely upon a new stairwell from the boardwalk to the monument and would incorporate a new viewing platform (near where the old one existed).

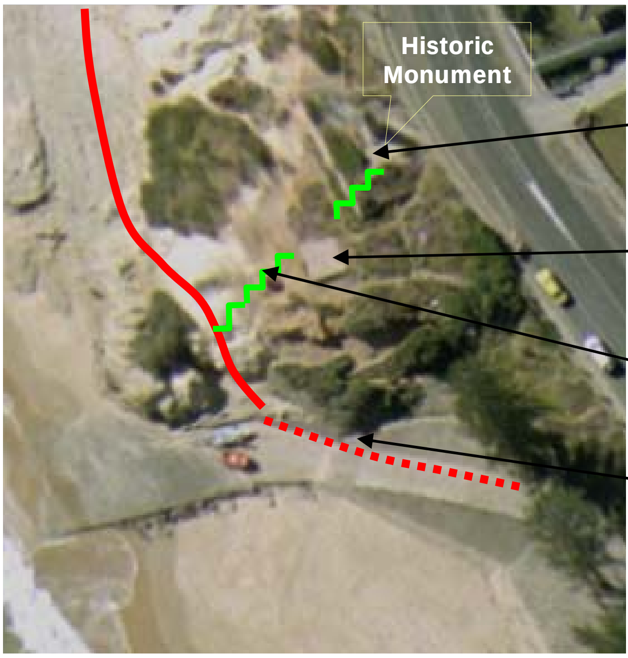


Figure 9 – Southern Section Access (Option 2)

Photo source: MapLand,
Department of Environment and Heritage

The preferred option would be Option 1 which utilises previously constructed areas and formalises points of informal access which are contributing to the demise of this area of the Bluff. It could potentially be the least costly option through the use of the existing infrastructure although it is possible that the ramp will require widening and replacement of the path which may have cracked and risen in parts.

The former viewing platform will provide for an excellent vantage point across the Bluff and along the beach and boardwalk and allows greater visual scrutiny of the activity on the Boardwalk than the monument area. This issue of surveillance was raised as a concern during consultation on the Foreshore Access Study and could in part be addressed through redeveloping this vantage point.

Unfortunately, because of the steepness of the cliff, it is considered that both access options to or from the monument will not allow disabled access.

6 Design Criteria

The design of a boardwalk at the base of Witton Bluff requires investigating all of the options available to ensure that the longevity, cost, aesthetic and safety aspects of the projects are taken into consideration. A boardwalk is a suitable recreational trail for Witton Bluff due to the following associated advantages:

- Minimal environmental damage during construction;
- Minimal erosion issues caused by the construction process;
- Little change in drainage patterns in comparison to the damming effect of pavement construction or concentration of water by use of stormwater pipes;
- Constraining the users to the defined pathways thus eliminating the risk to flora and minimises the safety issues relating to cliff stability (given adequate setback from the cliff); and
- Minimal environmental impact as a result of an elevated structure supported on discreet points in the natural environment.

A cost analysis of the most suitable options is essential when designing a boardwalk. The location, construction materials and budgetary requirements must be taken into consideration in the design.

6.1 Location

The proposed boardwalk is to be constructed in a marine environment; therefore safety, material selection and design are important aspects. The main use of the boardwalk is recreational and therefore will not be used heavily in extreme weather events thus reducing the requirement for design in extreme weather conditions (which would be the case if the boardwalk were used as a transport corridor for work or education). The environment should be allowed for when considering construction materials.

The piles of the boardwalk will likely be set into the rock beneath the boardwalk. Setting the piles into rock has strength advantages compared with a boardwalk in a wetland environment or on the beach itself where erosion may be a major influence.

6.2 Construction Materials

The advantages and disadvantages of the proposed systems were considered in consultation with the client.

6.2.1 Timber-framed Walkway

Advantages:

- Lower initial cost;
- Ease of construction (light-weight for handling materials into position);
- Compatibility with nearby structures (Port Noarlunga jetty etc);
- Adaptability on site
- Eco-friendly solution (less embodied energy, renewable resource).
- Higher aesthetic value

Disadvantages:

- Durability;
- Maintenance.

6.2.2 Precast Concrete Plank

Advantages:

- Reduced recurrent maintenance;
- Durability.

Disadvantages:
- Initial cost;
- Difficulty of handling (each plank weight over 100kg).
- Lower aesthetic value

6.2.3 Steel Framed with Light Weight Decking

Advantages:
- Single supports possible.

Disadvantages:
- Questionable corrosion resistance;
- Weight;
- Inflexible (all connections need to be prepared off site).

The disadvantages of the steel and concrete scheme compared with the timber scheme resulted in the preference for a timber scheme.

The timber species used for the decking is of particular importance due to the aesthetic, cost and engineering implications. The proposed boardwalk will be exposed to a full range of weather conditions; therefore the timber species is required to be tough, stable, resistant to UV degradation and durable.

Timber species have different properties, affecting their suitability, relating to:

- durability
- fire resistance
- shrinkage
- strength
- weight
- workability

Other factors, which are also related to timber selection, are: availability, preservatives and staining.

6.2.4 Durability

The durability of different timber types have been tested and the anticipated life-spans can be estimated based upon the testing results. The highest anticipated life-span range was 25-50 years, for non-embedded situations for the following species:

- Iron bark,
- Grey gum,
- Tallowwood,
- Gympie Messmate; and
- Cypress pine.

6.2.5 Fire Resistance

Due to the location and the lack of vegetation within close proximity to the proposed location of the boardwalk, fire is not considered a major factor influencing timber choice. However, it should be noted that hardwood has a better chance of survival during a fire event than softwood.

6.2.6 Shrinkage

Tangential shrinkage from unseasoned to seasoned timber can vary between approximately 2% and 10%, depending on the species type. Shrinkage factors should be considered in the detailed design phase, as it affects the ability of the structure to remain serviceable. A designer with experience in designing connections in timber structures capable of accommodating shrinkage is critical.

6.2.7 Strength

The following table indicates the strength difference between species types.

Species	Stiffness E MPa	Bending F'b MPa	Toughness
Iron Bark	16,000	22	H
Spotted Gum	14,000	17	H
Cypress Pine	6,900	5.5	L
Radiata Pine	6,900	5.5	M
Oregon (Douglas Fir)	7,900	6.9	L

6.2.8 Weight

The following table shows the range of unseasoned densities for various timbers. Spotted gum 150x75 has been adopted as a standard for comparison purposes and the depth (D stiffness) of the common grades of the other species has been computed so that they all exhibit the same stiffness, as this generally governs design.

Species	Timber density E MPa	Same stiffness		Same strength	
		D stiffness	Kg/m	D bending	Kg/m
Iron Bark	1,250	143	13.4	132	12.4
Spotted Gum	1,200	150	13.5	150	13.5
Cypress Pine	850	190	12.1	264	16.8
Radiata Pine	800	190	11.4	264	15.8
Oregon (Douglas Fir)	710	182	9.7	235	12.5

6.2.9 Workability

Hardwood is more easily worked while it is unseasoned; therefore it is best to keep it from drying out whilst in storage. Further construction details should be specified by the timber supplier and the construction contractor.

6.2.10 Timber Selection

On balance and based upon the success to date of its use at Granite Island, White Cypress Pine (WCP) is the preferred timber species for this project. WCP is an indigenous softwood timber, which has a low shrinkage (2.5%), a high density (680 kg/m3), and a hardness (6.5kN) exceeding most oak species.

WCP, as its name implies, is a light colour red that will be well suited aesthetically to the whitish colour of the lower limestone cliffs and underlying rock and the red upper part of the cliffs.

Chemical treatment to preserve the timber from termites and borers is not necessary due to the natural resistance, thought to be the distinct pine aroma of WCP.

WCP is obtained from managed native forests (Northern NSW / Southern QLD) and has frequently occurring knots, an even texture, and a straight grain.

Therefore, WCP is the preferred timber that best meets the requirements for the boardwalk at Witton Bluff.

6.3 Design Ideas

A timber boardwalk design using white cypress pine has been successfully implemented at Granite Island. A similar design could be adopted at Witton Bluff. The photos below illustrate the effectiveness of a timber boardwalk, constructed of WCP, in a coastal environment.

Photos 1, 2, 3 and 4 shows that the colour of the rock at Granite Island is similar in colour to the lower cliffs and rock platform at Witton Bluff.

Photos 7 and 8 illustrate viewing platforms near water environments. Viewing platforms could be used at Witton Bluff, incorporating interpretative signage, educating path users of historical and cultural significance. The viewing platform in Photo 7 would be better suited attached to the proposed boardwalk on the lower rock platform and the platform in Photo 8 could serve as a viewing area at the crest of the cliff near the memorial.

6.4 Safety in Design

Promoting and incorporating safe design practices for the development will be a primary requirement. Several issues have been identified as safety hazards including the potentially unstable cliffs and associated falling rocks and children climbing over the railing, both of which present human safety hazards.

Design measures to minimise public risk include allowing for a suitable set-back distance from the cliffs and to elevate the path; thereby reducing the likelihood to an acceptable level of falling rocks impacting on path users.

Vertical railing should be used as opposed to horizontal railing so that children cannot climb over the railing, causing injury. This feature was a key component of the Granite Island boardwalk (refer Photo 6). The location of the boardwalk makes this a critical issue. The cost of vertical railing is higher than using horizontal railing; however the safety benefits override the extra project expense.

6.5 Urban Design Opportunities

There are several options which have been identified as adding aesthetic value to the proposed base trail. These options are as follows:

- Lighting the cliff face will highlight the natural colours of the cliffs. The lights could be directed towards the sky up the cliff face to maximise their effect.
- Lighting of the boardwalk for safety purposes at night. Electricity supply does not currently exist at the base of the cliffs; therefore electrical infrastructure will need to be installed. There is a possibility of using solar powered lighting; however cumbersome battery packs will be associated with this option and cost will be a factor.
- The design of the path could incorporate a marine theme with elements such as masts and sails as part of the boardwalk infrastructure capturing the heritage of the area.
- Interpretative signage is recommended to allow boardwalk pedestrians to conduct a self-guided tour. Signage could refer to Aboriginal culture, European history and historical landmarks of the immediate coastal area such as table rock and the beach shelter as discussed in Section 3.7.

It must be noted that these suggestions have not been considered in the formation of the construction estimate in Section 7.

6.6 Width

The width of the proposed base trail should be 3.6 metres, which would accommodate the following users:

- People walking
- Cyclists
- Wheelchairs.

Alternatively, if a width of 3.2 metres is adopted due to width restrictions along the limestone platform, passing bays should be incorporated into the design.

These options shall be analysed and discussed during the detailed design stage.

6.7 Maintenance

6.7.1 Revetment Maintenance

Council require a utility vehicle (and infrequently larger vehicles) to be able to drive to the northern end of the limestone platform for maintenance purposes for the revetment. The design of the proposed base trail allows for a ramp at the northern end of the limestone platform to connect to the lower path. Therefore the ramp will need to be designed to allow adequate distance between the rock revetment and the ramp for a utility vehicle to drive in and reverse out.

