Coburg Peninsula Foreshore Erosion Updated Study Report

to

City of Colwood

SEABULK SYSTEMS INC.
Integrated Shipping Solutions

Our Reference: 661-01-2801998
Coburg Peninsula Foreshore Erosion:
Updated Study Report
Date of Issue: February 27, 2008

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City of Colwood
3300 Wishart Road
Victoria, British Columbia
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Attention: Michael Baxter, City Engineer

Dear Michael:

Re: Coburg Peninsula Foreshore Erosion: Updated Study Report

Further to our recent correspondence on the subject topic, we are pleased to present this updated letter report reviewing erosion issues on the Coburg Peninsula and engineered approaches to mitigate the erosion. The report updates include assessment of:

- Recent storm events on November 21st and January 4th;
- Impact of armouring isolated sections of shoreline;
- Rip rap armouring the peninsula foreshore;
- The ability of groynes to stabilize the foreshore and maintain a beach; and
- The ability of offshore breakwaters to stabilize the foreshore and maintain a beach.

1.0 Introduction

This work has been prepared with reference to the following study items provided by the City of Colwood:

1. What would be the order of magnitude costs to protect the Coburg Peninsula and adjacent beach as it stood this summer from the bridge at the north end to last house on Ocean Boulevard to the south for the next 20 years (understanding that the next 20 years may be somewhat less predictable than the previous 50 have been)?

2. Will the work involved above change visitors experience of the majority of the beach?

3. If that cost is several hundreds of thousands of dollars or more then would there be any significant saving if we narrowed the scope to simply protecting the infrastructure/structures from the bridge to the last house?

4. If none of this work is undertaken then what structures/infrastructure is at risk and how long do we have in each case?

Tasks undertaken as part of this study include:

- Review of selected existing research on the Coburg Peninsula, ***Appendix 1***;
- Site reconnaissance on January 15, 2008;
- Interview of Mr. Clem Dion, Production Superintendent at Producer`s Pit;
- Review of historical and aerial ortho-photography;
- Identification of coastal processes and erosion issues;
- Analysis of recent events, Nov-12 and Jan-4, that impacted the peninsula;
- Proposal of engineered approaches to mitigating erosion;
- Estimation of order of magnitude costs with contractor input on pricing; and
- Suggestions for implementing work.

Erosion issues that were apparent during the site reconnaissance include:

- Wave induced damage to the north abutment of the bridge on Ocean Boulevard;
- Over topping of Ocean Boulevard, mostly on the southern extension; and
- Beach deflation (loss of sediment) on the peninsula that has exposed pipelines near the DND Ranger Station.

Our interview with the Production Superintendant at Producer`s Pit and review of historical and aerial ortho-photography has revealed that the sediment discharged from the pit operations to the beach was a significant enhancement to the sediment supply. This was the dominant sediment source to the coast while the practice occurred. These sediment discharges have since been discontinued leaving only upcoast backshore erosion to supply beach sediments. This has since lead to beach deflation along the peninsula and has enabled increased the wave energy to pass over the tip of the peninsula and attack the bridge abutments on Ocean Boulevard.

Costs estimates provided in this study are prepared with contractor input so they reflect recent construction experience on coastal British Columbia. An opinion is provided on the impact of the proposals on the experience of visitors using the beach.

It is clear from the review of the literature on the Coburg Peninsula and the Esquimalt Lagoon that the area is very popular with the public and that the lagoon has significant environmental value. We have kept this important point in mind for the drafting of this letter.

This letter report refers to upcoast and downcoast directions. Downcoast is the direction of longshore transport, in this case north, along the peninsula. Reference is also made to the term sediments. In the context of this report it is the mobile particulate material on the beach, mostly sand, but also including silt, gravel and even cobble.

2.0 Background

Coastal Processes

Previous studies of the Coburg Peninsula, ***Appendix 1***, are excellent and provide a thorough description of the environment, coastal processes, geomorphology and history. The key points of the coastal processes are reviewed briefly here for reference.

Coburg Peninsula is a natural spit that separates Esquimalt Lagoon from Juan de Fuca Strait. The spit terminates near the northern margin of Esquimalt Lagoon where the currents generated by the tidal exchange between the lagoon and Juan de Fuca Strait are keeping a channel open.

The peninsula is a formation that has developed from longshore transport of sediments that have been historically supplied from backshore erosion and in more recent times from deliberate discharge of sediments to the foreshore in the vicinity of Producer's Pit. The beach along Coburg Peninsula has grown and deflated over the decades as a result of changes to sediment supply to the beach. It is important to keep in mind the sensitivity of spit formations like the Coburg Peninsula to upcoast sediment supply. Decreases in, or removal of, sediment supply can cause spit formations to erode.

Erosion Issues

Our interview with Mr. Clem Dion, Production Superintendent and employee at Producer's Pit for more than 25 years, has revealed that in the early days of the pit operation, sand was discharged directly to the foreshore as it had little commercial value – it was effectively a waste material. This statement is corroborated by aerial ortho-photography covering the period 1954 to 2007 provided by the City of Colwood. Early photographs, 1968 for example, ***Appendix 2***, shows sediments, presumably mostly sand, discharged to the foreshore and forming an alluvial fan forming immediately south of the marine loadout structure. In more recent aerial photography, sediment discharges to the foreshore are not apparent.

Aggregate mining operations at Producer's Pit have been underway since 1909. Early photographs from 1935 of the Coburg Peninsula and the Dugout Pub, ***Appendix 3***, show a very broad and apparently sandy beach at the northern tip of the Peninsula. Today the DND Ranger Station (formerly the Dugout Pub) is protected by rip rap built right to its foundation wall with the beach an estimated 2 to 3 metres below, ***Appendix 4***. It would appear the beach in the 1935 era had enhanced replenishment from sand discharges from aggregate mining operations upcoast. Since this practice has been discontinued the sediment supply to the beach has been reduced and has resulted in deflation of the foreshore relative to earlier times. Two pipelines that were once buried in the beach are now exposed, ***Appendix 4***. It is important to note with reference to the previous work, ***Appendix 1***, the natural sediment supply for the beach has been upcoast backshore erosion so the Coburg Peninsula beach is returning to a more natural state. An apparent problem is that the Peninsula was developed with a road, pub, parking areas and other facilities when the beach was in an inflated state. These developments are now potentially in jeopardy as the beach is deflating due to decrease in sediment supply.

Reference is made to a simple geometric model of a beach, ***Appendix 5***. The illustration shows a beach a slope of 10H: 1V. In the instance that the beach level drops 1 metre, the foreshore recesses 10 metres. If the beach level drops the backshore recedes at a multiple roughly equal to the slope of the beach expresses as run over rise.

Where Have the Beach Sediments Gone?

Sediments discharged onto the foreshore in the vicinity of Producer’s Pit will travel mostly along the upper shore to the tip of the Coburg Peninsula, ***Appendix 6***. Where sediments go after that will be either:

- Into Esquimalt Lagoon where they are deposited and contribute to the flood tidal delta forming in the lagoon; or
- Offshore onto lower foreshore tidal flats between the tip of the Coburg Peninsula and Rodd Point to the east.

The movement of littoral material either into the lagoon or offshore is facilitated by the strong currents that flow into an out of Esquimalt Lagoon.

Other Issues

The deflation of the beach has enabled waves to propagate at high tides over the tip of the peninsula and impact the northern abutment of the bridge on Ocean Boulevard. The impact of waves on the abutment might be focused by wave refraction as they propagate over the tip of the peninsula. The site reconnaissance and photos provided by Colwood show that the rock armouring has started to unravel exposing and washing out finer material from deeper within the bridge abutment fill.

Table 2: Coburg Peninsula
Summary of Elevations and Differentials along Coburg Peninsula

Transect	Description	Road Elevation (m – CHS)	HHW Elev. Difference (m)	Record Elev. Difference (m)
1	Southern Peninsula – Road	5.0	1.6	1.3
2	Southern Peninsula – Road	4.6	1.2	0.9
3	Southern Peninsula – Road	4.5	1.1	0.8
4	Southern Peninsula – Road	3.7	0.3	0.0
5	Mid Peninsula – Road	4.7	1.3	1.0
6	Mid Peninsula – Road	5.0	1.6	1.3
8	Northern Peninsula – Road	4.0	0.6	0.3
9	Northern Peninsula – Road	4.0	0.6	0.3
10	Northern Peninsula – Berm Crest	3.5	0.2	-0.2

Notes:

1. *Capital Regional District, Environmental Services, Ecosystem Profiles, 2005*
2. *HHWLT for Victoria is 3.4 m, Record WL for Victoria 3.7 m*

Ocean Boulevard runs along the spine of the Peninsula and crosses across a wooden trestle structure at the channel to the upland adjacent to Fort Rodd Hill National Historic Park. Study of the CRD Environmental Study shoreline profiles shows that the elevation of Ocean Boulevard along the Coburg Peninsula is low. The site reconnaissance uncovered evidence of recent overtopping of Ocean Boulevard, mostly on the southern extension. The City of Colwood reported the road was last closed on November 12, 2007 due to overtopping.

A summary of road elevations taken from the CRD environmental study are presented in ***Table 2***. If these profiles are correct, then it is apparent that the road will overtop during storms that coincide with high tides. It is noted that reference 7 of ***Appendix 1*** suggests there may be elevation errors in the profile data. The magnitude of the error is not stated. In any case, allowing for wave runup on the shore, the road elevation should be on the order of 1 to 2 metres above the record high water level. Most of the tabulated road elevations are well below this and the recent overtopping indicates the road elevation is low.

Sea Level Rise

The report 'State of the Pacific Ocean 2006' published by the Department of Fisheries and Oceans has been referenced for the latest understanding on sea level rise. An excerpt from the report entitled 'Coastal Sea Levels: Long Term Rise Continues' is attached as ***Appendix 7***.

The current trend for Victoria is a sea level rise of 6 cm per century. The tectonic movement of the Earth's crust plays a role in coastal sea level rise as noted by Tofino where the sea level has been falling at a rate of -15 cm per century. Sea level rise at Victoria is not a major factor in the design and planning of coastal infrastructure, but should be considered for projects that have long time horizons.

Recent Events Impacting the Peninsula

Two recent events impacting the peninsula have been identified by the City of Colwood for further investigation:

- 12-Nov-2007: Ocean Boulevard closed due to inundation; and
- 04-Jan-2008: Severe erosion at the northern tip of the peninsula.

An elementary analysis of these events was undertaken with reference to water level data from the Canadian Hydrographic Service and recorded wind speed and direction data, Victoria Harbour, from Climate Services, Environment Canada, ***Appendix 8***.

In the case of the November 12th event, the data shows high and rising tidal water levels combined with strong southeasterly winds on the morning to early afternoon of that day. Wind speeds peaked at 41 kph in Victoria Harbour in the 7AM to 8AM time frame and began to subside, switching to westerly by noon. Through the morning, the winds would have generated waves that would have impacted the shoreline of the Coburg Peninsula. In the afternoon, the change in direction to westerly would have eased the impact on the shore from waves. Through the morning the water levels rose and peaked in the 1PM time frame with an observed level of 3.31 metres and a residual of almost 0.6 m above predicted astronomical tide.

The nearly coincident occurrence of strong southeasterly winds and high water level are statistically independent events. The data suggests that had the peak winds and wind generated waves occurred four hours later in the day, the impact on the peninsula would have been more severe. As the events occurred, the time of the highest winds and waves lagged the peak water levels and that would have lessened the impact. The calculation of road freeboard puts the road a fraction of a metre above the observed water level in the 1PM time frame on that day. Although a wave hindcast and wave run-up analysis would be required for a definitive analysis, our experience suggests wind generated waves breaking on the Coburg Peninsula beach that morning could have wave runup that would push debris across the lower lying portions of the road.