6.7.2 Asset Maintenance

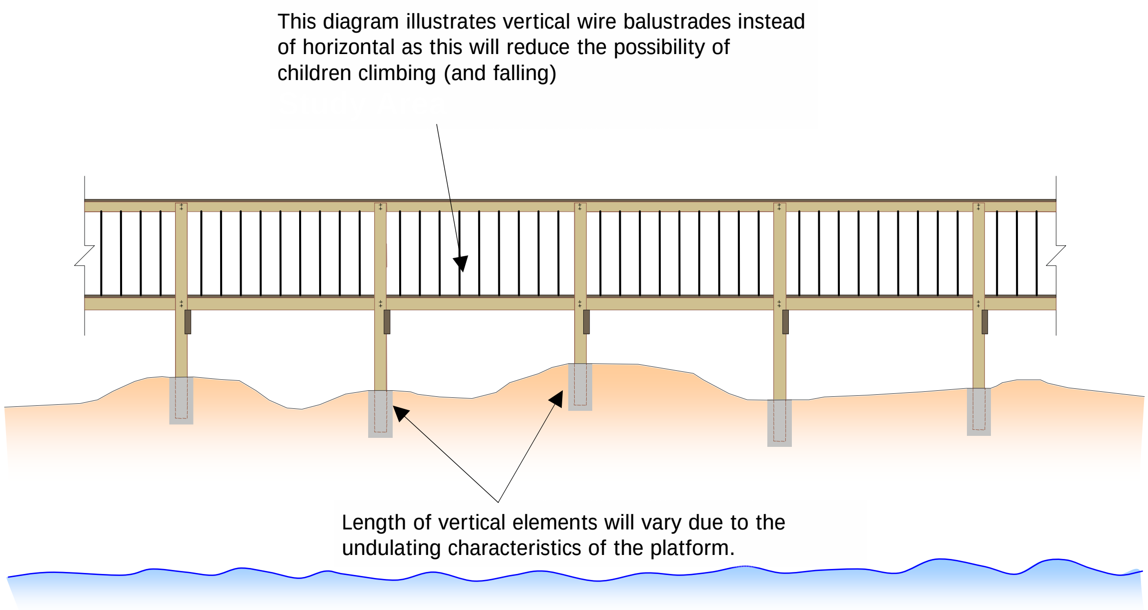
Council will need to consider long term asset maintenance and associated cost implications, which have not been addressed in the cost analysis (Section 7), however should be investigated during the preliminary design phase.

6.8 Construction Environmental Management Plan (CEMP)

In the recommendations to this report Council is advised of the need to prepare a detailed CEMP which will guide the environmental management of construction associated with the development. This plan will address a range of considerations including:

- construction noise which should be minimised so as to prevent disturbance of any bird species that may be roosting in the Bluff cliffs and to nearby residents;
- managing sediment resulting from boring of piles so that it does not escape into the marine environment;
- minimising impacts on flora;
- minimising dust emissions;
- ensuring vehicles can access the site without impacting on the beach and damaging the cliffs;
- providing for continued access to the beach for beach users; and
- controlling the spill of any hazardous chemicals which may be used during construction.

Figure 10 – Boardwalk Construction (mounting)



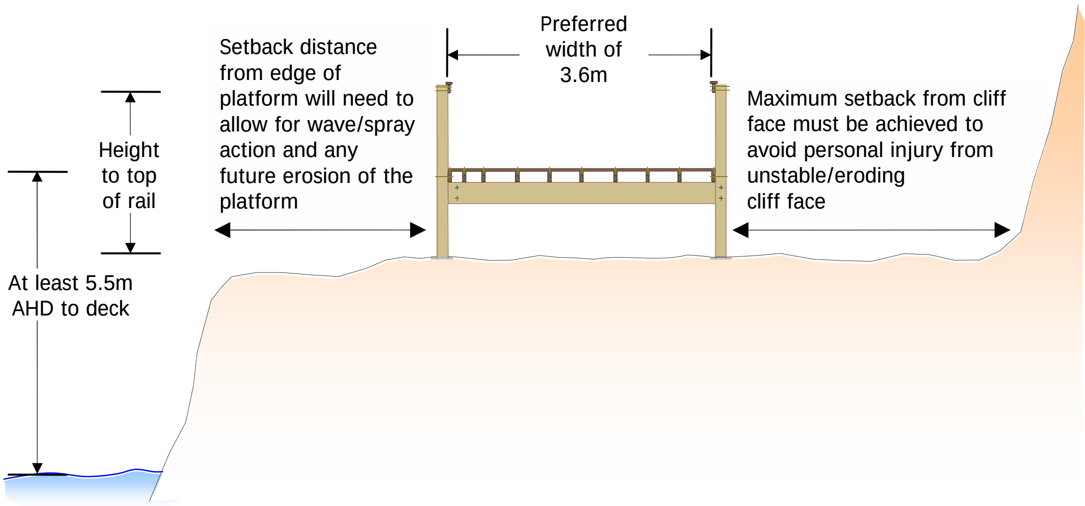


Figure 11 – Safety Design Features of a boardwalk

Granite Island Boardwalk Images


Photos 1 and 2: This type of boardwalk could be adapted to the coastal environment at Witton Bluff.


Photos 3 and 4: Stairs can be shaped to the existing environment. The timber compliments the colours and the general surroundings, which is similar to the Witton Bluff environment.


Photos 5 and 6: Added safety measures include steel vertical railings, which should be used in the construction of the Witton Bluff boardwalk for safety purposes.

Photo 7: This image was not taken at Granite Island, however seating and viewing areas could be adapted at Witton Bluff similar to as depicted example.

Photo 8: A viewing platform such as this one at Granite Island would promote the tourist potential of the area.

7 Cost Analysis

The cost options provided in this report are not supported by detailed measurement or design. As a consequence, they are a guide only to the probable costs which remain dependent on final design. Also relevant to cost are the following matters:

- The timber option assumes a width of 3.6 metres. The price is based on a timber structure, with White Cypress Pine being the most suitable choice. This timber is naturally termite resistant and has lower shrinkage than a hardwood.
- This estimate is only for the elements listed in direct relation to the Boardwalks. No allowance has been made for any other structures that form part of the overall plan. Specifically excluded from this estimate are:
  - Stairs.
  - Proposed interpretative signage.
  - Proposed seating areas.
  - Re-vegetation if required.
  - Powered lighting.
- This cost analysis is limited to assessing timber options; however materials such as concrete and recycled plastic can be investigated during a detailed cost analysis.

Cost Guide

The total proposed length of the boardwalk is approximately 400m with related improvements such as stairs to the monument likely to increase the overall length. However, the cost estimate will be based upon the length of the primary boardwalk.

The final costs will be affected by numerous factors, including the following:

- Geological conditions for the support of structures on the beach and the cliff face, including detailed investigations by an appropriately qualified geologist.
- The final material selections based on the environmental and geological constraints.
- Access for machinery and materials delivery etc.
- Safety issues (balustrading during construction).

Considering the number of unresolved issues at this stage, we have based our cost opinion on our experience with similar projects with appropriate allowances for escalation and the like.

These are:-

Location	Length	Width	Total Cost	$ Cost/m2	$ Cost/m
Granite Island White cypress pine	Flat 40m Stairs 60m	2.4m typically up to 6.2m at lookouts 1.8m (ave 2.5m)	$415,000	$1,660/m2	$4,150/m
West Beach shared path CCA treated timber	88m	3.6m	$170,000	$540/m2	$1,950/m

Notes

1. Granite Island had difficult access, curvilinear layout and is mainly stairs. Because it is narrow the cost of the balustrading is relatively high per square metre of deck.
2. West Beach had easy access, easy pile driving in sand for posts, wide uniform width deck and virtually straight, simple balustrading.
3. Costs include builder's preliminaries and professional fees.
4. For Witton Bluff the estimate allows for socketing posts in the limestone, the relatively difficult access and the higher cost of the timber.

On the basis of these previous projects, our broad total project value estimate for the Witton Bluff project, inclusive of professional fees, is in the order of $1,200,000. This represents a lineal metre rate of approximately $3,000 for the boardwalk. Once the preferred design and routes have been determined a totally integrated design including stairs and improvements to concrete ramps will enable a completely detailed costing of the project to be made.

Should the City of Onkaparinga require a more accurate cost opinion for this project, we strongly recommend that a preliminary design be undertaken, including the appropriate geological assessment to refine the appropriate cost allowances.

Figure 12 – Approximate distances

Photo source: MapLand,
Department for Environment and Heritage

8 Conclusions

A base trail at Witton Bluff is a feasible option if the environmental aspects of the project are suitably managed. The main environmental and design issues associated with the project have been addressed below:

- One of the most important factors in determining the location and initial feasibility of a trail was to assess the geotechnical suitability of the location. It was concluded that a trail on the sloping face of the cliff or adjacent to the cliff crest was not feasible due to geotechnical constraints.

- If the base trail is constructed on the limestone platform at the base of the cliff, which is the preferred option, the setback from the face of the cliff above the platform must be adequate to minimise the risks to path users and path infrastructure associated with potential impacts from erosion, soil slumps and rock falls from the unstable cliff face. The setback from the seaward edge of the platform must be adequate to minimise the risks to path users and path infrastructure associated with potential collapse of existing caves and overhangs in the limestone. These risks can be managed during the design and planning phase of the project by ensuring that adequate setbacks are achieved.

- The presence of caves and overhangs in the limestone platform at the base of the cliff which, should they collapse, will collapse rapidly and without warning. Therefore the erection of signage warning beach users of the risks associated with the limestone platform is recommended based upon the findings from the geotechnical study.

- The best method of construction for the shared path to satisfy the site conditions is an elevated timber board walk. The design standards should comply with Austroads Part 14 Cycles and AS 1428.1 *Design for Access and Mobility.*

- The main civil engineering issues that have an environmental impact are the disturbances to the platforms for access for plant and equipment and the generation of spoil from the excavation of holes for the posts. Work methods should be developed to appropriately manage the risks to minimise environmental harm.

- There appears to be no cultural or heritage issues which will impede project construction. However, during the planning and design of the base trail, adequate signage in respect to Aboriginal heritage and previous significant landmarks, such as the beach shelter and Table Rock should be addressed.

- There is very little significant vegetation at the location of the proposed trail; therefore the ecological impact will be minimal.

- Social aspects of the proposal must be considered and managed appropriately. Public notification, and if necessary consultation, must begin early in the process to effectively manage public opposition to the path. The environmental advantages should be presented in a format to promote the project and encourage public support for the trail.

- The preferred route alignment along the limestone platform will be required to link via a suitably graded ramp to the existing shared path to the north and extend southerly to the point where it joins the pedestrian and boat ramp access way enabling continual uninterrupted access for the entire route including disabled access.

- The preferred material for boardwalk construction is timber, which should be designed to aesthetically blend with the limestone platform. The preferable timber is white cypress pine based on the success of the Granite Island boardwalk.

- The design of the timber boardwalk will embrace safety design standards including vertical railing to deter climbing over rails and setbacks from the cliffs in order to minimise risk to users from rockfalls / landslides.

- The estimated cost of the boardwalk based upon a structure approximately 400m long including boardwalk, ramps and possible stairwell access will be in the order of $1,200,000. Detailed costings from a suitably qualified cost consultant are strongly recommended.

9 References

Gatton Sawmilling Company, January 1998, *Boardwalk Design Guide*.

Connell Wagner, June 2002, West Beach Shared Path Design.

City of Onkaparinga Development Plan 17 March 2005

MapLand, Department for Environment and Heritage, Pirie St, Adelaide

Earth.google.com – satellite imaging reference

Protected Matters Search Tool, Department for Environment and Heritage www.deh.gov.au

Australian Standards

Access
AS 1428.1 *Design for Access and Mobility*
Austroads Part 14 Cycles and AS 1428.1 *Design for Access and Mobility.*

Risk Management
Australia/New Zealand Risk Management Standard (AS/NZS 4360-1999: Risk Management)

Appendix A

URS Geotechnical Report

R E P O R T

Geotechnical Assessment for Witton Bluff Base Trail Environmental Feasibility Study

Prepared for

Connell Wagner Pty Ltd

Level 9, 55 Grenfell Street
Adelaide SA 5000

15 July 2005

42656111/WITTON BLUFF BASE TRAIL GEOTECH REPORT.DOC

URS

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Date: **15 July 2005**
Reference: 42656111
Status: Final

Contents

Plates

Plates 1-24 are located in a dedicated section of this report

Appendices

Further to our proposal to Connell Wagner Pty Ltd (CW) dated 21 January 2005, URS Australia Pty Ltd (URS) is pleased to present the following geotechnical assessment, as part of the Witton Bluff Base Trail Environmental Feasibility Study (the feasibility study).

The scope and methodology for provision of geotechnical input to the feasibility study is:

- Review of concept plans and other existing documentation for the proposed works.
- Review of the site setting and the geotechnical conditions and processes at the site.
- Assessment of the interaction between the proposed works and the geotechnical environment, identification of geotechnical opportunities and constraints, and recommendations to support further concept development and planning for the works.

The document “Foreshore Access Plan, Stage 1 – Christie Creek to Port Noarlunga, Community Update” prepared by the City of Onkaparinga (Council) states that the Witton Bluff Base Trail was to be a continuation of the existing trail along the base of the northern half of Witton Bluff.