The observed water level of 3.31 metres on November 12th was 0.45 metres below the record of 3.76 metres and would rank 38th out of 57 observed annual extreme water levels during the period 1950 to 2006, ***Appendix 9***. We would conclude that the event of November 12th that impacted the Coburg Peninsula shoreline was significant, but that much larger waters levels, winds and waves are possible and these larger events will occur in the future. More detailed statistical analysis will be required to assign a probability of occurrence to the event.

In the case of the January 4th event, we have again high water levels combined with strong southeasterly winds generating waves. In this instance, winds and high water levels combined almost ideally to create severe conditions. Southeasterly winds at Victoria Harbour peaked in the 10AM to noon time frame and the water levels peaked about the same time at 3.79 metres at 11AM, ***Appendix 8***. This event is reported to have caused significant erosion off the top of the end of the peninsula, damage to the north bridge abutment armouring and erosion on the upcoast and downcoast margins on the DND Ranger Station, including the parking lot on the north side.

The observed water level of 3.379 metres on January 4th was 0.321 metres below the record water level and would rank 30th out of 57 observed annual extreme water levels during the period 1950 to 2006, ***Appendix 9***. It appears the event enabled enough wave energy to propagate over the tip of the peninsula and damage the armouring on the north bridge abutment. It is also noted that the loss of material off the tip of the peninsula is not likely to be replaced by a natural deposition as the longshore sediment supply has been reduced over past levels. This implies that the risk of wave induced erosion at the north bridge abutment has gone up. The event of January 4th was significant but much larger water levels, winds and waves are possible and these larger events will occur in the future.

Impact of Isolated Rip Rap Armouring

The rip rap armouring around the DND Ranger Station has created a hard promontory along the linear peninsula beach. The rip rap armouring stands proud of the beach profile and is obvious when viewed from beach level, ***Appendix 4***.

A brief literature review was done to find references to the impact of rip rap hardened foreshore on adjacent unprotected foreshore. An analysis of a deflating beach and armoured slope geometrics was also done.

The US Army Corp of Engineers Shore Protection Manual (1984) refers to work by Coastal Engineer Robert Dean, "Coastal Structures and Their Interaction With the Shoreline", that suggests that rip currents can form adjacent to coastal structures due to the channelling of longshore current, ***Appendix 10***. There is insufficient information to be conclusive on the matter; however, at high water levels the rip rap promontory would present a blockage on the foreshore that could conceivably be capable of creating a rip current along its upcoast margin. Whether the rip current would have sufficient magnitude to aggravate beach erosion in its vicinity is unknown. In relatively benign conditions, the ability of promontory structures such as groynes to trap sediment on their downcoast sides is well known and this would suggest that the beach would tend to build over time on this side.

In the case of the analysis of a deflating beach and an isolated armoured promontory, our main conclusion is that the wave energy that can reach the slope over time will increase as the beach deflates, ***Appendix 11***. In the simplified analysis shown, the breaking wave height on the slope is assumed to be about the depth of breaking. It is also important to note that the wave energy is proportional to the square of the breaking wave height, so a doubling in the depth of breaking will increase the wave energy four fold. The analysis suggests that the breaking wave heights on the rip rap slope will increase over time as the beach deflates, but it also assumes that increasing wave height and energy can be developed and propagate to the slope. The conclusion of the analysis is that beach deflation will increase the severity of impacts on the DND Ranger Station as logs and debris are cast upslope when storm waves break and run up the slope.

3.0 Erosion Mitigation

3.1 Foreshore Armouring

The illustration of foreshore armouring entitled ‘Armour Stone Repair Ocean Bvld. Extension’, City of Colwood, February 19, 1998, ***Appendix 12***, presents a possible method of mitigating foreshore erosion. Rip rap placement along a shoreline, often deemed the ‘hard’ approach, requires heavy armour stone that is stable when subject to wave breaking, run-up and possibly even over-topping. In the case of over-topping the crest elevation can be established high enough to avoid this. The City of Colwood illustration shows the crest elevation as matching the elevation of the road. Noting that the elevation of Ocean Boulevard varies, the crest of the rip rap revetment would also vary and be subject to overtopping.

The underlayer below the armour stone is a key component of a rip rap revetment. The size of the armour stone is critical to the formation of a filter to avoid loss of fine material from deeper within the slope.

The use of filter fabric is popular but can be difficult to install. Our experience and opinion is that a properly engineered and constructed slope using materials that meet specified gradations will be stable and should not see loss of fines from behind the slope. The construction method is critical for stable rip rap slopes. Stability can be significantly enhanced by building the armour rock up and keying in armour rock. Armour rock should not be dumped. A large tracked excavator, preferably with an articulating thumb for rock handling, would be suitable equipment for this type of construction.

If the City of Colwood chooses to tackle erosion issues by foreshore armouring, it would be advisable for the slope to be fully engineered with more detailed specification including:

- Crest Elevations;
- Slopes;
- Self launching toe;
- Material size and properties for armour and underlayer; and
- Plan form.

In the case of the north bridge abutment, rebuilding of the rip rap armouring around the abutment would be an effective and appropriate measure for this area. Again, in this area it would be advisable for the slope to be fully engineered with more detailed specifications as previously noted. The scope of foreshore armouring is presented on an area plan ***Case 1, Appendix 13***.

Seawalls are an alternative to rip rap as they also present a 'hard barrier' against the sea. At Coburg Peninsula a seawall would be more problematic than rip rap as it would require a deeper foundation and result in greater construction cost for no significant benefit over rip rap.

Visitor Experience

Armoring a shoreline with rip rap can be effective at stopping foreshore erosion and recession of the backshore, however, it will not stop deflation of the beach due to reduced sediment supply. The beach elevation could continue to drop over time. Armouring the Coburg Peninsula would not enhance the public experience as visitors would have to navigate a 2H: 1V rip rap slope to access the beach. Also, the beach might be completely inaccessible during high tides. This will be particularly noticeable during the winter when high tides occur during the day, visitors arriving at the shore would find the water up to the rip rap slope with no beach to walk on.

3.2 Beach Replenishment

This approach would basically involve recovering sediments that built up the beach in the recent past from their offshore deposition areas and pumping them back on the beach at points along the shore from mid peninsula upcoast to the vicinity of Producer's Pit. The result of this exercise would be to raise and broaden the beach. Deployment of a floating dredge plant, preferably a cutter suction dredge, would be required to undertake this work.

Assuming a target deposition of about 100 cubic metres of sediment per metre of beach deposited over 3.0 kilometres of peninsula and coast immediately to the south, about 250,000 cubic metre of sediment would have to be dredged. A cutter suction dredge working at an average productivity of 20,000 cubic metres per day could conceivably complete the beach replenishment in a time frame of several weeks.

Beach replenishment is a common practice on beaches worldwide, ***Table 3***.

Table 3: Examples of Beach Replenishment Projects

Location	**Beach**	**Remarks**
Florida, USA	Sand Key	See Appendix 14
Rio de Janeiro, Brazil	Copacabana	
New York, USA	Coney Island	
South Carolina, USA	Myrtle Beach	Extensive Ongoing Programme
Cancun, Mexico	Cancun	
Barbados	Rockley	Includes Offshore Breakwater

Beach Replenishment is a temporary measure and it will be necessary to periodically redeploy dredging equipment to rebuild the beach. Beach replenishment requires monitoring programmes to determine the frequency of refill. Examples of beach replenishment projects with cost data and project experience in Australia are covered in ***Appendix 14***.

An issue relating to beach replenishment that can not be ignored at Coburg Peninsula is the transport of sediments beyond the tip of the peninsula. A portion of these sediments will be transported into Esquimalt Lagoon and be deposited on the pro-grading flood tidal delta in the lagoon. These sediments and the advancement of the delta into Esquimalt Lagoon can be controlled by constructing a sediment trap on the lagoon side of the bridge. A sediment trap will be large pool excavated at the lagoon entrance that will enable flow velocities to fall and sediments to be deposited. A sediment trap will require periodic monitoring and excavation. Material removed from the sediment trap can be re-deposited back on the beach upcoast of the southern end of Ocean Boulevard. In the absence of these measures as part of a beach replenishment project, the development of the delta into the lagoon will continue. The scope of beach replenishment is presented on an area plan ***Case 2***, ***Appendix 13***.

Visitor Experience

Beach replenishment projects generally enhance visitor experience. As noted in ***Table 3***, many of the world's most popular public have been the subject of beach replenishment projects. A built up beach would have a broader area available for recreational activity. In the winter, more beach area would be available for public use that is currently available along the peninsula. It is important to keep in mind that the beach enhancement is only temporary and in time would require replenishment.

3.3 Coastal Structures

Two types of coastal structures that could be employed at Coburg Peninsula include groynes and offshore breakwaters. Examples of these structures are covered in ***Appendices 14 and 15***. Both are usually constructed of rock with a heavy outer rock armouring for stability when subject to breaking waves. Main points on these structures:

- Permanent;
- Costly to build;
- Will cause an dramatic change in the shape of the beach; and
- Can stabilize a coastline by enabling sediment to be trapped resulting in a beach realigned normal to the prevailing incident wave direction.

In the case of groynes, an array of the structures would be required along the 3 km length of shoreline that is the subject of this study. For the purposes of developing the order of magnitude scope and cost, a groyne length and spacing of 100 m and 200 m is assumed. About fifteen of the structures would be required along the peninsula. Groynes function by interrupting longshore sediment transport and trapping sediment on their downcoast sides. The Coburg Peninsula doesn't have any sediment to give up in this regard, so an array of groynes would have to be filled on their downcoast sides as part of their construction.

In the case of offshore breakwaters, a length of about 180 m per structure at a spacing of about 300 m has been assumed. An offshore breakwater functions by interfering with incident waves causing diffraction in the lee of the structure. The diffracted wave pattern enables a tombolo to build in behind the breakwater. As in the case of groynes, the Coburg Peninsula doesn't have any sediment to give up so the structures would have to be backfilled in the tombolo area as part of their construction. Material excavated for the foundation structure could be used for this.

The construction of a groyne or offshore breakwater near the tip of the Coburg Peninsula could be effective in mitigating certain shore erosion issues:

- Build the beach in front of the DND Ranger Station;
- Reduce wave impact on the Ocean Boulevard bridge abutments; and

- Direct longshore sediment transport away from the lagoon entrance.

Coastal structures are an effective but costly approach to mitigating shore erosion. They would require more planning, design and analysis to implement. They also function as a sediment trap that could be periodically harvested to recover material for transportation by truck down the peninsula and re-deposited on the beach south of Ocean Boulevard. The scope of groyne and offshore breakwater coastal structures is presented on area plans, ***Cases 3 and 4, Appendix 13***.

Visitor Experience

The beaches created by coastal structures are generally considered an enhancement. The visitor experience will probably be positive but opinions may vary noting that the beach is artificially fixed by dominant coastal structures built out of rock.

3.4 Combination Approach

A combination approach is intended to deal with immediate concerns with future work to be added as budgets become available. The scope of combination work proposed includes:

- Protection of the southern extension of Ocean Boulevard and the pumping station;
- Protection of the tip of the peninsula where bridge abutments and the DND Ranger Station are being impacted by waves.

The combination approach outlined in this study assumes:

- Rip rap foreshore armouring for the southern extension of Ocean Boulevard; and
- Rip rap foreshore armouring with a groyne at the tip of the peninsula.

The scope of the combination approach is presented on area plan ***Case 5, Appendix 13***.

It should be realized that the combination approach is shown for comparison and evaluation against other shoreline treatments, it is not a recommendation. The combination approach has a number of issues, the main one being that the critical areas of the peninsula may be protected by foreshore treatment, the remainder of the peninsula will remain vulnerable to erosion. In the short term this may not be a very apparent issue, but in the long run it will become apparent.

Visitor Experience

The visitor experience will depend on the type of shoreline treatment installed. The previous comments would apply in this instance:

- Foreshore rip rap armouring – not an enhancement;
- Array of groynes – generally regarded as an enhancement; and
- Offshore breakwater – generally regarded as an enhancement.

Beach in the central area of the peninsula would continue to deflate in the absence of a shoreline treatment. The visitor experience would decline in this area over time until a shoreline treatment is installed.

3.5 Do Nothing

The foreseeable results of doing nothing will include:

- Short term avoidance of capital expenditure;
- Continued over topping of Ocean Boulevard;
- Continued degradation of the north bridge abutment fill armouring; and
- Possible continued deflation of the peninsula beach over time due to decreased sediment supply.

Elevation data, ***Table 2***, suggests that Ocean Boulevard was built 'at grade' on Coburg Peninsula. Realizing that the peninsula has been both built up and breached historically by extreme wave and water level events, future events of the magnitude that built the peninsula will occur and be exceeded. In the absence of an increase in sediment discharge to the foreshore upcoast of the peninsula, the beach will not rebuild to levels it had in the past. If the beach continues to deflate, the foreshore will push back and may reach the road putting it at risk of undermining in a severe storm coinciding with high water levels. We do not have enough information to accurately assess the time frame or risk of this process. A series of beach profiles over time would normally be required to make this assessment.

The north bridge abutment armouring has begun to fail and will continue to degrade in winter storms in the absence of remedial work. This work alone is fairly straight forward and should in our opinion be undertaken. The scope of this work is presented on area plan ***Case 6, Appendix 13***.

Visitor Experience

The 'Do Nothing' visitor experience will be mostly 'more of the same'. Deflation of the beach may continue depending on the amount of sediment supplied from upcoast backshore erosion. The result will be a decrease in area available for recreation as the upper foreshore migrates towards Ocean Boulevard.

4.0 Costs

Project order of magnitude costs have been prepared for comparative purposes, ***Table 5***. A relatively more detailed comparison of engineered shoreline treatments is presented in ***Appendix 16*** and includes costs and issues.

The costs have been prepared with contractor input. The cost of similar projects has been pro-rated for estimated quantities for Coburg Peninsula. Accurate cost estimation for any of the proposed work items can be made if a design and work programme is developed in more detail.

Table 5: Coburg Peninsula
Cost Comparison of Engineered Erosion Mitigation Methods (Abridged)

Item	Description	Time Frame	Visitor Experience	Magnitude Cost
1	Foreshore Armouring 3 km Coburg Peninsula	Long Term	Not an Enhancement	$2.1 M
2	Beach Replenishment 250,000 m^3	Short Term – Perhaps 5 to 10 years	Enhancement	$2.5 M
3	Coastal Structure – Groyne – Array of 16 Structures	Long Term	Enhancement	$4.8 M
4	Coastal Structure – Breakwater – Array of 9 Structures	Long Term	Enhancement	$11.5 M
5	Partial Armouring With Groyne at North End of Spit	Long Term	Enhancement	$0.9 M
6	Bridge Abutment Reconstruct 50 m Abutment Armouring	Long Term	Not an Enhancement	$35 k
7	Do Nothing	Not Applicable	Not an Enhancement	$0

Cost Estimate Assumptions

Coburg Peninsula Foreshore Armouring: Heavy armour with self launching toe apron at 10 cubic metres per metre of beach, underlayer at 4 cubic metres per metre of beach. Supply and install engineered rip rap slope at 2H: 1V rate $700 per metre of beach.

North Bridge Abutment Fill Armour Reconstruction: same assumptions as above for Coburg Peninsula, above.

Beach replenishment: Assumed replenishment volume 70 cubic metres of sand per metre of beach distributed from Producer's Pit to the northern tip of Coburg Peninsula. Dredging rate including mobilization, demobilization and crew living out allowances for one month project time frame is $10 per cubic metre.

Coastal Structure – Single Offshore Breakwater: Assumptions for an engineered coastal structure build using marine equipment:

- Length: 100m, side slopes 2H: 1V;
- Heavy rock armour: 8 ton weight - 8,000 cubic metres;
- Light rock armour: 4 ton weight - 8,000 cubic metres;
- Underlayer: 300 mm minus - 8,000 cubic metres;
- Core material: shot rock - 24,000 cubic metres; and
- Tombolo - 30,000 cubic metres of mostly sand.

Coastal Structure – Single Groyne: Assumptions for an engineered coastal structure built from land:

- Length: 50m, side slopes 2H: 1V;
- Heavy rock armour: 8 ton weight - 500 cubic metres;
- Light rock armour: 4 ton weight - 500 cubic metres;
- Underlayer: 300 mm minus - 500 cubic metres;
- Core material: shot rock - 500 cubic metres; and
- Beach Fill - 5,000 cubic metres of mostly sand.

5.0 Implementation

Foreshore armouring is entirely a land based construction. There are many suitably equipped and experienced Vancouver Island Contractors to bid this type of work. Rock supply might involve delivery by barge if it is brought in from an existing quarry such as Texada Island or Pitt River if a local source is not found.

Beach replenishment would have to be undertaken by a contractor with dredging capability. In British Columbia, this is Fraser River Pile & Dredge Limited of New Westminster. Other marine contractors have dredging capability but would be limited to clam shell dredging which is a comparatively low productivity approach that in not likely to be competitive with suction dredging.

Construction of an offshore breakwater would be within the capability of coastal marine contractors. Groynes could be built from the upland enabling land based contractors to bid this type of work.

6.0 Further Work

This study reviews possible engineered approaches to mitigating erosion issues on the Coburg Peninsula. It will be necessary to undertake additional engineering and environmental studies to develop the proposals further. The scope of further work would depend on the direction the City of Colwood would chose to take on the issues. Some areas of further investigation might include:

- More detailed engineering and cost estimation of selected shore protection method(s);
- Wave hindcasting and runup calculations in the case of foreshore armouring, coastal structures or vertical realignment of Ocean Boulevard;
- Hydrographic and possibly seismic surveys to affirm offshore sediment deposition areas and volumes in the case of beach replenishment; and
- Environmental study to assess the impact of any of the proposed engineered approaches to mitigating erosion.

7.0 Conclusions and Recommendations

Study of historic and aerial ortho-photographs of Coburg Peninsula shows that the beach in the past was artificially enhanced by sediment discharges from the operations at Producer's Pit. The sediment discharges have since been discontinued and leaving only upcoast backshore erosion as a shoreline sediment supply. The result has been deflation of the beach over time as evidenced by the drop in beach level that is apparent along the peninsula, particularly around the DND Ranger Station where pipelines crossing the beach are exposed.

Recent events impacting the foreshore in the study area include:

- Erosion at the north bridge abutment on Ocean Boulevard on January 4, 2008; and
- Over topping of Ocean Boulevard resulting in deposition of debris on the road and on November 12, 2007 closure of the road.

Elementary analysis of these events reveals that they were due to the combination of high water levels and wind generated waves. The event of November 12th could have more severe had the wind generated waves coincided more closely with the high tides. The event of January 4th had wind generated waves occurring coincidently with the high tides. These events were large but far from record events. More extreme events are possible.

Installation of foreshore rip rap armouring will harden the shoreline to resist erosion. This approach will not enhance the visitor experience and will make the beach inaccessible during high water levels. This approach has a relatively low cost and is for practical purposes permanent.

Beach replenishment offers the highest visitor experience but is a temporary measure and would require additional replenishment in time. This approach has a relatively low cost but will also have ongoing periodic costs to maintain the beach as it deflates over time.

Coastal structures like groynes and offshore breakwaters could offer longer term stabilization of the shoreline but with a dramatic alteration on the shape of the beach. These structures offer a generally positive visitor experience as they are able to create small but stable pocket beaches. These structures will have a relatively high cost.

If the City of Colwood chooses undertake any engineered work on the shoreline, additional study would be required that would include engineering and environmental assessment. A beach monitoring programme comprising periodic survey of shore profiles would also be advisable.

We expect the ‘do nothing’ alternative would see continued deflation of the beach and recession of the shoreline toward Ocean Boulevard. The beach surface will self armour and become rockier as finer sediments are carried down coast and offshore. Continued encroachment of the shoreline toward the road is likely if beach deflation continues.

We would recommend the engineering and construction of more robust rip rap armouring around the north bridge abutment. Preparation of engineering drawings and specifications for the bridge abutment work is advisable. We would be prepared to provide a fee estimate for this if requested.

If the City of Colwood seeks to avoid overtopping and periodic closure of Ocean Boulevard, raising the road would be required. Raising the road would require further engineering study including integrating the vertical realignment with existing facilities and provision of hardening along the road margins to resist erosion.

We trust that the information provided in this study serves your current needs and now await your further instructions.

Sincerely,
SEABULK SYSTEMS INC.

Carlos Johansen, P.Eng.
Vice-President, Marine

Enclosures

Appendix 1
Previous Studies and Research

Appendix 1 – List of References

1. "City of Colwood, Royal Roads Foreshore Erosion", Hay & Company Consultants, December 1986.

2. "Royal Bay Development, Beach Erosion and Coastal Processes, Study 1C", A Joint Report by Coastal and Ocean Resources Inc. and Thurber Engineering Ltd., November 1997.

3. "State of the Pacific Ocean 2006, Ocean Status Report 2007/001", Fisheries and Ocean Canada, Science, Pacific Region.

4. "Armour Stone Repair, Ocean Blvd Extension", City of Colwood Engineering Department, Feb 19, 1998, File 10.3.2.2

5. Aerial Ortho-photographs 1954, 1968, 1980, 1984, 1990, 1997, 2001, 2003, 2005, 2007

6. Coburg Peninsula Environmental Study, Capital Regional District, 2005, Profiles of Coburg Peninsula, Figures 1 to 10.

7. "Sediment Erosion, Transport and Depositional Processes at Coburg Peninsula", Terri Evans, Jessica Van Winden, Jacolby Giuseppini, 2006.