At a site inspection on 22 March 2005 involving the project team and Council officers, the geographical extent of the proposed base trail was confirmed as follows:

- The northern end of the proposed base trail will connect in to the southern end of the existing path at the base of the cliffs at Witton Bluff, a little north of Anderson Avenue.
- The southern end of the proposed trail will connect in to the existing beach access path which leads to the boat ramp north of Port Noarlunga Jetty, about half way between Saltfleet Street and Castleton Avenue.

There were no other Council specified constraints on the vertical and horizontal alignment of the path, or on the structural form of the path.

The main sources of geotechnical information relating to the study site are contained in the following documents, which have been reviewed as part of this study.

- Golder Associates "Coastal Cliff Stability Geotechnical Investigation". Report prepared for City of Onkaparinga, May 2001.
- URS Australia "Detailed Cliff Stability Investigations, Stage 2 Report, Risk Assessment and Risk Management Strategy for Site Areas A to I". Preliminary draft report prepared for City of Onkaparinga, January 2004.

In addition, the further assessment of the Port Noarlunga to Witton Bluff (South) site that URS has undertaken for Stage 3 of the detailed cliff stability investigations consultancy for Council was also reviewed.

The results of this review are set out below.

4.1 Golder Associates 2001 Report

The Golder Associates (Golder) study extended from Hallett Cove in the north to Sellicks Beach in the south, though some lengths of coastline were not assessed within the overall 30 km length of the study area. The Witton Bluff area, extending from the Port Noarlunga Jetty opposite Saltfleet Street to Beach Road at Christies Beach, was one of the lengths of coastline that Golder examined.

The purpose of the Golder study was to "…advise on the coastal and other processes, which are presently affecting the stability of the coastal cliffs and associated assets and advise on the hazards and risks involved.". One of the main outcomes of the Golder study was the presentation of a table and figure that ranked the assessed risk level for each length of cliff. The risk rankings were "…intended to allow Council to prioritise the implementation of appropriate risk management strategy.".

Golder's work was thus a fairly broad scale study. The risk rankings determined by Golder's risk assessment for each site showed that 9 sites studied by Golder had a relative risk ranking of 1, 2 or 3 (1 meaning the highest relative risk, 2 meaning the second highest relative risk, and so on). The Golder work was subsequently used by Council to scope the detailed cliff stability investigations that are currently being undertaken by URS, which is giving more detailed consideration to all of the 9 relatively more risky sites identified by Golder. These 9 sites were subsequently denoted Areas A to I by Council. One of the 9 risky sites identified by Golder, that was subsequently denoted Area A by Council, includes the study area for the current Witton Bluff Base Trail Environmental Feasibility Study.

The geological sequence mapped by Golder in the area of the current study comprises massive limestone at the base of the cliffs (Blanche Point Formation) overlain by limestone and sands of the Port Willunga Formation, and Ngaltinga Clay and Quaternary sediments.

In the area of the current study, Golder assessed the cliff toe to have a low to medium rate of recession and the crest to have a medium rate of recession. Hence, the cliff crest was assessed to be recessing faster than the cliff toe.

The main forms of geotechnical instability hazards associated with the cliffs at Witton that were identified by Golder comprised:

- Small volume, high velocity rock falls and erosion gullying (the hazard considered by Golder to have the least risk)
- Medium to high volume, low to high velocity landslides and rock slides (the hazard considered by Golder to have an intermediate risk)
- Medium to high volume, high velocity cave and overhang collapses (the hazard considered by Golder to have the greatest risk).

Golder assigned the southern half of Witton Bluff (that part of Witton Bluff south of the point) a relative risk ranking of 2, meaning that this site was, along with several other sites, considered to be the equal second riskiest site of all the sites they examined for their study.

4.2 URS Australia 2004 Report

The URS 2004 report included a more detailed examination of the 9 risky areas identified by the Golder report, including the Port Noarlunga to Witton Bluff (South) area, denoted Area A in the 2004 report. In the discussion of Area A that follows, it should be borne in mind that it is only the southern three quarters of Area A that corresponds to the current study area for the Witton Bluff Base Trail.

4.2.1 Geological Field Mapping

URS undertook geological field mapping of Area A and the results are set out below. The written discussion is supplemented by references to plates that are attached to this Witton Bluff Base Trail report and which were taken during the site inspection for the Witton Bluff Base Trail in March 2005. Marked up contour plans showing the results of the geological hazard mapping done by URS for the 2004 report, and the locations at which the plates were taken during the March 2005 site inspection, are enclosed in Appendix A of the current report.

This cliff is highest at the point of Witton Bluff then gradually drops down to the beach at Port Noarlunga.

The base of the slope is in Blanch Point Formation limestone that forms platforms up to 4 metres high at the beach over the southern three-quarters of Area A (that part of Area A corresponding to the Witton Bluff Base Trail project site). The limestone is relatively erosion resistant and provides protection to the base of the slope from wave undercutting, although relatively slow cave and overhang formation is occurring (Plates 1-2, 11-15, 17).

In the northern quarter of Area A (that part of Area A beyond the northern limit of the Witton Bluff Base Trail project site), a rock revetment has been placed where it appears the slope had been undercut to form a small bay (Plates 7 and 8). Rock fill was also placed behind the revetment to fill in this small bay

(Plates 6 and 9). There is a near vertical cliff behind the revetment up to approximately 20 metres high (Plates 6, 9 and 10). Minor rock falls are noted from this cliff (Plates 6, 9 and 10).

The limestone beds dip to the south at an angle of 2 to 3 degrees. The lower beds form a strong base platform to the weaker rock beds and soil layers above (Plates 3, 22, 24). Wave action creates vertical faces in the lower, stronger limestone beds up to several metres high at beach level (Plates 16, 18, 20) and also erodes caves. In one of the caves located at the northern end of the Witton Bluff Base Trail site (Plates 11-13), a continuous vertical defect with strike 350 degrees outcrops over at least 20 metres (Plate 12). In places it is open up to 50 mm and clean. In other places calcrete fills the defect. In that cave the defect provides a release surface in the roof that could potentially lead to collapse of the cave. Another release surface is provided by the horizontal gap near the top of this cave that extends up to 6 m inward from the seaward edge of the limestone platform (Plate 13). Other overhangs in the limestone are forming and may collapse, including one that forms a small limestone point near the boat ramp (Plates 1 and 2) and another a little south of the cave shown in Plates 11-13 (Plates 14 and 15).

The upper beds in the limestone are 3-4 metres high with medium thickness and spacing. These beds are softer than the lower beds and tend to form flatter slopes at 40-50 degrees to the horizontal and contain more clayey and silty materials. These materials are heavily gullied from surface run off and foot traffic (Plates 5, 19, 21 and 23). Children have been observed playing in these erodible upper limestone beds.

Overlying the limestone is 2 to 4 metres thickness of weakly cemented red-brown sands and gravels (Plates 5-6, 9-11, 16, 18-21 and 23). There are clayey layers in this unit. The beds in this unit are of medium thickness and the weaker beds are preferentially eroded, creating overhangs that periodically collapse. This unit is severely gullied from surface water run off. In addition, the actions of pigeons roosting in this unit in the northern section of Area A and general foot traffic from informal walking tracks on this slope exacerbate the erosion.

Overlying the sands are the high plasticity clays of the Ngaltinga Formation (Plate 4). These are severely gullied by surface runoff, with the gullying also exacerbated by foot traffic. Erosion of the underlying sand undercuts this formation, leading to over steepening and minor slumping. The erosion of this unit has affected infrastructure at the top of the slope. Examples of this are:

- Undercutting of the existing monument near the southern end of the site.
- Undercutting of the footpath close to the existing monument near the southern end of the site.
- Undercutting of the road cable barrier supports and arcuate cracking on the Esplanade road pavement near the undercutting of the road cable supports, north of Castleton Avenue.

There are minor deposits of aeolian fine sands forming a topsoil at the crest of this slope. These are typically less than one metre thick, patchy in location and with a high organic content. These sands are subject to the same erosion from surface water and foot traffic as the other soil units.

This slope and beach are heavily used. There are numerous informal walking tracks on the slope that have exacerbated erosion (Plate 23). These tracks also pass over unstable overhangs. Numerous people have been observed using these tracks. In particular, people seek shelter in the caves on the beach and below the limestone overhangs.

Vegetation cover is sparse, with erosion removing most of the cover. As vegetation cover is removed, the process of erosion and further vegetation removal is accelerated.

4.2.2 Identified Geological Hazards

Based on the results of the geological field mapping for the site, URS identified the following geological hazards associated with the cliff in Area A:

1. Rock falls from the limestone platform at the beach. Three areas (one cave and two blocks) were observed that will fall at some time in the future. The falls will be up to 5 m^3 in size. Currently, people sit under these caves and overhangs. The hazard impact is on public safety only. If these overhangs are removed then this hazard can be downgraded.

2. Runoff and foot traffic erosion and subsequent slumping/debris flow in soil units. This hazard is occurring now. Slumps would be relatively small (up to 3-4 m^3 in size) and would only impact on people directly under a slump if they were on the informal walking tracks on the slope in the southern three quarters of Area A. Therefore, there is low exposure to this hazard. The main consequence of this hazard is slope regression back towards the road where the road is already being affected. There is the potential for an undercut slump to take out the road edge and to impact on the road users on the southern two thirds of the road length where the cliff edge is 0-5 metres from the road. As a short term risk reduction, the two areas primarily affected (road cracking near the lookout, and the existing monument) could be treated by placing fill and vegetation. The risk could then be downgraded. However in the longer term the whole slope must be addressed or this mechanism will recur. In the northern quarter of Area A there is a buffer of approximately 7-10 metres between the cliff edge and the road. However, people can access the area directly below the slope due to the informal walking tracks present on the slope. Therefore, although the road is less likely to be impacted, public safety is an issue. This is also where the impacts of the pigeons are greatest.

3. Mechanism 2 above, which undercuts the surface calcrete and creates an unstable edge. People have been observed walking and siting on the cliff edge, which could collapse at any time. Falls would be small and not impact on infrastructure, however they could impact on people near the edge. Fences and signs warn of the danger and these should be maintained and, if appropriate, their coverage should be expanded (this has since been done). Any falling blocks would be unlikely to reach the beach due to the geometry of the slope, and therefore such rock falls would not present a significant danger to beach users.

4. In the steep section of cliff in the northern quarter of Area A where the revetment has been placed, erosion of the sand beds by water and pigeons can lead to slumps and rock falls of up to several cubic metres. This is currently occurring.

4.3 Risk Assessment

Based on the geological field mapping and the identified geological hazards, URS undertook a risk assessment of each of the 9 sites that were examined as part of the 2004 report. The results of this risk assessment showed good agreement with the results of the Golder risk assessment, even though the details of the URS risk assessment differed from those of the Golder risk assessment. URS concluded that Area A was one of the three riskiest coastal cliff sites in the portfolio of nine sites that were examined, mainly because of:

- The presence of caves and overhangs in the limestone platform at the base of the cliff which, should they collapse, will collapse rapidly and without warning.
- The presence of a relatively busy roadway (The Esplanade) and associated infrastructure adjacent to the crest of an unstable cliff along the majority of the length of Area A.
- The relative popularity of this stretch of the coast with beach users.

Site Inspection

On 22 March 2005, a walk over site inspection covering the longitudinal extent of the proposed Witton Bluff Base Trail was conducted by the project team and Council officers. Geotechnical aspects of the project site were inspected by Dr Matthew Duthy from URS. Marked up plans showing the cliff slope instability and erosion features, and the locations of photographs taken by URS at the time of the inspection, are enclosed in this report. Copies of the photographs are attached to this report as a series of annotated plates. Relevant geotechnical observations made during the time of the site inspection are referred to in the geotechnical assessment given in Section 6.

Based on the existing geotechnical information that was reviewed in Section 4 and on the results of the site inspection undertaken by the project team on 22 March 2005, a geotechnical assessment of the proposed Witton Bluff Base Trail has been undertaken and the results are set out below.

6.1 Alignment

There are five possible alignments for the proposed Witton Bluff Base Trail:

1. Along the crest of the cliff
2. Across the gullied slope between the limestone base platform and the cliff crest
3. Along the limestone base platform
4. Along reclaimed land formed by constructing a fill embankment protected by a rock revetment and located immediately seaward of the face of the limestone base platform
5. Some combination of the foregoing four options.