8. "Maintaining the Adelaide Coastline", South Australian Coast Protection Board, No. 28, September 1993

9. Storm Damage Report for BEL602A Coburg Spit, November 14, 2005, by Dean Steinke, Internal Report, Department of National Defense

Appendix 2
Aerial Ortho-Photograph 1968


1968

Appendix 3
Coburg Peninsula and Dugout Pub 1935

Photo 1: Dugout Pub on Coburg Peninsula, Circa 1935

Photo 2: Aerial View of Coburg Peninsula, Circa 1935

Appendix 4
DND Ranger Station 2007

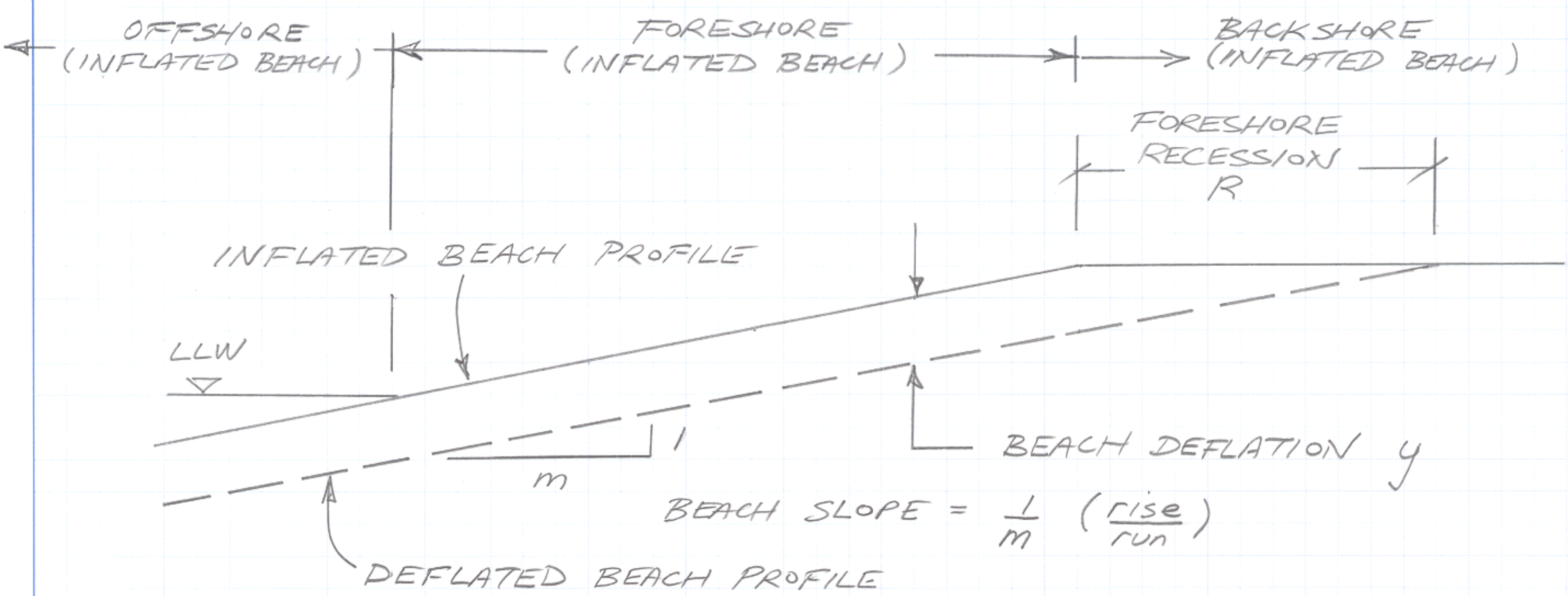
Appendix 5
Beach Erosion Geometrics

SEABULK

Project: COLWOOD No.: 661 Date: 25.JAN.08

By: MATTILA Checked:

BEACH GEOMETRY – APPENDIX 5



FORESHORE RECESSION DUE TO BEACH DEFLATION:

$$R = m \cdot y$$

EXAMPLE:

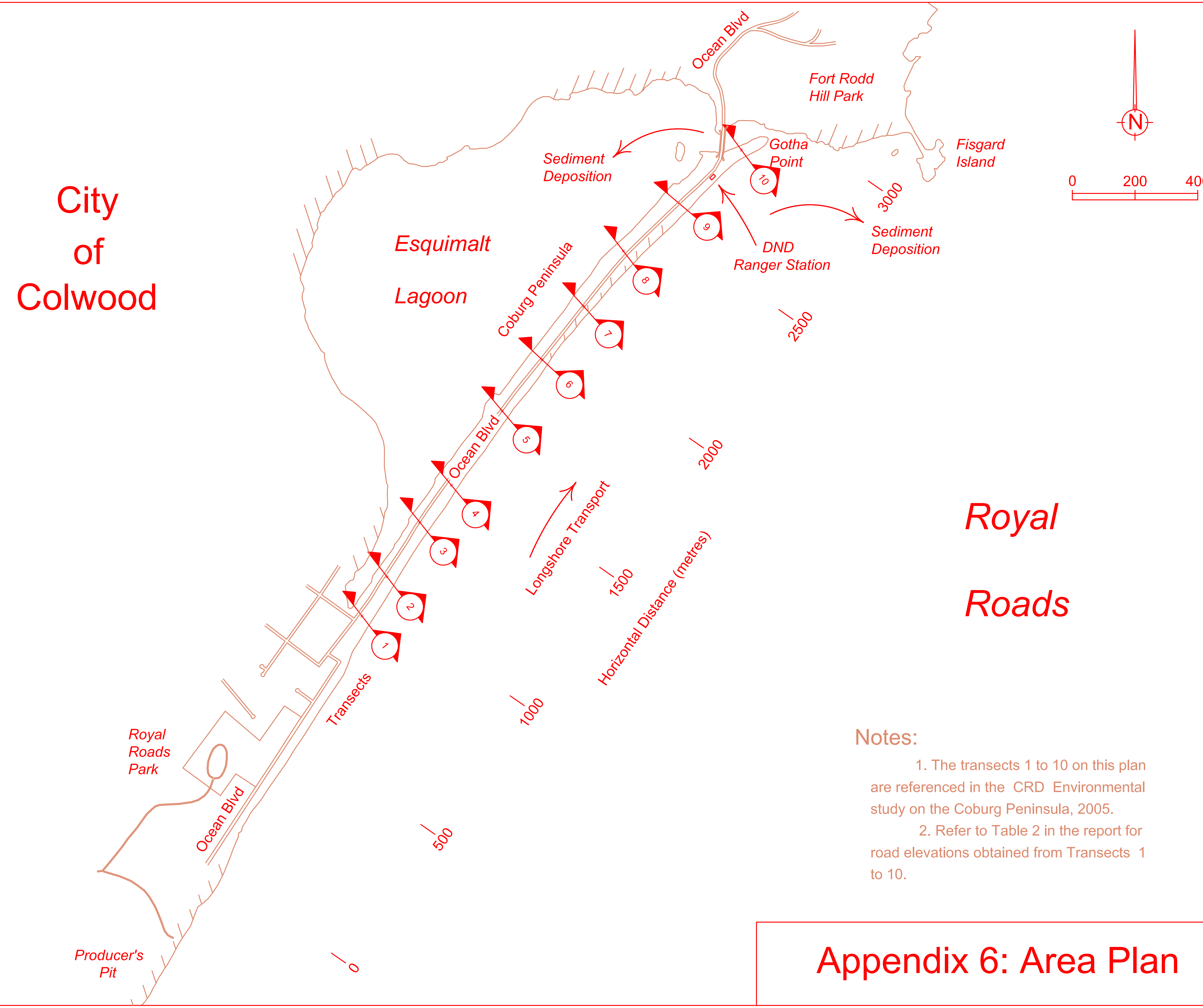
BEACH SLOPE = 10H:1V, DEFLATION = 1 m

$R = m \cdot y = 10 \cdot 1 = 10$ m RECESSION.

NOT TO SCALE

Appendix 6
Study Area Plan

Appendix 6: Area Plan



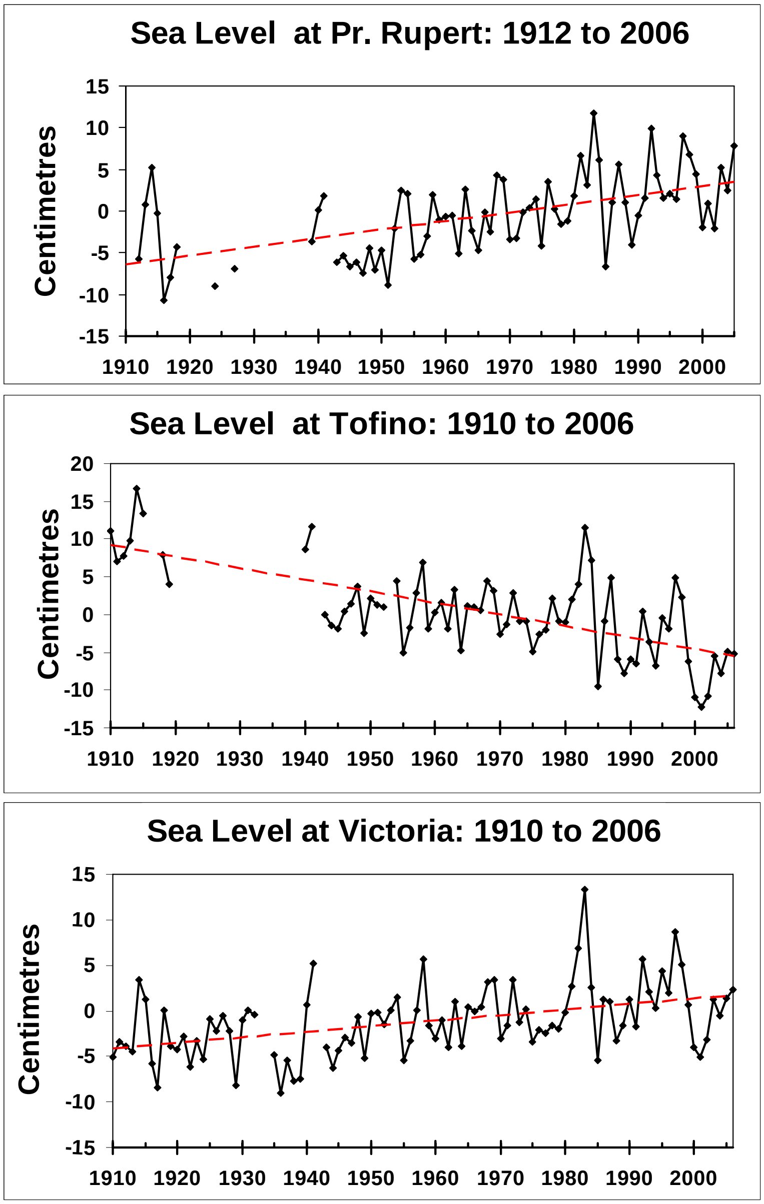
Notes:

1. The transects 1 to 10 on this plan are referenced in the CRD Environmental study on the Coburg Peninsula, 2005.
2. Refer to Table 2 in the report for road elevations obtained from Transects 1 to 10.

Appendix 7
Coastal Sea Levels: The Long Term Rise Continues

Coastal Sea Levels: Long Term Rise Continues

Bill Crawford, Fisheries & Oceans Canada



The Canadian Hydrographic Service monitors levels along the coast. The records at left show deviations from long-term average levels at three BC ports. Dashed red lines show the linear trend over the record length.

These trends are listed below (in cm/century):
Prince Rupert +11
Victoria +6
Tofino -15

Tectonic motion is lifting the land at Tofino faster than sea level is rising, so local sea level is actually dropping at a rate of 15 cm per 100 years. The next Cascadia Subduction Zone earthquake will drop the land at Tofino and along the west side of Vancouver Island by a metre or so, and send a major tsunami toward the BC coast.

Figure A35. Graphs of annually averaged sea levels at three British Columbia Ports. Long-term linear trends are plotted as red dashed lines.

Global sea levels rose about 10 to 20 cm over the 20th century (=0.1 to 0.2 cm/year). Satellite observations since 1993 indicate a global rise of 0.3 cm per year. The Intergovernmental Panel on Climate Change (IPCC 2007) predicts sea level to rise by 20 to 60 cm over the 21st century (=0.2 to 0.6 cm/year) and to continue rising for many centuries.