6.1.1 Option 1 – Along Cliff Crest

Any trail located at the level of the cliff crest will need to be set back behind the crest, since the cliff crest is subject to ongoing recession caused by erosion, soil slumping and calcrete rock falls. A minimum set back distance of the order of 5 m is desirable between the cliff crest line and the seaward edge of the trail, to provide an adequate buffer between the current location of the cliff crest and the edge of the trail. This buffer would minimise the potential for the trail to be undermined by regression of the cliff crest in the short term, since it will permit regular inspection and monitoring of cliff regression before it affects the trail and will provide adequate time and adequate space for remedial works to the cliff crest, in the form of filling, revegetation and the like, to be undertaken in the future if required.

Currently, there is a concrete footpath that runs along the west edge of the Esplanade over the length of the study area. However, this footpath is quite narrow. In addition, generally there are only a few metres of buffer at most between the seaward edge of the footpath and the crest of the cliff. At some locations, such as above the monument at the southern end of the site, and north of Castleton Avenue, the edge of the footpath is already being undermined by regression of the cliff crest.

In order to provide a trail of adequate width for multiple use and with a suitable minimum set-back from the cliff crest, part of the current width of the Esplanade roadway will have to be taken over. This scenario, while not having any adverse geotechnical implications, may require one way traffic or single lane constrictions at some locations along the Esplanade. This will have environmental impacts in terms of restricted traffic flows, access for residents and parking availability.

Alternatively, the trail could partly or wholly extend seaward of the cliff crest. This scenario will require either fill to be placed over the upper part of the sloping cliff face to support the path pavement, or a partly suspended or wholly suspended board walk structure for the path to be supported by columns founded on the upper part of the cliff face. The placement of fill will have environmental impacts associated with loss of native vegetation, construction phase noise and dust, and construction phase interruptions to traffic and parking. A suspended boardwalk structure will have the same impacts, but on a somewhat lesser scale. In addition, temporary enabling works to provide safe access to construction locations and safe working platforms for construction will have similar environmental impacts

More importantly, a trail that is located at or near the level of the cliff crest and which extends partly or wholly seaward of the crest line, will be founded on a part of the cliff face that is geotechnically unstable. This is because the upper part of the cliff face is subject to ongoing recession due to erosion processes, which leads to over-steepening and slumping of the weak soils that form the majority of the upper part of the cliff face, and which also leads to undermining and falls of the thin calcrete cap rock near the crest level. Any fill or column footings that were constructed on the cliff face to support a trail would also be adversely affected by these cliff instability processes. This poses a risk to path users as well as the path infrastructure itself, because of the potential for eventual undermining and collapse of the path support system.

For these reasons, a trail along the cliff crest is only considered to be a feasible option from a geotechnical perspective if it is set back landward from the cliff crest. However, since this will likely require the trail alignment to intrude on the current width of the Esplanade, the current width of the Esplanade would need to be reduced. Since this may have a significant adverse effect on traffic, access and parking along the Esplanade, a trail along the cliff crest is unlikely to be the preferred option on environmental grounds.

6.1.2 Option 2 - Across Gullied Slope of Cliff

A trail that ran across the gullied slope between the limestone base platform and the cliff crest would require either fill to be placed to provide a level surface for construction of a pavement for the path, or a suspended board walk structure for the path supported by columns founded on the sloping cliff face. The cliff slope between the limestone base platform and the cliff crest generally features gullies that are deeply incised at a number of locations. In addition, the cliff slope is typically 45 degrees to the horizontal but in some locations is near vertical. This means that extensive filling would be required to create a level surface for a pavement, and column heights would be significant for a suspended board walk structure. In addition, the significant height and steepness of the slope means that construction of either a pavement or boardwalk path will be difficult, expensive and time consuming because of the very poor accessibility. The poor accessibility also means that environmental impacts will be significant, in the form of loss of native vegetation, construction phase noise and dust, and construction phase interruptions to traffic and parking. This is because significant enabling works will be required to provide safe access to construction locations and safe working platforms for construction, such as creation of access tracks for construction vehicles, plant and equipment.

However, of even greater importance is the fact that the sloping part of the cliff face is geotechnically unstable. The face is comprised of sands, clays and soft limestone that are relatively weak and are subject to ongoing gully erosion, over steepening and slumping. Any embankment fill or boardwalk column footings that were constructed on the sloping cliff face to support a trail would also be adversely affected by these cliff instability processes. This poses a risk to path users as well as the path infrastructure itself, because of the potential for eventual undermining and collapse of the path support system. There is also a risk that path users and path infrastructure will be impacted by gully erosion, soil slumps and calcrete cap rock falls from the slope above the path.

For these reasons, a trail across the gullied cliff slope is not considered to be a feasible option from a geotechnical perspective.

6.1.3 Option 3 – Along Limestone Base Platform

The limestone base platform presents an obvious corridor for a path, because it is relatively planar and flat, and a path along the limestone base platform would truly be a "base trail". From a geotechnical perspective, it is desirable for the horizontal alignment of the path to run along the middle of the limestone base platform, rather than at the seaward edge of the platform or at the landward edge of the platform. At the seaward edge of the platform, there is a risk of collapse of the limestone at a number of locations where caves and overhangs have developed. Although cave and overhand development is a slow process, when collapse does eventually occur failure is rapid and without prior warning. This poses a risk to the path infrastructure and path users. Another reason for setting the path back from the seaward edge of the limestone platform is that spray from waves hitting the vertical face of the limestone platform will be a little less if the path alignment is set back from the edge. At the landward edge of the platform, there is a risk that path users and path infrastructure will be impacted by gully erosion, soil slumps and rock falls from the significant height of steep slope above the path. For these reasons, a buffer of several metres between each of the path edges and each of the limestone platform edges is desirable. The actual buffer at a given location will depend on, among other things, the geotechnical risk at that particular location along the path. A smaller seaward buffer may be acceptable if the limestone platform at the location in question has no cave or overhang development, and a smaller landward buffer may be acceptable if the slope above the limestone platform at the location in question is smaller in height, shallower in slope or shows less sign of instability. In addition to providing suitable buffers between the path and the geological hazards, suitable signage can be provided to inform path users of the geological hazards and highlight the associated geotechnical risks of leaving the path to access other parts of the limestone platform.

Since the limestone platform itself is geotechnically stable apart from its seaward edge, the platform will form a suitable foundation for either a pavement path or a suspended boardwalk path. However, the limestone platform surface becomes slippery when wet, and so it will not be suitable to act as the wearing surface of a base trail. Rather, a pavement or boardwalk constructed on the limestone platform will be required to control slip hazards for path users.

There are several locations along the length of the site where appropriate buffer distances will not be able to be met. The most obvious example of this is over the width of the embayment feature north of Castleton Avenue, where the limestone platform has been completely eroded by wave action. In order to provide a link between the northern limestone platform and the southern limestone platform, a boardwalk form of path acting as a bridge will be necessary over the width of the embayment, supported by piles driven into the beach below. Alternatively, a fill embankment founded on the beach and protected by a rock revetment could provide the link between the northern and southern limestone platforms. Another location where the buffer distances cannot be achieved is at the large gully feature in the limestone platform south of Castleton Avenue. This would require infilling with rock to support a pavement path, or suspension of a boardwalk path over the width of the gully, with the boardwalk supported by driven piles founded on the rock underlying the beach sand.

The limestone platform dips gently to the south, and this means that the height of the platform above beach level is around 4-6 m north of the embayment but only around 0.5-3 m south of the embayment. Reference to contour plans of the site confirm that the seaward edge of the northern platform is over +4 m AHD in elevation, whereas the seaward edge of the southern platform is typically between +2 m AHD and +3 m AHD in elevation. The absence of scree at the toe of the sloping cliff face above the southern limestone platform suggests that the southern platform is submerged during high tides. Some scree removal is also likely for the northern platform due to sea spray and subsequent drainage over the platform surface, especially for the southern, lower part of the northern platform.

Data from Dr Murray Townsend of the Coastal Protection Branch (email from Dr Townsend to Connell Wagner dated 1/4/05) shows that the 1 in 100 year water level is +2.15 m AHD (high tide plus storm surge), to which 0.4 m of wave set-up and 1.5 m of wave run-up are added, giving a level of 4.05 m AHD. This level excludes any allowance for long term sea level rise. This level is consistent with the maximum sea levels that can be approximately inferred from the contour information and the presence or absence of scree on the limestone platforms. Connell Wagner convened a meeting with Jenny Deans of the Coastal Protection Branch on 5/4/05, at which Ms Deans provided the following information to Connell Wagner and URS. The revetted and infilled length of coast line immediately north of the northern end of the Witton Bluff Base Trail study area suffered significant storm damage several years ago by wave over-wash. This caused slumping of the top of the seawall over part of its length north of the point of Witton Bluff, and scouring of the rubble fill landward of the seawall over significant lengths both north and south of the point of Witton Bluff. This damage required a $0.5M repair and raising of the reclaimed ground surface. Dr Townsend had advised in his email of 1/4/05 that here the top of the rock armour is at +5.0 m AHD. This allows for approximately 1 m of sea level rise between the present time and 2100.

The implication of this for the proposed base trail is that the path will need to be set at a similar level to protect it from tidal inundation or significant wave spray. Although this will be straightforward for the northern limestone platform where the platform level is already adequate or nearly so, it will be more difficult for the southern limestone platform. It will be easier to construct a suspended boardwalk path over the southern limestone platform by progressively increasing the supporting column height with increasing distance southward, than it will be to construct a pavement path by progressively increasing the height of a supporting fill embankment with increasing distance southward.

The limestone base platform is reasonably accessible from beach level for the southern platform, and from the existing path for the northern platform if a fill ramp is constructed from the existing path up to the platform level some 2 m higher. This, and the fact that no vegetation is present on the limestone platform, means that environmental impacts will not include disruption to the Esplanade traffic and parking, loss of native vegetation and noise and dust impacts for residents and users of the Esplanade. Environmental impacts would be essentially limited to construction traffic, noise and dust impacts to beach users, and minor sedimentation of the sea. Environmental impacts would be higher for a pavement form of path, especially where a supporting fill embankment was necessary to achieve a minimum elevation to prevent tidal inundation, than they would for a suspended boardwalk form of path. The ability to access and then work on path construction on the southern limestone platform will be partly dictated by tide times, given access will be from the beach for this platform and both the beach and the platform are submerged during high tides.

Given all of the foregoing, a trail along the limestone base platform is considered to be not only a feasible option but also a preferred option from a geotechnical perspective. The same conclusion is also likely from an overall environmental impact perspective.

6.1.4 Option 4 – Along Reclaimed Land

This option would involve reclamation of a strip of beach or sea immediately in front of the limestone base platform to provide a corridor for the path. This would involve construction of an armour protective layer on the seaward face of the reclaimed land, with the reclaimed land itself formed by filling between the armour layer and the limestone platform. The end product would effectively be a southwards extension of the existing rock revetted and filled area that extends northwards towards the point of Witton Bluff from the northern end of the Witton Bluff Base Trail project site.

The coastal cliff would not present any geotechnical risks to a path formed along reclaimed land or to users of such a path, provided that the path had a suitable seaward buffer distance from the locations of any caves and overhangs in the adjacent limestone platform that might otherwise result in impacts should such caves and overhangs collapse. It would be necessary to ensure that the design of the reclaimed land had an adequate factor of safety against slope instability, and that the rock armour design was robust enough and the finished level of the reclaimed land was high enough to minimise the potential for erosion by tidal inundation, wave action or sea spray.

Since this option would involve a significant amount of earthmoving and large quantities of fill, including expensive and resource limited armouring, there would be significant environmental impacts associated with this option. These impacts will be felt mostly by beach users and the marine environment rather than by residents, users of the Esplanade or the terrestrial environment. The construction phase impacts will comprise construction traffic, noise and dust, sedimentation and turbidity of the marine environment, and impacts on foreshore flora and fauna. There will also be a significant visual impact, in that the natural form of the limestone platform at the base of the cliff will be wholly or partly covered.

Based on the above considerations, a trail along reclaimed land seaward of the limestone base platform is considered to be not only a feasible option but also a preferred option from a geotechnical perspective. However, this option is unlikely to be a feasible option from either an environmental impact perspective or from a cost perspective.

6.1.5 Option 5 – Some Combination of Options 1-4

From a geotechnical perspective, any trail option that involved location of a significant length of the path on the unstable sloping face of the cliff is considered infeasible. This rules out any combination option involving Option 1 and/or Option 2. The only combination option considered geotechnically feasible is then Option 3 combined with Option 4.

From a cost and environmental perspective, Option 3 would need to be the dominant option in the combination. A possible combination of Option 3 and Option 4 may involve constructing the path on the limestone base platforms wherever there is sufficient lateral buffer distance between the path edges and the platform edges for this to be feasible. Where there is insufficient buffer, armour protected fill reclamation could be undertaken, such as over the width of the embayment and over the gullied pinch point a little south of the embayment. In each case, the reclamation would replace a suspended board walk structure with supports piled into the beach.

Such a combination of Options 3 and 4 would have essentially the same geotechnical considerations as Option 3 and hence be not only a feasible option but also a preferred option geotechnically. However, environmentally it will not be as attractive as Option 3, because of the various construction phase impacts and post construction visual impacts associated with the locations of reclamation.

6.1.6 Preferred Option

Based on the foregoing review of the various options for alignment of the path, Option 2 can be rejected because it is geotechnically infeasible. Options 1, 3, 4 and 5 are all geotechnically feasible, but Options 1 and 4 are inferior to Option 3 on environmental impact grounds and can be rejected on this basis. This leaves Option 3 as the preferred option, or possibly a combination Option 5 comprising predominantly Option 3 with Option 4 in areas where the limestone platform is narrow or absent.

The remainder of this geotechnical assessment considers Option 3 alone.

6.2 Form of Path

There are two forms that the path may take: a pavement type path, or a boardwalk type path.

A pavement type path would involve utilising the limestone base platform as a subgrade, and constructing a pavement comprising one or more granular layers with an asphaltic concrete surface seal, or a concrete layer, or possibly a clay brick or concrete block pavement. Since the limestone subgrade is strong and inert and the path traffic loading is nominal, the choice of composition of the pavement is governed by non-geotechnical considerations such as cost, durability and appearance. Another possible form of pavement is to use the limestone surface itself as the pavement. This is geotechnically feasible, but the need to cut into the limestone platform to create the required uniform surface, the associated drainage issues post construction, and the slippery nature of the limestone when wet, will rule this alternative out on cost and safety grounds.

A boardwalk type path would involve a suspended timber framed walkway, supported by timber columns. The columns would be founded in shallow piers that would be excavated into the surface of the limestone platform and then backfilled with concrete after the column had been placed in the pier.

A boardwalk form of path has a number of geotechnical advantages over a pavement form of path. Firstly, because a boardwalk will be somewhat elevated above the limestone base platform surface, it is less likely to be impacted by gully erosion, minor slumping or falls of the weak soils and rocks forming the sloping cliff face above the strong limestone base platform. Secondly, any loss of support from the limestone platform due to a collapse of an adjacent cave or overhang at the seaward edge of the platform is expected to be better accommodated by a boardwalk than by a pavement, since the boardwalk is likely to be able to better redistribute loads away from locations of undermining by virtue of being tied together as a structural frame. Thirdly, the posts, balusters and rails that would be a necessary safety feature of a boardwalk form of path (but which may not be necessary for a pavement form of path) would provide a degree of barrier protection to users of the path from direct impacts from gully erosion, soil slumps or falls of weak rock, even were these to impact on the boardwalk parapets themselves. Fourthly, a boardwalk will be more effective than a pavement in controlling informal access to the limestone platform surface, which becomes very slippery when wet and presents a significant slip hazard for persons walking over the platform. Fifthly, as outlined earlier, a pavement form of path would require an embankment fill build-up above the top of the limestone base platform where the limestone platform was too low to provide the required elevation to avoid tidal inundation or wave over wash. The embankment fill would be susceptible to erosion and slope instability from wave and sea spray action, and also from terrestrial stormwater run-off, unless the batter slopes were suitably protected and not overly steep. In contrast, properly designed column supports and excavated pier footings to a boardwalk will be much less susceptible to wave action induced instability, and do not present an impedient to free drainage of terrestrial stormwater run-off, tidal inundation or sea spray run-off from the surface of the limestone platform.

Over the width of the embayment, and over the width of gully features in the limestone base platform, a boardwalk form of path would act as a bridge and be supported by piles (timber, steel or concrete) driven below the beach surface. The piles would be driven until they encountered rock, which is expected at a relatively shallow depth. A geotechnical investigation would be necessary to confirm the foundation conditions at this location. The piles would carry vertical compressive loads by end bearing on the rock, but the expected shallow penetration of the piles and significant unsupported length above beach level means that the piles would need to be braced to carry lateral loads from waves and tides.

The alternative of a pavement form of path would involve construction of a fill embankment founded on the beach sand, comprising an armour protective layer on the seaward face of the embankment, with the embankment itself formed by filling between the armour layer and the limestone platform. It would be necessary to ensure that the design of the embankment had an adequate factor of safety against slope instability, and that the armour design was robust enough and the finished level of the embankment was high enough to minimise the potential for erosion by tidal inundation, wave action or sea spray.

Based on the foregoing considerations, a boardwalk form of path is preferred over a pavement form of path for geotechnical reasons.

6.3 End and Intermediate Path Connections

6.3.1 Northern End

At the northern end of the Witton Bluff Base Trail study area, there is a vertical drop of about 2 m between the higher level of the limestone base platform and the lower level of the infilled land behind the rock armour protection further northward. This vertical step will need to be overcome by either a sloping fill embankment or a sloping boardwalk ramp, to provide the required access between the existing path level to the north and the top of the limestone base platform to the south. There are no significant geotechnical implications for either of these options, given that the infilled land is already at a sufficiently high level to minimise wave induced overtopping and erosion, and the existing path is offset a reasonable distance from the base of the tall cliff to the north and is also separated from the cliff face by a wire fence. However, a sloping boardwalk ramp is favoured from a land take, surface drainage and visual impact perspective, since suitably flat side slopes (say 1V:2H) would need to be provided to a fill embankment that would result in an embankment footprint width of over 10 m. A fill embankment would cause significantly more interference for future maintenance of the rock revetment and the reclamation fill behind it than a boardwalk ramp would.

6.3.2 Southern End

At the southern end of the Witton Bluff Base Trail study area, the top of the limestone base platform tapers down to beach level, and a point feature comprising undercut limestone separates the southern end of the limestone base platform from the existing boat ramp. The two main options for connection of the proposed Witton Bluff Base Trail to the Port Noarlunga Esplanade Trail are either to route the path around the limestone point to link with the boat ramp, or to run the path up from the level of the limestone platform around the back of the limestone point over the former gazebo pad adjacent to the existing monument, and then connect into the base of the existing promenade that joins the top of the boat ramp.

The first of these options would involve the path running off the southern end of the limestone base platform, with the foundation for the path support system (embankment fill in the case of a pavement form of path, and columns in the case of a boardwalk form of path) then changing from limestone to beach sand. The path and its support system would have to be designed for the erosion and lateral load impacts of waves, which will be significant as waves break on the vertical face of the limestone point. This would require rock armour to the seaward face in the case of a fill embankment supporting a pavement path, and support piles that are driven through the beach sand to rock and braced above beach level in the case of a suspended boardwalk path. Since the limestone point has an existing overhang, it will also be necessary to offset the path from the face of the point so that should the overhang collapse in the future it will miss the inner edge of the path.

The second of these options would involve the path running up the northern face of the ridge line behind the limestone point, then down the southern face of the ridge line to join the promenade. In doing so, the foundation for the path would change from the limestone that forms the base platform to the weak sands and clays that form the cliff material above the limestone base platform. Due allowance would need to be made for erosion and slumping of the weak foundation materials above the limestone base platform level.

However, the length of path that would be located over such material is short (of the order of 20 m), the slope height is not great (the increase in path elevation will be about 6 m maximum), the path would run at an angle up the northern slope and down the southern slope rather than straight up and down the slope, and the ridge is relatively flat behind the point. This means that erosion and slumping of the slope material in this area will be relatively modest and unlikely to be critical for the path.

Based on geotechnical considerations, taking the path over the back of the limestone point rather than around the front of the limestone point is preferred, mainly because the former option avoids the significant wave erosion and lateral load impacts at a location at which waves break.

Environmental impacts associated with either of the foregoing options for connection at the southern end of the Witton Bluff Base Trail are likely to be similar and involve construction phase vehicular traffic, noise, dust and turbidity impacts, and post construction visual impacts. The option of taking the path around the limestone point may have construction phase impacts on the foreshore flora and fauna, while the option of taking the path up behind the limestone point may have impacts on terrestrial flora and fauna, including native vegetation.

Regardless of the route option, a boardwalk form of path is preferred to a pavement form of path, because a boardwalk will involve significantly less land take, is less susceptible to geotechnical instability caused by erosion of the foundation, and will have less environmental impact.

The foregoing information concerning the option of taking the path over the back of the limestone point is equally applicable to other local connections at the southern end of the base trail, such as a connection between the path and the existing monument.

6.3.3 Intermediate Connections

At one or both ends of the embayment feature that separates the northern limestone base platform from the southern limestone base platform, a connection from the path level down to the beach level is possible. Clearly, such a connection could only be utilised when tide levels were low enough to expose the beach at the base of the connection. A connection in the form of a tapered fill embankment would be founded on the beach sand and would need to be protected from wave erosion on all sides. A connection in the form of a ramped board walk would be supported by piles driven through the beach sand and founded on the underlying rock. Whatever form such a connection takes, it would have to be designed to cater for a high degree of potential erosion and lateral load impact from waves, as suggested by the very presence of an embayment at this location. Damage or even destruction of the connections following storm events is quite possible, since the connections would be located where the waves break against the seaward face of the limestone platform. These considerations do not favour construction of intermediate connections between a higher level path and the lower level beach. The same conclusion would apply to any proposed connection between the path at the northern end of the Witton Bluff Base Trail site and the beach at this location.

Based on the geotechnical assessment presented in Section 6 of this report, and on the findings from the review of earlier work and from the site inspection in March 2005, the following key conclusions and recommendations are made:

7.1 Conclusions

- The cliff over the length of the Witton Bluff Base Trail comprises a hard limestone base platform that supports a sloping face formed of clay and sand units over weak limestone. The hard limestone base platform is subject to long term erosion by wave action, resulting in the slow development of caves and overhangs along parts of the limestone base platform. The weaker units above the base platform are subject to extensive and ongoing gully erosion, leading to over-steepening and slumping of soil on the sloping face, and hence undermining and rock falls of the calcrete present near the cliff crest.

- These geotechnical hazards pose a potential risk to path infrastructure and path users, in the form of potential undermining and collapse of path support systems founded on unstable cliff material, and/or physical impacts from landsliding of unstable cliff material above the path level.

- These geotechnical risks mean that it is infeasible for the proposed path to be located on the unstable sloping face of the cliff above the limestone base platform. Although it is geotechnically feasible for the path to be located landward of the cliff crest or along a rock armour protected reclaimed strip of land immediately seaward of the limestone base platform, the preferred option for alignment of the path is along the limestone base platform, based on geotechnical considerations combined with environmental impact and cost considerations.

- The preferred position of the path over the width of the limestone base platform is approximately along the middle of the platform, so as to minimise geotechnical risk associated with potential collapse of caves and overhangs that are present at some locations on the seaward edge of the limestone base platform, while also minimising geotechnical risk associated with gully erosion, soil slumping and rock falls from the unstable sloping cliff face above the landward edge of the limestone base platform.

- Based on an assessment of the geotechnical risks to path infrastructure and path users, and on other engineering and environmental considerations, a boardwalk form of path is preferred to a pavement form of path.

- Special consideration will be required at locations where the path cannot be supported by the limestone platform because the platform is too narrow or is absent altogether, most notably over the width of the embayment feature. For a suspended boardwalk form of path, the path at such locations would act as a bridge and be supported by piles driven through the beach sand and founded on the underlying rock.

- The connection from the northern end of the Witton Bluff Base Trail to the existing path to the north could be formed by a boardwalk that ramps down from the northern edge of the limestone base platform to the reclaimed land below.
- The connection from the southern end of the Witton Bluff Base Trail to the Port Noarlunga Esplanade could be formed either by taking the path around the seaward face of the limestone point present at the southern end of the limestone base platform, or by taking the path over the ridge landward of the limestone point. The latter option is preferred from a geotechnical perspective, because it avoids wave erosion and load impacts on the path support structure. The latter option also means that other connections from the path can be more easily undertaken, such as between the path and the existing monument.
- Intermediate connections from a Witton Bluff Base Trail path level on top of the limestone base platform down to the beach level are possible but are not favoured because they will be subjected to significant wave action that may damage or even destroy the connections during storm events.