Links: Canadian Hydrographic Service (http://www-sci.pac.dfo-mpo.gc.ca/charts/home_e.htm)
Contact: Bill Crawford (CrawfordB@pac.dfo-mpo.gc.ca)

Appendix 8
Extreme Event Analysis
November 12, 2007 and January 4, 2008

City of Colwood/ Seabulk Systems Inc.

Extreme Event Analysis - November 12, 2007 - Coburg Peninsula

Index	Date	Local Time	Wind Speed[1] (kph)	Wind Direction[1] (degrees)	Predicted Water Level (m)	Observed Water Level (m)	Setup Residual (m)	Record Height Difference (m)	Road Freeboard (m)	Remarks
25	12-Nov-07	0:00			0.807	1.000	0.193	2.760	2.700	
26	12-Nov-07	1:00			1.130	1.282	0.152	2.478	2.418	
27	12-Nov-07	2:00			1.485	1.654	-0.190	2.106	2.046	
28	12-Nov-07	3:00			1.844	2.090	-0.045	1.670	1.610	
29	12-Nov-07	4:00			2.135	2.424	0.105	1.336	1.276	
30	12-Nov-07	5:00			2.319	2.634	0.199	1.126	1.066	
31	12-Nov-07	6:00	39	140	2.435	2.817	0.284	0.943	0.883	Southeasterly winds
32	12-Nov-07	7:00	41	140	2.533	2.902	0.295	0.858	0.798	Southeasterly winds
33	12-Nov-07	8:00	41	140	2.607	2.936	0.288	0.824	0.764	Southeasterly winds
34	12-Nov-07	9:00	32	140	2.648	3.082	0.399	0.678	0.618	Southeasterly winds
35	12-Nov-07	10:00	17	170	2.683	3.140	0.408	0.620	0.560	
36	12-Nov-07	11:00	20	220	2.732	3.146	0.379	0.614	0.554	
37	12-Nov-07	12:00	37	270	2.767	3.241	0.482	0.519	0.459	High water levels, westerly winds
38	12-Nov-07	13:00	41	260	2.759	3.310	0.598	0.450	0.390	High water levels, westerly winds
39	12-Nov-07	14:00	35	260	2.712	3.228	0.599	0.532	0.472	High water levels, westerly winds
40	12-Nov-07	15:00	26	260	2.629	3.073	0.593	0.687	0.627	
41	12-Nov-07	16:00	26	260	2.480	2.853	0.617	0.907	0.847	
42	12-Nov-07	17:00	33	250	2.236	2.558	0.642	1.202	1.142	
43	12-Nov-07	18:00	13	260	1.916	2.132	0.590	1.628	1.568	
44	12-Nov-07	19:00	26	250	1.542	1.643	0.522	2.117	2.057	
45	12-Nov-07	20:00	20	270	1.121	1.148	0.434	2.612	2.552	
46	12-Nov-07	21:00	17	260	0.714	0.655	0.197	3.105	3.045	
47	12-Nov-07	22:00			0.458	0.475	0.033	3.285	3.225	
48	12-Nov-07	23:00			0.442	0.491	0.491	3.269	3.209	

Notes:

1. Record extreme water level occured on January 2, 2003 at 3.76 m CHS
2. Environment Canada hourly data report for Victoria Harbour Airport, YWH, Climate ID: 1018615, Latitude 48° 25.200' N, Longitude 123° 23.400' W

City of Colwood/ Seabulk Systems Inc.
Extreme Event Analysis - January 4, 2008 - Coburg Peninsula

Index	Date	Local Time	Wind Speed[1] (kph)	Wind Direction[1] (degrees)	Predicted Water Level (m)	Observed Water Level (m)	Setup Residual (m)	Record Height Difference (m)	Road Freeboard (m)	Remarks
25	04-Jan-08	0:00			1.850	2.210	0.360	1.550	1.490	
26	04-Jan-08	1:00			2.053	2.406	0.353	1.354	1.294	
27	04-Jan-08	2:00			2.228	2.552	0.324	1.208	1.148	
28	04-Jan-08	3:00			2.396	2.701	0.305	1.059	0.999	
29	04-Jan-08	4:00			2.546	2.854	0.308	0.906	0.846	
30	04-Jan-08	5:00			2.644	2.973	0.329	0.787	0.727	
31	04-Jan-08	6:00	20	120	2.700	3.068	0.368	0.692	0.632	
32	04-Jan-08	7:00	20	100	2.752	3.071	0.319	0.689	0.629	
33	04-Jan-08	8:00	19	110	2.814	3.215	0.401	0.545	0.485	High water levels, southeasterly winds
34	04-Jan-08	9:00	17	80	2.850	3.300	0.450	0.460	0.400	High water levels, southeasterly winds
35	04-Jan-08	10:00	39	100	2.832	3.338	0.506	0.422	0.362	High water levels, southeasterly winds
36	04-Jan-08	11:00	35	100	2.761	3.379	0.618	0.381	0.321	High water levels, southeasterly winds
37	04-Jan-08	12:00	32	130	2.638	3.231	0.593	0.529	0.469	High water levels, southeasterly winds
38	04-Jan-08	13:00	24	160	2.448	3.085	0.637	0.675	0.615	
39	04-Jan-08	14:00	11	170	2.172	2.831	0.659	0.929	0.869	
40	04-Jan-08	15:00	17	120	1.809	2.453	0.644	1.307	1.247	
41	04-Jan-08	16:00	20	130	1.403	2.068	0.665	1.692	1.632	
42	04-Jan-08	17:00	43	140	1.023	1.733	0.710	2.027	1.967	
43	04-Jan-08	18:00	22	130	0.746	1.511	0.765	2.249	2.189	
44	04-Jan-08	19:00	26	130	0.625	1.428	0.803	2.332	2.272	
45	04-Jan-08	20:00	24	150	0.673	1.405	0.732	2.355	2.295	
46	04-Jan-08	21:00	28	150	0.852	1.604	0.752	2.156	2.096	
47	04-Jan-08	22:00			1.114	1.720	0.606	2.040	1.980	
48	04-Jan-08	23:00			1.424	2.056	0.632	1.704	1.644	

Notes:
1. Record extreme water level occured on January 2, 2003 at 3.76 m CHS
2. Environment Canada hourly data report for Victoria Harbour Airport, YWH, Climate ID: 1018615, Latitude 48° 25.200' N, Longitude 123° 23.400' W

Appendix 9
Victoria Extreme Water Levels
1950 to 2006

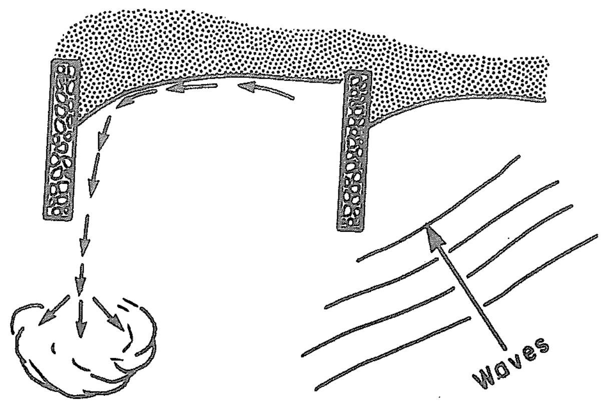
Observed Annual Extreme Water Levels
Victoria, B.C., 1950 to 2006, Chronological

Index	Year	Month	Day	Time (PST)	Height (m)
1	1950	12	9	1200	3.35
2	1951	11	30	1305	3.69
3	1952	12	30	1015	3.52
4	1953	11	22	1213	3.49
5	1954	1	5	1220	3.41
6	1955	12	25	945	3.51
7	1956	1	5	900	3.32
8	1957	12	19	1120	3.38
9	1958	12	26	1215	3.23
10	1959	1	8	1202	3.38
11	1960	12	n.a.	n.a.	3.35
12	1961	1	n.a.	n.a.	3.26
13	1962	11	n.a.	n.a.	3.12
14	1963	2	4	1005	3.31
15	1964	12	19	1240	3.42
16	1965	1	2	1137	3.33
17	1966	1	6	1120	3.46
18	1967	12	3	1302	3.57
19	1968	11	21	1301	3.50
20	1969	12	11	1406	3.71
21	1970	11	30	1240	3.29
22	1971	12	2	1202	3.25
23	1972	12	19	1052	3.45
24	1973	1	16	935	3.61
25	1974	1	15	801	3.54
26	1975	12	26	859	3.27
27	1976	12	8	1246	3.11
28	1977	12	11	1332	3.31
29	1978	1	5	1011	3.50
30	1979	12	20	1244	3.25
31	1980	1	12	904	3.34
32	1981	11	14	1424	3.59
33	1982	12	16	758	3.51
34	1983	1	27	1028	3.65
35	1984	11	27	1109	3.29
36	1985	2	11	719	3.08
37	1986	12	29	1059	3.40
38	1987	12	6	1213	3.49
39	1988	11	22	1216	3.45
40	1989	6	30	2238	3.14
41	1990	1	9	955	3.38
42	1991	12	18	1008	3.19
43	1992	12	8	1034	3.40
44	1993	12	13	1158	3.40
45	1994	1	4	807	3.10
46	1995	1	10	909	3.26
47	1996	12	10	1157	3.29
48	1997	1	1	742	2.64
49	1998	12	2	1227	3.29
50	1999	1	29	1027	3.27
51	2000	1	16	948	3.11
52	2001	1	12	1227	3.51
53	2002	12	16	1041	3.36
54	2003	1	2	1118	3.76
55	2004	12	13	1310	3.36
56	2005	12	31	1214	3.65
57	2006	1	2	1053	3.43

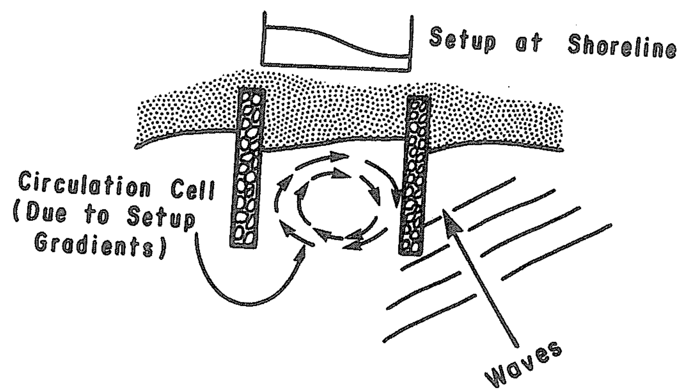
Observed Annual Extreme Water Levels
Victoria, B.C., 1950 to 2006, Ranked Highest to Lowest