7.2 Recommendations

URS recommends that, based on geotechnical and other engineering and environmental considerations:

- The Witton Bluff Base Trail should run along the top of the limestone base platform, and be aligned with the approximate middle of the limestone base platform width.
- A boardwalk form of path should be adopted rather than a pavement form of path.
- The foregoing outline concept for the Witton Bluff Base Trail should be taken to the next stage of design development and environmental assessment, given the geotechnical feasibility of the path concept that has been demonstrated in the current report.

Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Connell Wagner Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 21 January 2005.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between March and July 2005 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The precision with which conditions are indicated depends largely on the frequency and method of observation and sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

Plates

Plate 1 View of southern end of proposed base trail

Plate 2 View of overhang at the point near southern end of proposed base trail

Plate 3 **Looking north along southern limestone base platform that is present over southern third of project site**

Plate 4 **Geotechnical hazard warning for weak soil and limestone above southern limestone base platform near monument**

Plate 5 Gully erosion and minor rock falls in weaker limestone above southern limestone base platform

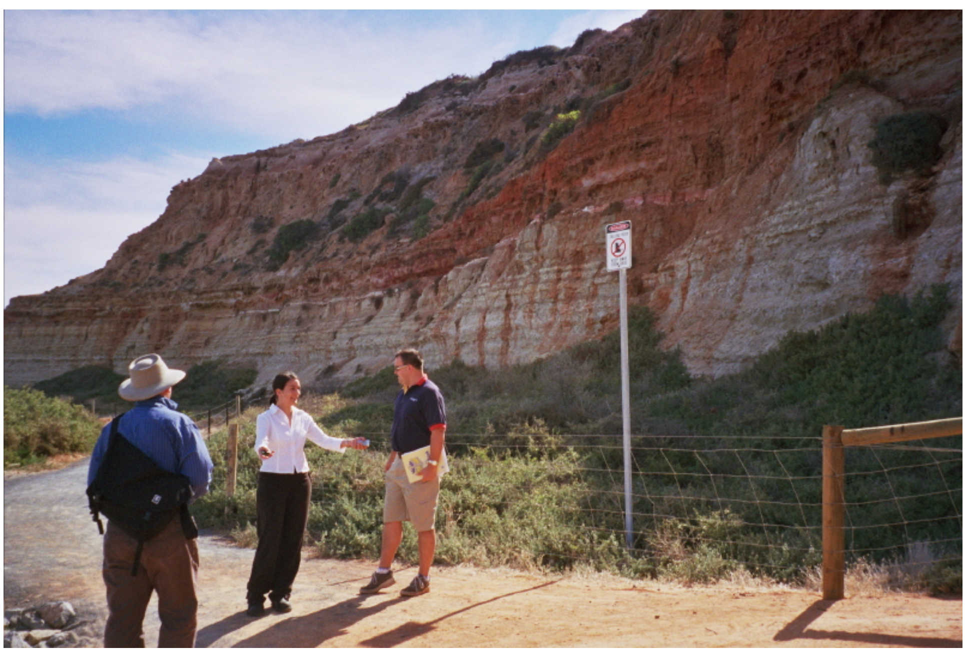


Plate 6 Fenced and signed buffer between existing base trail at Witton Bluff and base of cliff, north of project site

Plate 7 Looking south at end of existing base trail at Witton Bluff and northern end of proposed continuation of base trail

Plate 8 Southern end of rock armoured slope protecting existing base trail at Witton Bluff, and commencement of limestone base platform beyond, that is present over northern half of project site

Plate 9 **Looking south from the point at Witton Bluff, along existing base trail north of project site**

Plate 10 **Erosion gullying and minor rock falls in cliff face above existing base trail at Witton Bluff, north of project site**

Plate 11 Cave in northern limestone base platform at northern end of project site

Plate 12 Partly infilled vertical defect providing release surface in the cave from Plate 11

Plate 13 Deep, thin, eroded horizontal space near top of cave from Plate 11

Plate 14 View of limestone blocks in northern limestone base platform, with sub-vertical defects providing potential release surfaces

Plate 15 Defects and voids in limestone blocks from Plate 14

Plate 16 Looking south at local embayment where limestone base platform has been eroded away by wave action

Plate 17 **Cave/overhang formation in limestone at base of embayment**

Plate 18 **Looking towards start of southern limestone base platform beyond southern extent of embayment**

Plate 19 **Erosion gullying in softer limestone above base of embayment**

Plate 20 **Looking from end of southern limestone base platform at southern edge of embayment, to start of northern limestone base platform beyond northern extent of embayment**

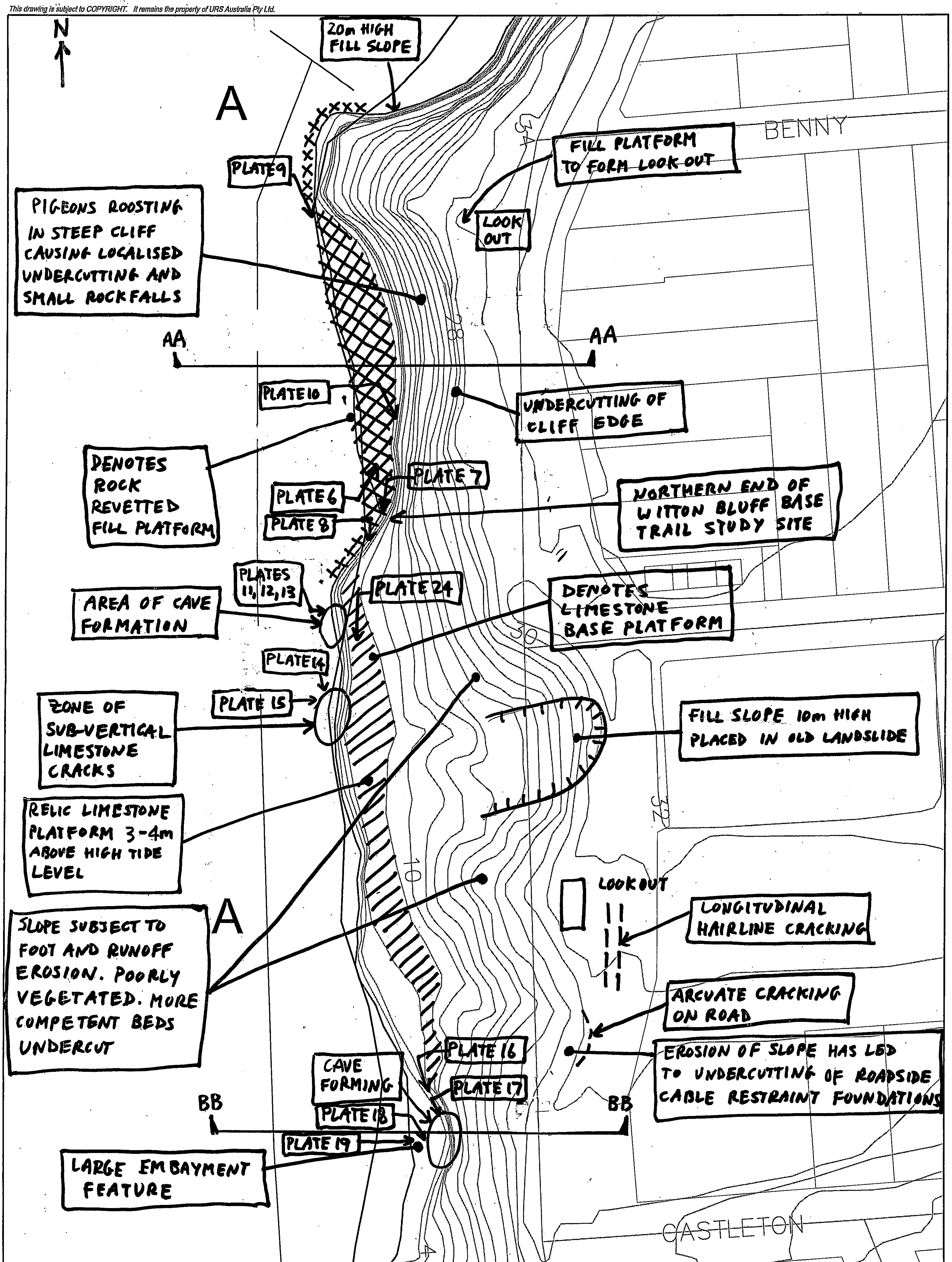
Plate 21 **Gully erosion in softer limestone above southern limestone base platform south of embayment**

Plate 22 **Looking south along southern limestone base platform to south of embayment**

Plate 23 **Informal walking path along top of weak limestone above embayment**

Plate 24 **View from near northern end of proposed base trail, looking south along top of northern limestone base platform that is present over northern half of site**

Appendix A
Geological Hazard Mapping for Port Noarlunga to Witton Bluff (South)



URS

DETAILED CLIFF STABILITY INVESTIGATIONS

City of Onkaparinga

PROJECT
DETAILED CLIFF STABILITY INVESTIGATIONS

0 40m
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TITLE
GEOLOGICAL MAPPING FOR AREA A
SHEET 1 OF 2

FIGURE: 3 Rev. A

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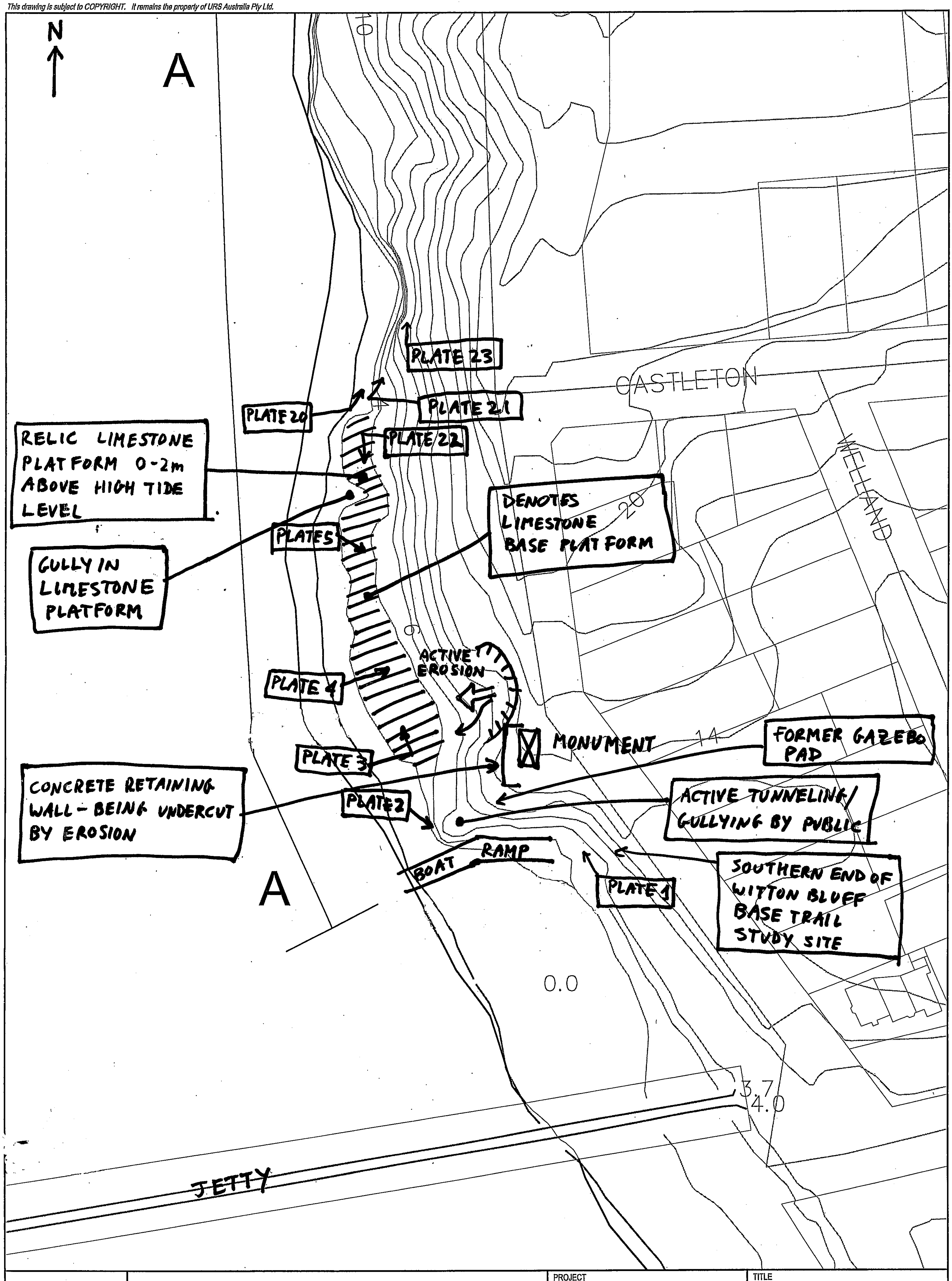

URS

City of Onkaparinga

PROJECT
DETAILED CLIFF STABILITY INVESTIGATIONS

0 40m

1:1,000

TITLE
GEOLOGICAL MAPPING FOR AREA A
SHEET 2 OF 2

FIGURE: 4

Rev. A

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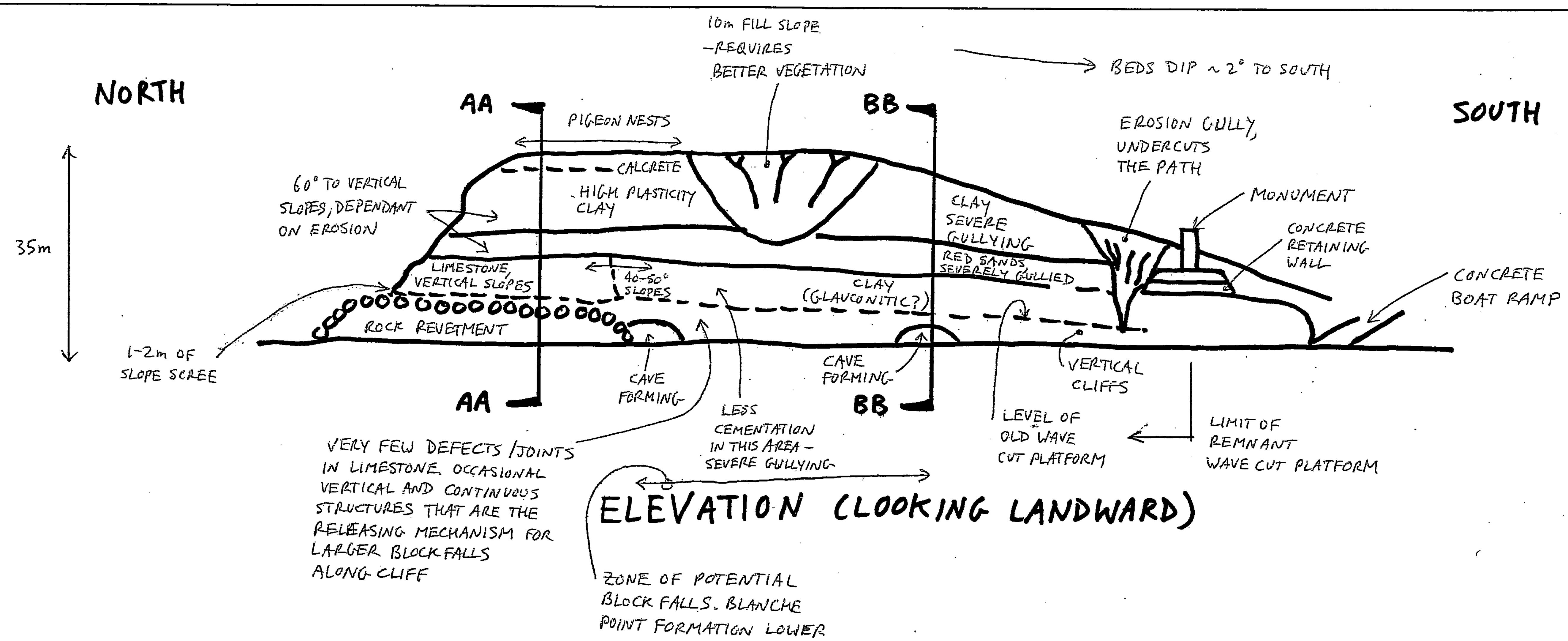
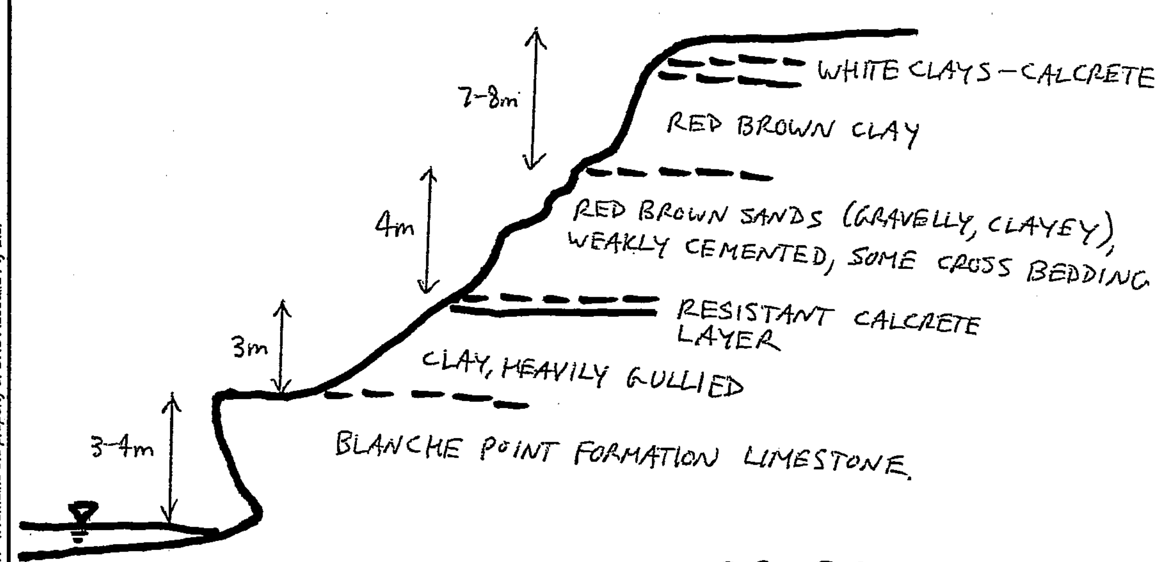
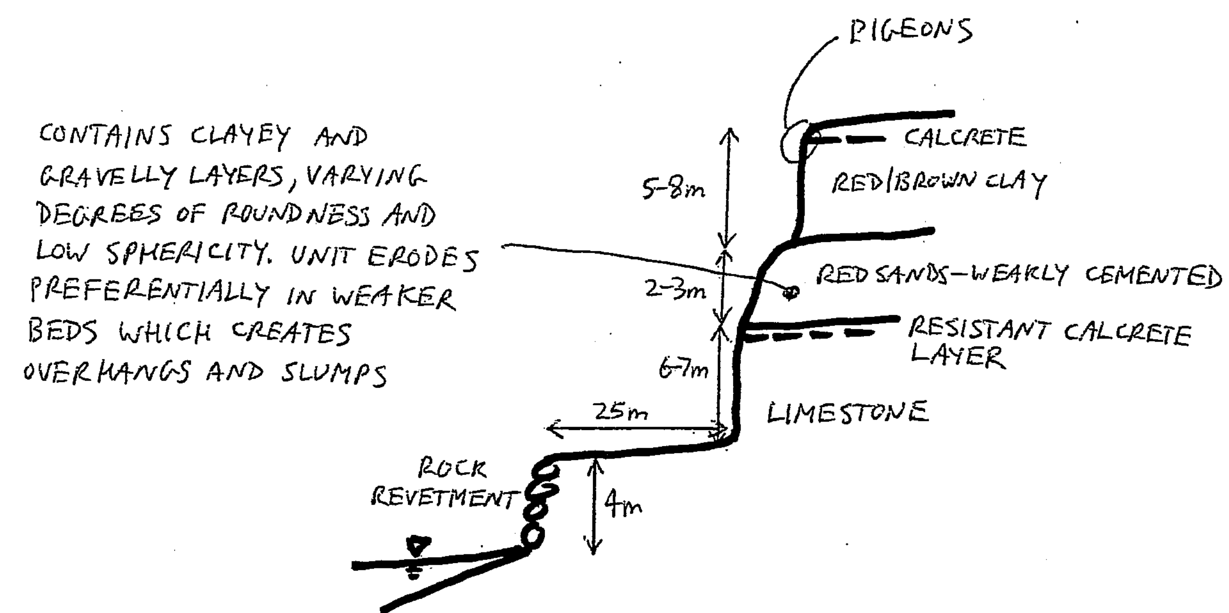


ELEVATION (LOOKING LANDWARD)



SECTION BB-BB



SECTION AA-AA

URS

City of Onkaparinga

PROJECT	TITLE
DETAILED CLIFF STABILITY INVESTIGATIONS	GEOLOGICAL SECTIONS AND ELEVATIONS FOR AREA A - SHEET 1 OF 1
NOT TO SCALE	FIGURE: 5 Rev. A
	FILE No.: 47325/003/DRAWINGS/47325-003-006-01.dwg

Appendix B

Selected Site Photographs

View of the picturesque limestone cliffs at Witton Bluff looking east from the beach

View looking north along the limestone platform, the location of the proposed trail

View looking south southwest. The path is proposed to be located along the platform in the foreground (where people are standing). Port Noarlunga jetty is visible in the background of the photograph.

View looking north along the Esplanade. A footpath exists on the western edge of the road, however this path is considered unsafe for foot and bicycle traffic.

View looking west northwest. The location of the proposed trail is on the identified limestone platforms.

View looking north at the northern extent of the proposed path. Currently the existing dolomite path terminates where at its southern end at the location of a limestone platform.

Southern End connection to existing boat ramp

Man made cave underneath southern bluff


Site of cliff slump under investigation by URS

View south over southern point (note rise)

Southern platform looking southward

Southern platform looking northward

Site of former platform shelter (note hole pattern)

View of embayment looking northwards

Northern Platform face (low tide)

End of northern platform above revetment

Looking north from north platform to existing path

View north along northern platform

View south along northern platform

Embayment looking to south

Embayment from southern platform (view north)

Cliff face at embayment

Looking south along northern limestone platform


View across boat ramp to connection path


View up towards monument over south point


Cliff overhang (Face in the cliff)


Cliffs above embayment


Path closure sign southern end

Appendix C

Witton Bluff Species List

Witton Bluff Species List

Scientific Name	Common Name	Conservation Status		
		AUS	SA	SL
Acacia longifolia var. sophorae	Coastal Wattle			
**Agave americana*	Century Plant			
Alyxia buxifolia	Sea Box			R
Atriplex cinerea	Coast Saltbush			
Atriplex paludosa ssp. cordata	Marsh Saltbush			
**Avena sp.*	Oat			
**Bromus diandrus*	Great Brome			
Carpobrotus rossii	Native Pigface			
**Coprosma repens*	New Zealand Mirror-bush			
**Cynara cardunculus*	Artichoke Thistle			
**Cynodon dactylon*	Couch			
Danthonia sp.	Wallaby-grass			
Dianella revoluta var. revoluta	Black-anther Flax-lily			
**Diplotaxis tenuifolia*	Lincoln Weed			
Disphyma crassifolium ssp. clavellatum	Round-leaf Pigface			
**Drosanthemum candens*	Rodondo Creeper			
Enchylaena tomentosa var. tomentosa	Ruby Saltbush			
**Euphorbia terracina*	False Caper			
**Galenia pubescens var. pubescens*	Coastal Galenia			
**Gazania linearis*	Gazania			
Halosarcia pergranulata ssp. pergranulata	Black-seed Samphire			
Isolepis nodosa	Knobby Club-rush			
**Lagurus ovatus*	Hare's Tail Grass			
**Lavatera arborea*	Tree Mallow			
Leucophyta brownii	Coast Cushion Bush			
**Limonium companyonis*	Sea-lavender			
**Lolium rigidum*	Wimmera Ryegrass			
**Lycium ferocissimum*	African Boxthorn			
Maireana oppositifolia	Salt Bluebush			
Muehlenbeckia gunnii	Coastal Climbing Lignum			
Myoporum insulare	Common Boobialla			
Nitraria billardierei	Nitre-bush			
**Olea europaea ssp. europaea*	Olive			
Olearia axillaris	Coast Daisy-bush			
**Pennisetum clandestinum*	Kikuyu			
Pimelea serpyllifolia ssp. serpyllifolia	Thyme Riceflower			
**Piptatherum miliaceum*	Rice Millet			
**Plantago lanceolata var. lanceolata*	Ribwort			
**Polygala myrtifolia*	Myrtle-leaf Milkwort			