Ranking	Percentile	Year	Month	Day	Time (PST)	Height (m)
1	100%	2003	1	2	1118	3.76
2	96%	1969	12	11	1406	3.71
3	94%	1951	11	30	1305	3.69
4	90%	2005	12	31	1214	3.65
5	90%	1983	1	27	1028	3.65
6	87%	1973	1	16	935	3.61
7	85%	1981	11	14	1424	3.59
8	83%	1967	12	3	1302	3.57
9	80%	1974	1	15	801	3.54
10	79%	1952	12	30	1015	3.52
11	78%	2001	1	12	1227	3.51
12	78%	1955	12	25	945	3.51
13	78%	1982	12	16	758	3.51
14	77%	1968	11	21	1301	3.50
15	77%	1978	1	5	1011	3.50
16	76%	1953	11	22	1213	3.49
17	76%	1987	12	6	1213	3.49
18	73%	1966	1	6	1120	3.46
19	72%	1972	12	19	1052	3.45
20	72%	1988	11	22	1216	3.45
21	71%	2006	1	2	1053	3.43
22	70%	1964	12	19	1240	3.42
23	69%	1954	1	5	1220	3.41
24	68%	1986	12	29	1059	3.40
25	68%	1992	12	8	1034	3.40
26	68%	1993	12	13	1158	3.40
27	66%	1957	12	19	1120	3.38
28	66%	1959	1	8	1202	3.38
29	66%	1990	1	9	955	3.38
30	64%	2004	12	13	1310	3.36
31	64%	2002	12	16	1041	3.36
32	63%	1950	12	9	1200	3.35
33	63%	1960	12	n.a.	n.a.	3.35
34	63%	1980	1	12	904	3.34
35	62%	1965	1	2	1137	3.33
36	61%	1956	1	5	900	3.32
37	60%	1963	2	4	1005	3.31
38	60%	1977	12	11	1332	3.31
39	58%	1998	12	2	1227	3.29
40	58%	1970	11	30	1240	3.29
41	58%	1984	11	27	1109	3.29
42	58%	1996	12	10	1157	3.29
43	57%	1999	1	29	1027	3.27
44	56%	1975	12	26	859	3.27
45	55%	1961	1	n.a.	n.a.	3.26
46	55%	1995	1	10	909	3.26
47	54%	1971	12	2	1202	3.25
48	54%	1979	12	20	1244	3.25
49	53%	1958	12	26	1215	3.23
50	49%	1991	12	18	1008	3.19
51	45%	1989	6	30	2238	3.14
52	43%	1962	11	n.a.	n.a.	3.12
53	42%	2000	1	16	948	3.11
54	42%	1976	12	8	1246	3.11
55	41%	1994	1	4	807	3.10
56	39%	1985	2	11	719	3.08
57	0%	1997	1	1	742	2.64

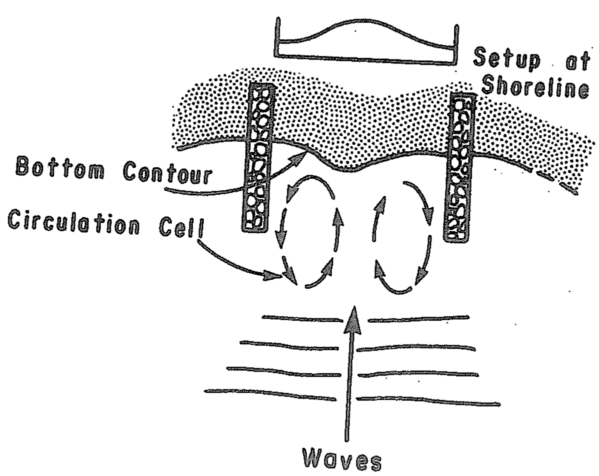
Appendix 10
Excerpt From Shore Protection Manual (1984)
Rip Current Formation Due to Channeling of Longshore Current



a. Rip current formation due to channeling of longshore current.



b. Circulation within a groin compartment due to variation in longshore setup.



c. Circulation cell within a groin compartment due to energy dissipation at the groins and variable setup.

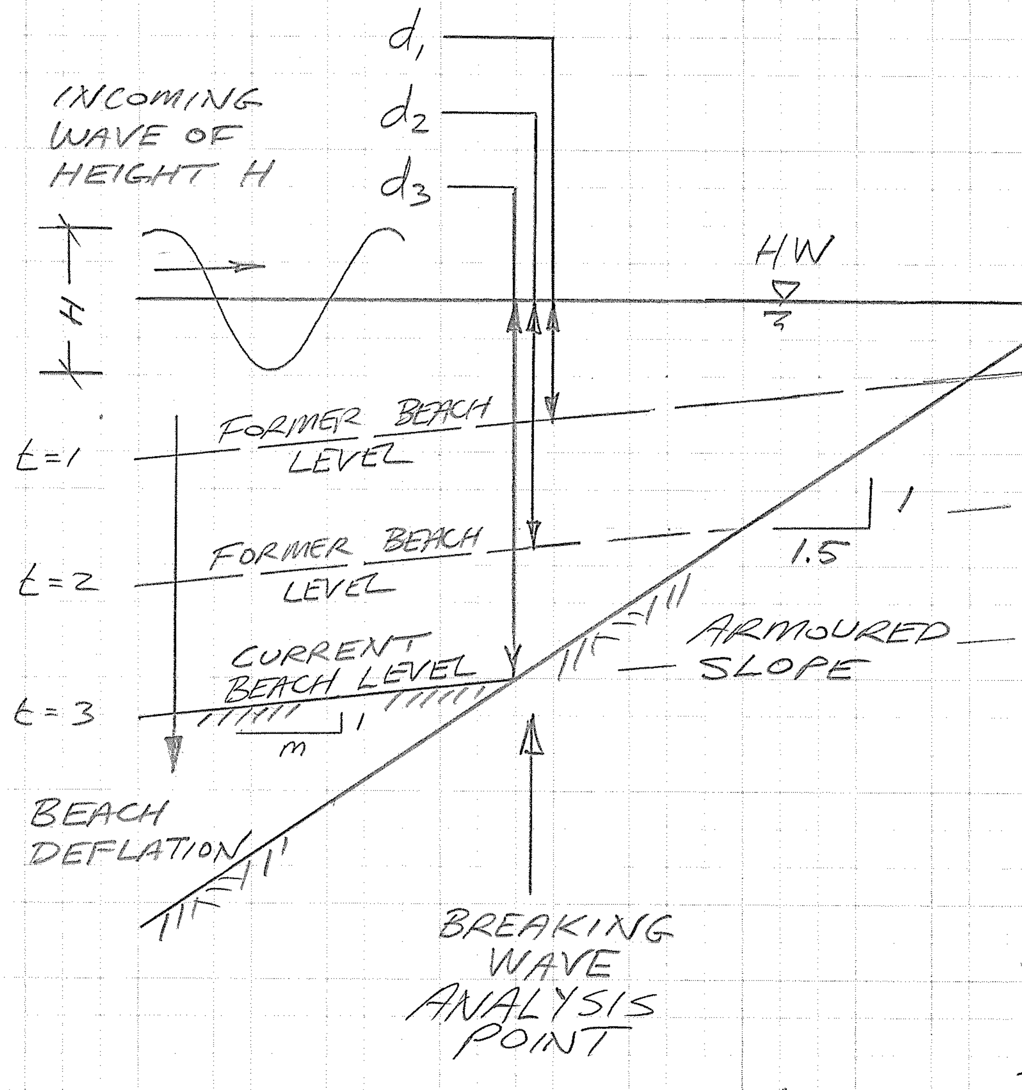
Figure 5-11. Three mechanisms for creating rip currents between groins (from Dean, 1978).

Appendix 11
Deflating Beach and Armoured Slope Geometrics

Project COLWOOD No. 661 Date 12.FEB.08
By MATTILA Checked ______ Page ___ of ___

DEFLATING BEACH AND ARMOURED SLOPE GEOMETRICS - APPENDIX 11

ISOLATED
RIP RAP PROMONTORY
WITH END RETURNS
ON A DEFLATING BEACH



ELEVATION
NTS

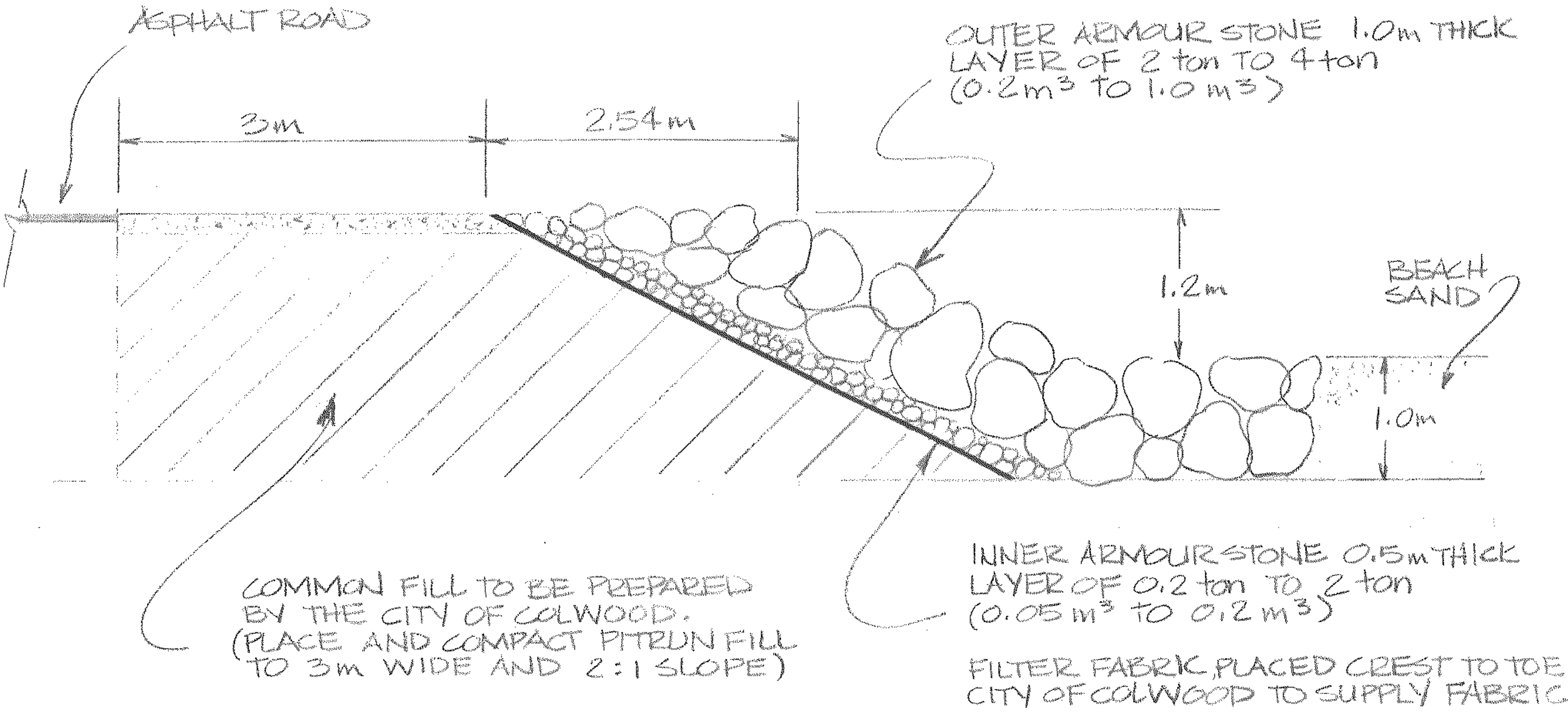
MAXIMUM BREAKING WAVE HEIGHT H_b ON THE SLOPE IS APPROXIMATELY EQUAL TO THE DEPTH AT BREAKING, d_t

EXAMPLES:

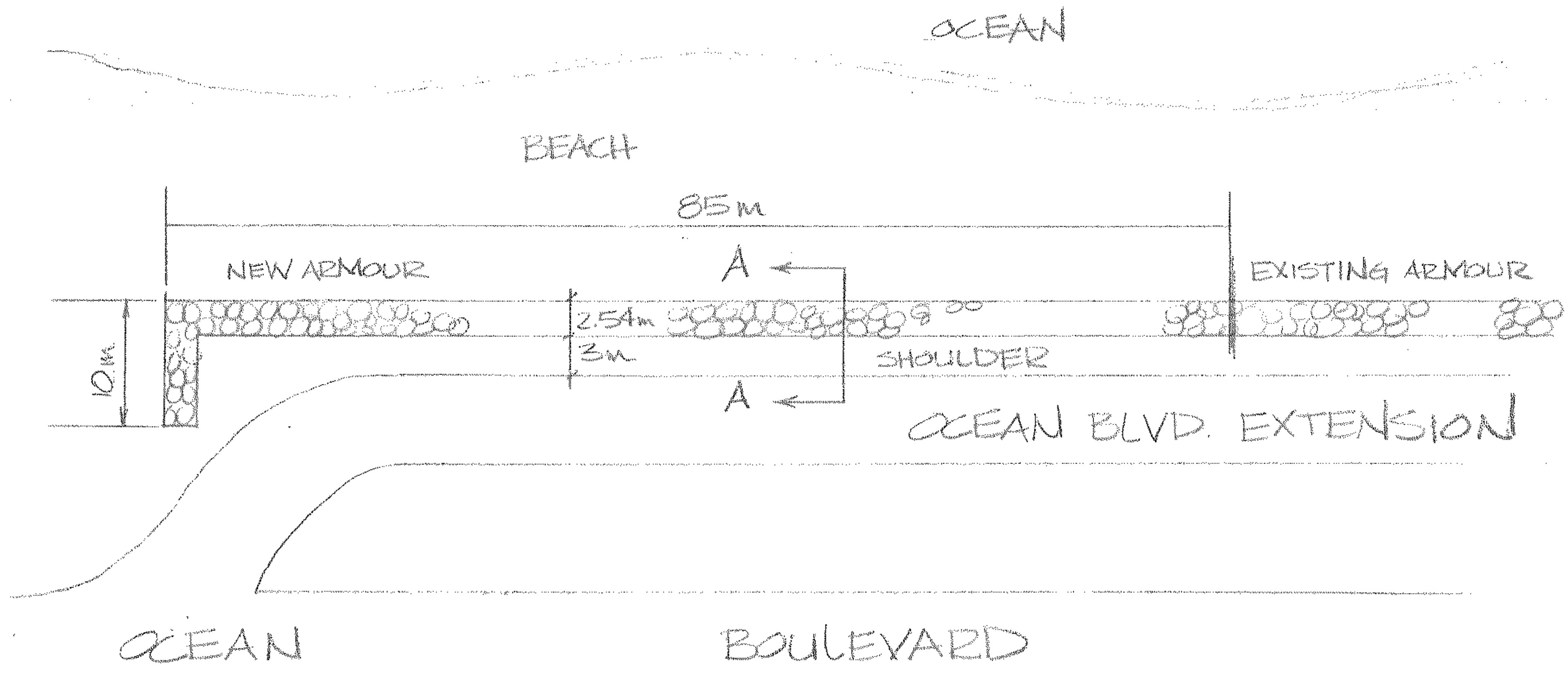
t	d_t (m)	H_b	E_b (J/m^2)	E_{ratio}
1	0.5	0.5	0.3	1.0
2	1.0	1.0	1.2	4.0
3	1.5	1.5	2.8	9.0

AS THE BEACH LEVEL DROPS THE BREAKING WAVE HEIGHT AND ENERGY ON THE SLOPE INCREASES.

Appendix 12
Armour Stone Repair Ocean Bvld. Extension
City of Colwood, February 19, 1998



CROSS SECTION A-A (TYP)
1:50



PLAN VIEW
1:500

TITLE

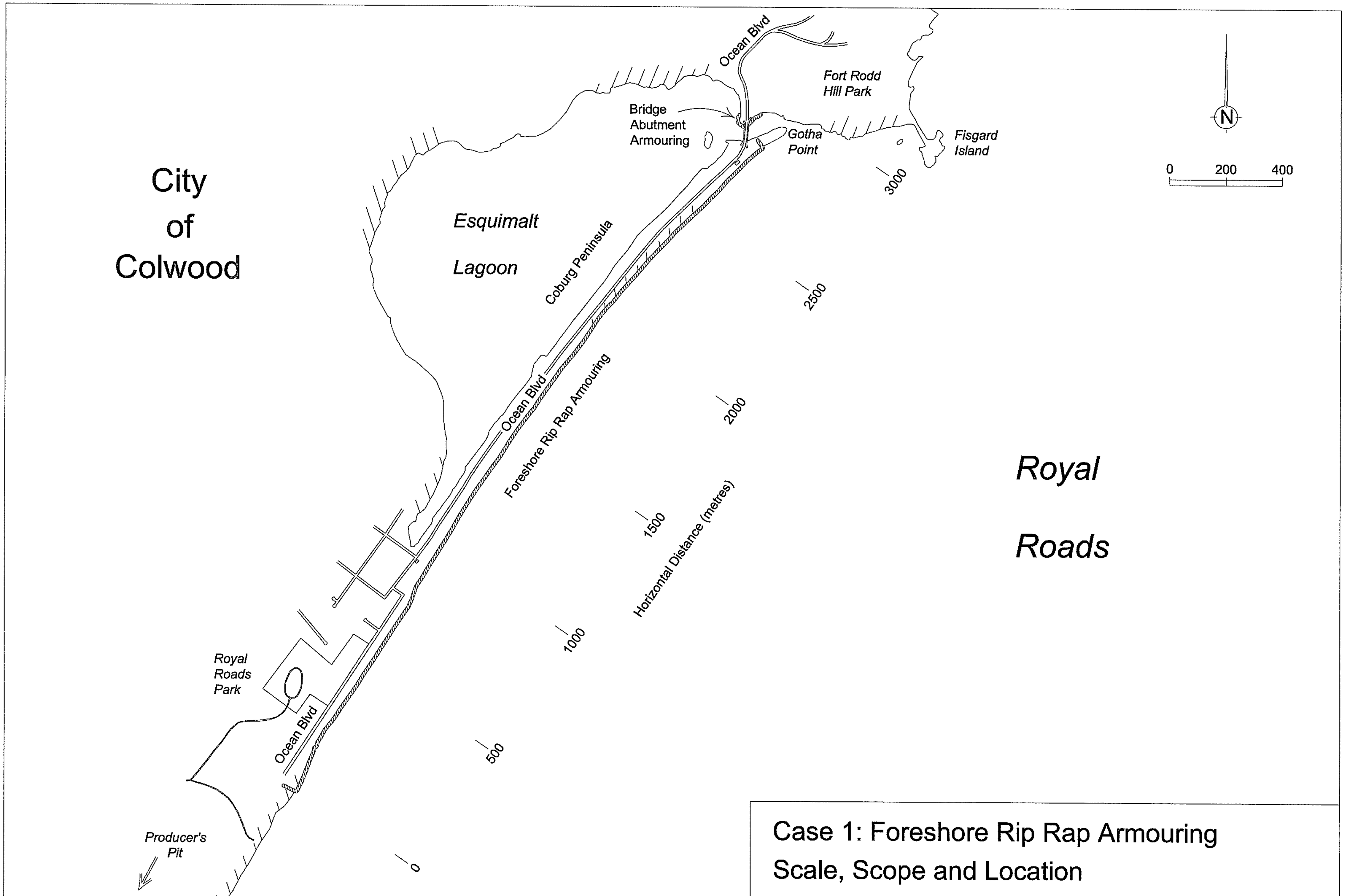
ARMOUR STONE REPAIR OCEAN BLVD. EXTENSION