Scientific Name	Common Name	Conservation Status		
		AUS	SA	SL
Rhagodia candolleana ssp. candolleana	Sea-berry Saltbush			
Samolus repens	Creeping Brookweed			**U**
Scaevola crassifolia	Cushion Fanflower			**R**
**Sonchus asper*	Prickly Sow-thistle			
Spinifex sericeus	Rolling Spinifex			
Stipa sp.	Spear-grass			
**Tamarix aphylla*	Athel Pine			
Threlkeldia diffusa	Coast Bonefruit			
Zygophyllum billardierei	Coast Twinleaf			**R**

AUS = Australia, SA = South Australia, SL = Southern Lofty Botanical Region

Summary:

Regional Conservation Status

	SL
Rare	3
Uncommon	1

Indigenous species:	25
Alien species:	23
Total number of species:	48

Appendix D

EPBC Act Protected Matters Report

Australian Government
Department of the Environment and Heritage

Protected Matters Search Tool

You are here: DEH Home > EPBC Act > Search

15 July 2005 13:09

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

The Australian Natural Resources Atlas at http://www.environment.gov.au/atlas may provide further environmental information relevant to your selected area. Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.deh.gov.au/epbc/assessmentsapprovals/index.html

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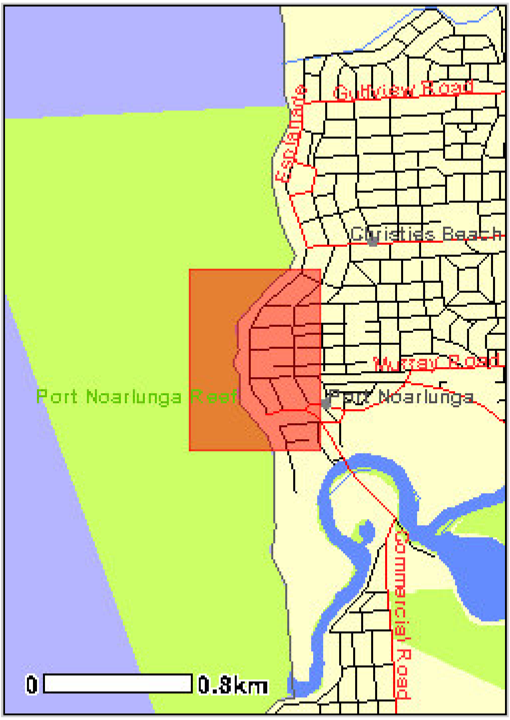
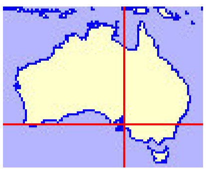


Search Type: Area

Buffer: 1 km

Coordinates: -35.140892,138.463661, -35.151282,138.463661, -35.151282,138.471209, -35.14089,138.471209



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.deh.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Significance: (Ramsar Sites)	None
Commonwealth Marine Areas:	Relevant
Threatened Ecological Communities:	None
Threatened Species:	22
Migratory Species:	23

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.deh.gov.au/heritage/index.html.

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.deh.gov.au/epbc/permits/index.html.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Places on the RNE:	None
Listed Marine Species:	53
Whales and Other Cetaceans:	9
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	2
Other Commonwealth Reserves:	None
Regional Forest Agreements:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Areas [Dataset Information]

Approval may be required for a proposed activity that is likely to have a significant impact on the environment in a Commonwealth Marine Area, when the action is outside the Commonwealth Marine Area, or the environment anywhere when the action is taken within the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Within 3 Nautical Mile Limit

Threatened Species [Dataset Information]	Status	Type of Presence
Birds		
Diomedea amsterdamensis Amsterdam Albatross	Endangered	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross	Endangered	Foraging may occur within area
Diomedea exulans Wandering Albatross	Vulnerable	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Vulnerable	Species or species habitat may occur within area
Halobaena caerulea Blue Petrel	Vulnerable	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Vulnerable	Species or species habitat may occur within area

Pterodroma mollis Soft-plumaged Petrel	Vulnerable	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe	Vulnerable	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche chrysostoma Grey-headed Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus * Blue Whale	Endangered	Species or species habitat may occur within area
Eubalaena australis * Southern Right Whale	Endangered	Species or species habitat may occur within area
Isoodon obesulus obesulus Southern Brown Bandicoot	Endangered	Species or species habitat may occur within area
Megaptera novaeangliae * Humpback Whale	Vulnerable	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion	Vulnerable	Species or species habitat may occur within area
Sharks		
Carcharodon carcharias Great White Shark	Vulnerable	Species or species habitat may occur within area
Plants		
Euphrasia collina subsp. osbornii* Osborn's Eyebright	Endangered	Species or species habitat likely to occur within area

Migratory Species [Dataset Information]	Status	Type of Presence
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail	Migratory	Species or species habitat may occur within area
Migratory Wetland Species		
Birds		
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Migratory	Species or species habitat may occur within area
Rostratula benghalensis s. lat. Painted Snipe	Migratory	Species or species habitat may occur within area

Migratory Marine Birds

Diomedea amsterdamensis Amsterdam Albatross	Migratory	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross	Migratory	Foraging may occur within area
Diomedea exulans Wandering Albatross	Migratory	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Migratory	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Migratory	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Migratory	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Migratory	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross	Migratory	Species or species habitat may occur within area
Thalassarche chrysostoma Grey-headed Albatross	Migratory	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Migratory	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Migratory	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross	Migratory	Species or species habitat may occur within area

Migratory Marine Species

Mammals

Balaenoptera edeni Bryde's Whale	Migratory	Species or species habitat may occur within area
Balaenoptera musculus * Blue Whale	Migratory	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale	Migratory	Species or species habitat may occur within area
Eubalaena australis * Southern Right Whale	Migratory	Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin	Migratory	Species or species habitat may occur within area
Megaptera novaeangliae * Humpback Whale	Migratory	Species or species habitat may occur within area

Sharks

Carcharodon carcharias Great White Shark	Migratory	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Dataset Information]	Status	Type of Presence
Birds		
Apus pacificus	Listed -	Species or species habitat may occur

Fork-tailed Swift	overfly marine area	within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Listed - overfly marine area	Species or species habitat may occur within area
Catharacta skua Great Skua	Listed	Species or species habitat may occur within area
Diomedea amsterdamensis Amsterdam Albatross	Listed	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross	Listed	Foraging may occur within area
Diomedea exulans Wandering Albatross	Listed	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross	Listed	Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe	Listed - overfly marine area	Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle	Listed	Species or species habitat likely to occur within area
Halobaena caerulea Blue Petrel	Listed	Species or species habitat may occur within area
Hirundapus caudacutus White-throated Needletail	Listed - overfly marine area	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel	Listed	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel	Listed	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area
Pterodroma mollis Soft-plumaged Petrel	Listed	Species or species habitat may occur within area
Rostratula benghalensis s. lat. Painted Snipe	Listed - overfly marine area	Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross	Listed	Species or species habitat may occur within area
Thalassarche cauta	Listed	Species or species habitat may occur

Shy Albatross		within area
Thalassarche chlororhynchos Yellow-nosed Albatross, Atlantic Yellow-nosed Albatross	Listed	Species or species habitat may occur within area
Thalassarche chrysostoma Grey-headed Albatross	Listed	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross	Listed	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross	Listed	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross	Listed	Species or species habitat may occur within area
Fishes		
Acentronura australe Southern Pygmy Pipehorse	Listed	Species or species habitat may occur within area
Campichthys tryoni Tryon's Pipefish	Listed	Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish	Listed	Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish	Listed	Species or species habitat may occur within area
Hippocampus abdominalis Eastern Potbelly Seahorse, New Zealand Potbelly, Seahorse, Bigbelly Seahorse	Listed	Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse	Listed	Species or species habitat may occur within area
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish	Listed	Species or species habitat may occur within area
Hypselognathus rostratus Knife-snouted Pipefish	Listed	Species or species habitat may occur within area
Kaupus costatus Deep-bodied Pipefish	Listed	Species or species habitat may occur within area
Leptoichthys fistularius Brushtail Pipefish	Listed	Species or species habitat may occur within area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish	Listed	Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish	Listed	Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish	Listed	Species or species habitat may occur within area
Notiocampus ruber Red Pipefish	Listed	Species or species habitat may occur within area
Phycodurus eques Leafy Seadragon	Listed	Species or species habitat may occur within area
Phyllopteryx taeniolatus Weedy Seadragon, Common Seadragon	Listed	Species or species habitat may occur within area
Pugnaso curtirostris	Listed	Species or species habitat may occur

Pug-nosed Pipefish		within area
Solegnathus robustus Robust Spiny Pipehorse, Robust Pipehorse	Listed	Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish	Listed	Species or species habitat may occur within area
Stigmatopora nigra Wide-bodied Pipefish, Black Pipefish	Listed	Species or species habitat may occur within area
Stipecampus cristatus Ring-backed Pipefish	Listed	Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish	Listed	Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish	Listed	Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish	Listed	Species or species habitat may occur within area
Vanacampus poecilolaemus Australian Long-snout Pipefish, Long-snouted Pipefish	Listed	Species or species habitat may occur within area
Vanacampus vercoi Verco's Pipefish	Listed	Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri New Zealand Fur-seal	Listed	Species or species habitat may occur within area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal	Listed	Species or species habitat may occur within area
Neophoca cinerea Australian Sea-lion	Listed	Species or species habitat may occur within area

Whales and Other Cetaceans [Dataset Information]	Status	Type of Presence
Balaenoptera edeni Bryde's Whale	Cetacean	Species or species habitat may occur within area
Balaenoptera musculus * Blue Whale	Cetacean	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale	Cetacean	Species or species habitat may occur within area
Delphinus delphis Common Dolphin	Cetacean	Species or species habitat may occur within area
Eubalaena australis * Southern Right Whale	Cetacean	Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin	Cetacean	Species or species habitat may occur within area
Megaptera novaeangliae * Humpback Whale	Cetacean	Species or species habitat may occur within area
Tursiops aduncus Spotted Bottlenose Dolphin	Cetacean	Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin	Cetacean	Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Dataset Information]

Onkaparinga River Recreation Park, SA

Port Noarlunga Reef Aquatic Reserve, SA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the *Environment Protection and Biodiversity Conservation Act 1999*. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under "type of presence". For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the migratory and marine provisions of the Act have been mapped.

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites;
- seals which have only been mapped for breeding sites near the Australian continent.

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgments

This database has been compiled from a range of data sources. Environment Australia acknowledges the following custodians who have contributed valuable data and advice:

- New South Wales National Parks and Wildlife Service
- Department of Sustainability and Environment, Victoria
- Department of Primary Industries, Water and Environment, Tasmania
- Department of Environment and Heritage, South Australia Planning SA
- Parks and Wildlife Commission of the Northern Territory
- Environmental Protection Agency, Queensland
- Birds Australia
- Australian Bird and Bat Banding Scheme
- Australian National Wildlife Collection
- Natural history museums of Australia
- Queensland Herbarium
- National Herbarium of NSW
- Royal Botanic Gardens and National Herbarium of Victoria
- Tasmanian Herbarium
- State Herbarium of South Australia
- Northern Territory Herbarium
- Western Australian Herbarium
- Australian National Herbarium, Atherton and Canberra
- University of New England
- Other groups and individuals

ANUCLIM Version 1.8, Centre for Resource and Environmental Studies, Australian National University was used extensively for the production of draft maps of species distribution. Environment Australia is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Last updated:

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