CITY OF COLWOOD

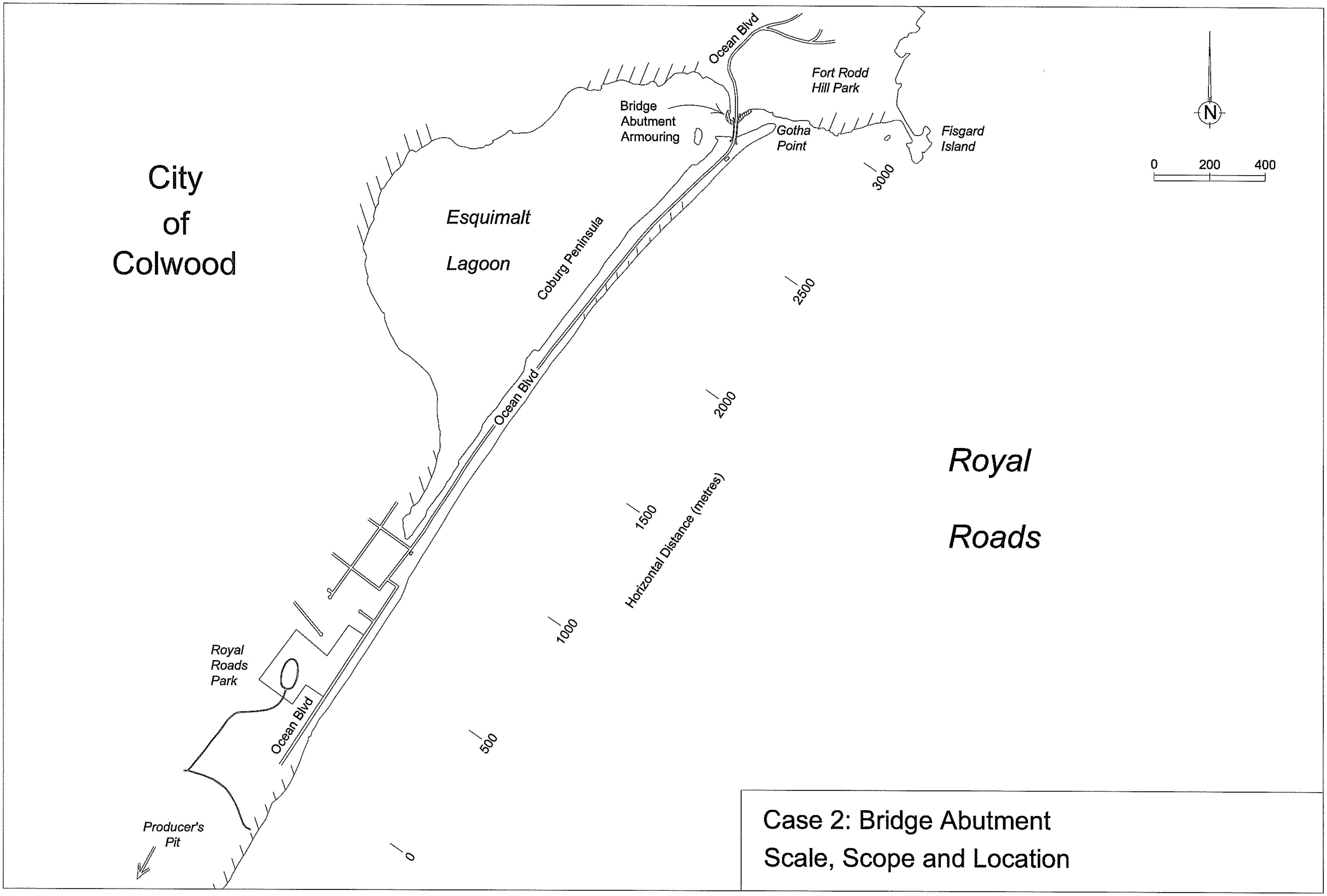
ENGINEERING DEPARTMENT

DATE: FEB 13, 1998	SCALE: AS SHOWN	DWG. NO. 1 OF 1
APPROVED BY:	FILE NO. 10.3.2.2	

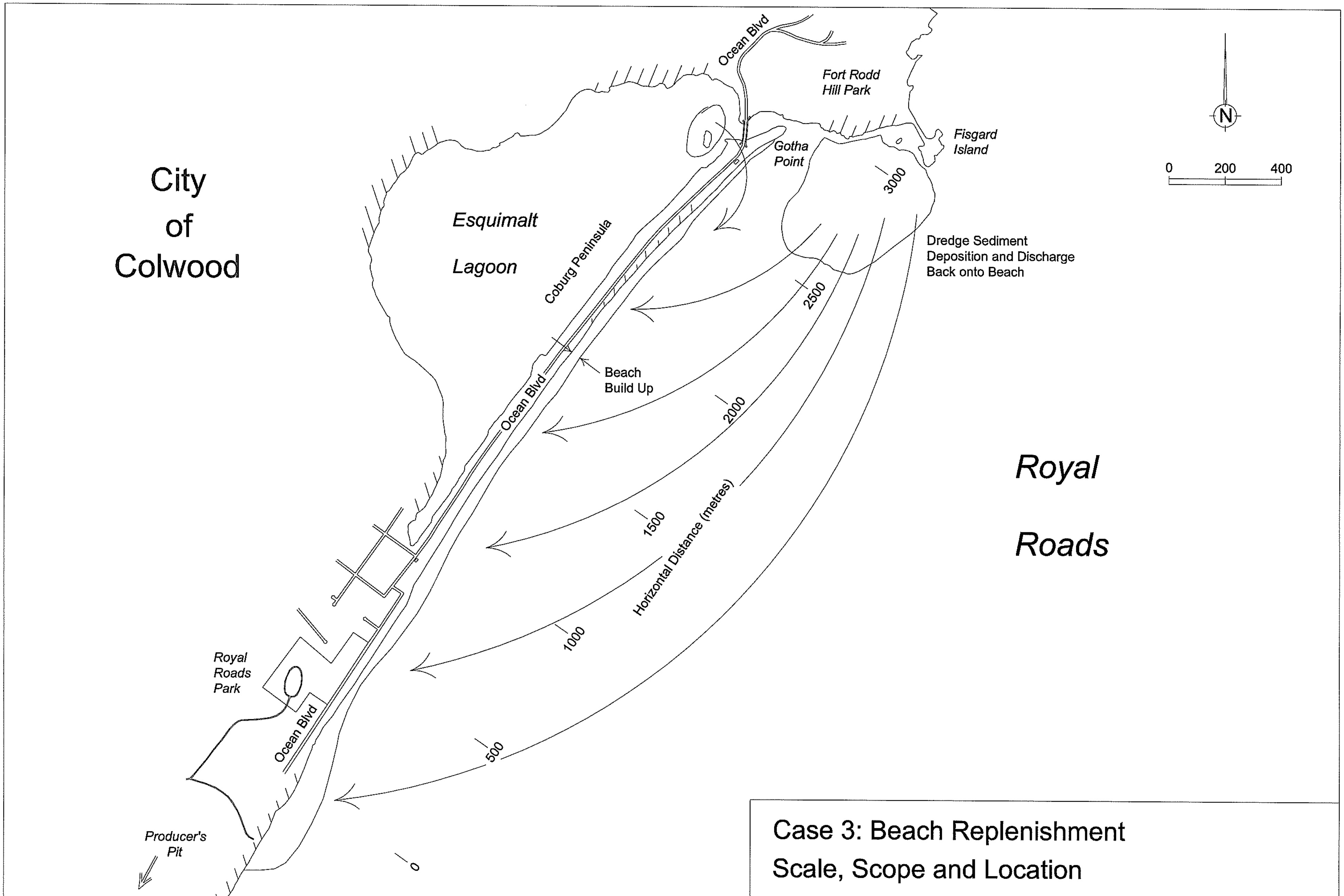
Appendix 13
Shoreline Treatment Plans
Scale, Scope and Location



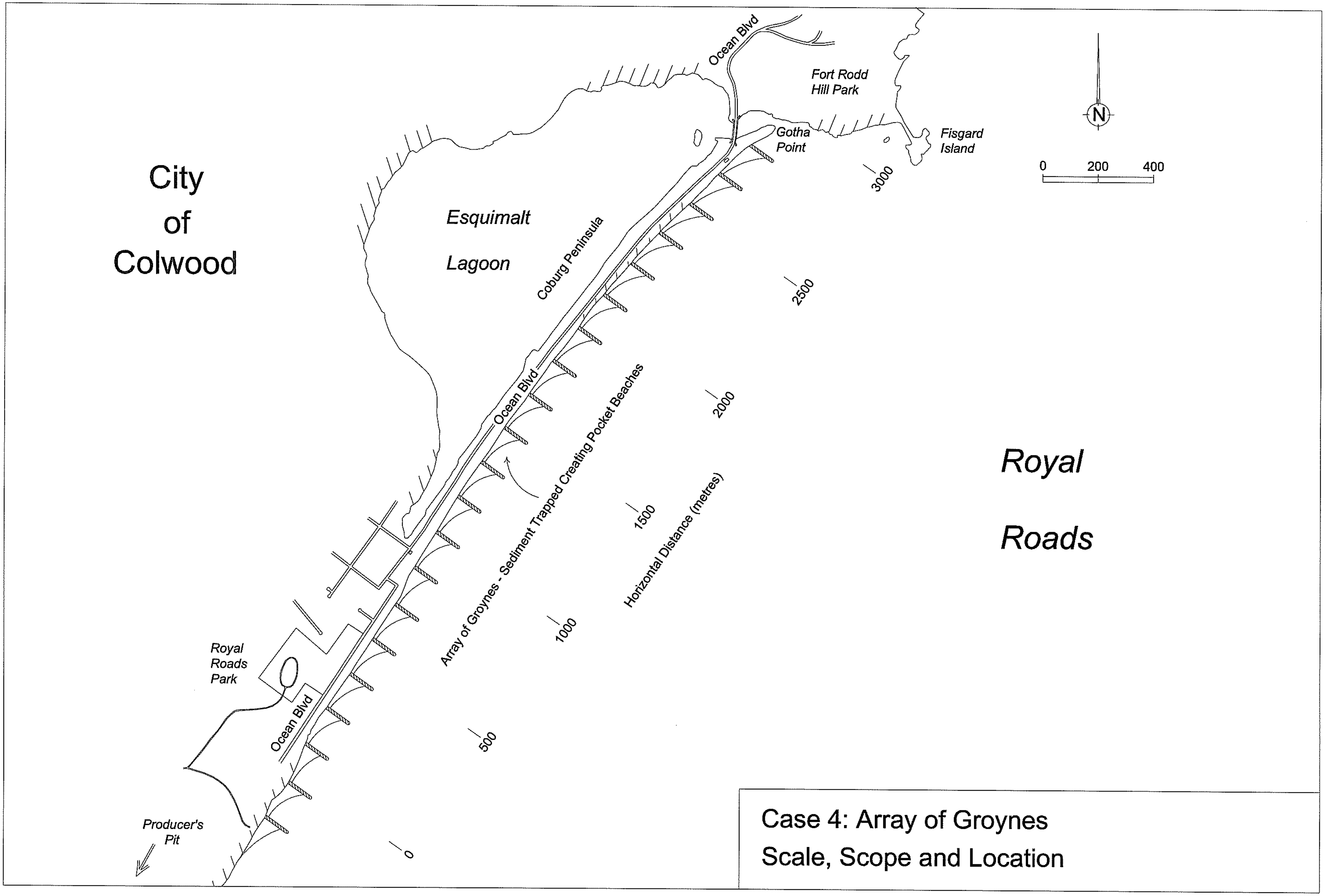
Case 1: Foreshore Rip Rap Armouring
Scale, Scope and Location



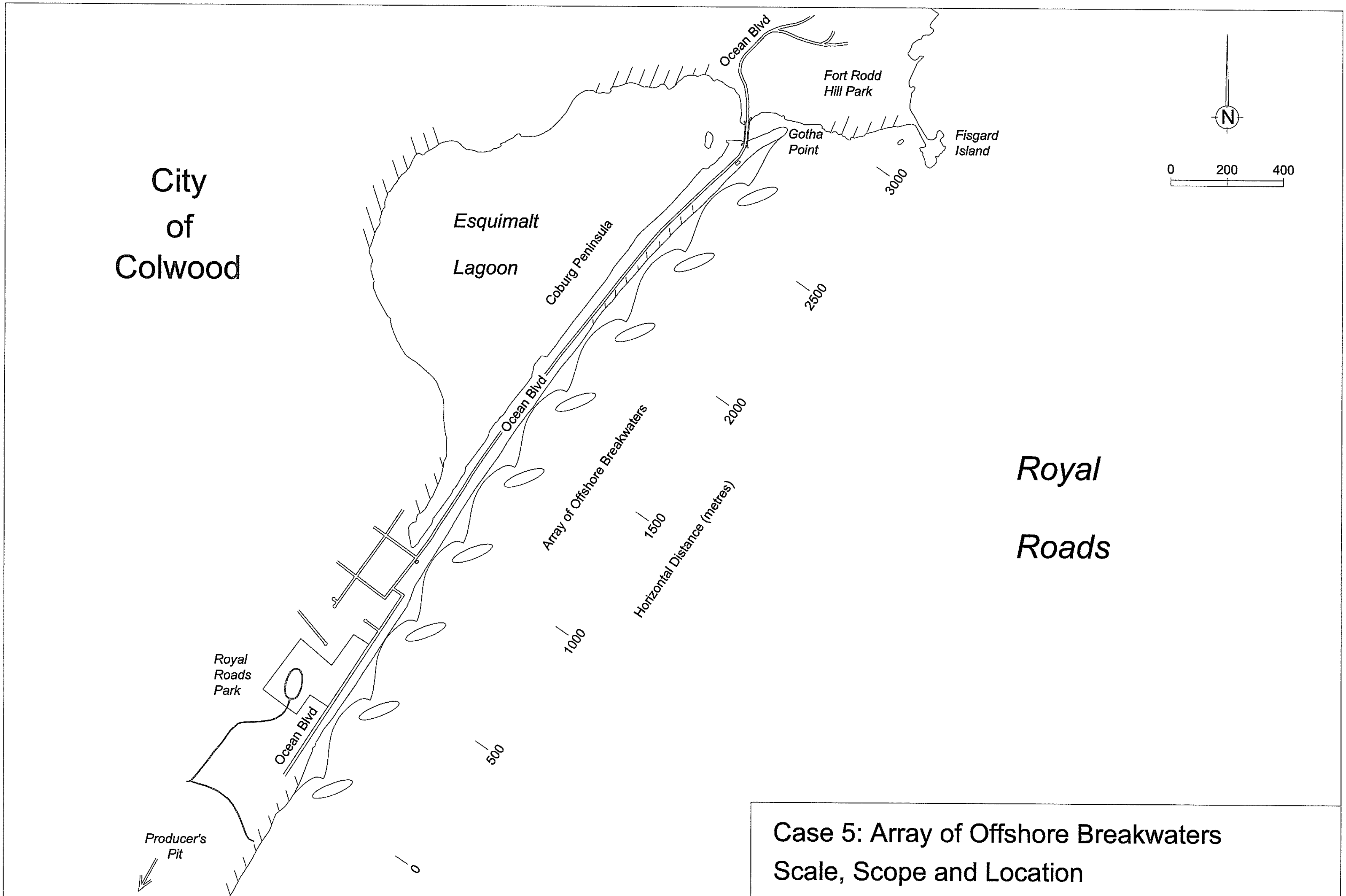
Case 2: Bridge Abutment Scale, Scope and Location



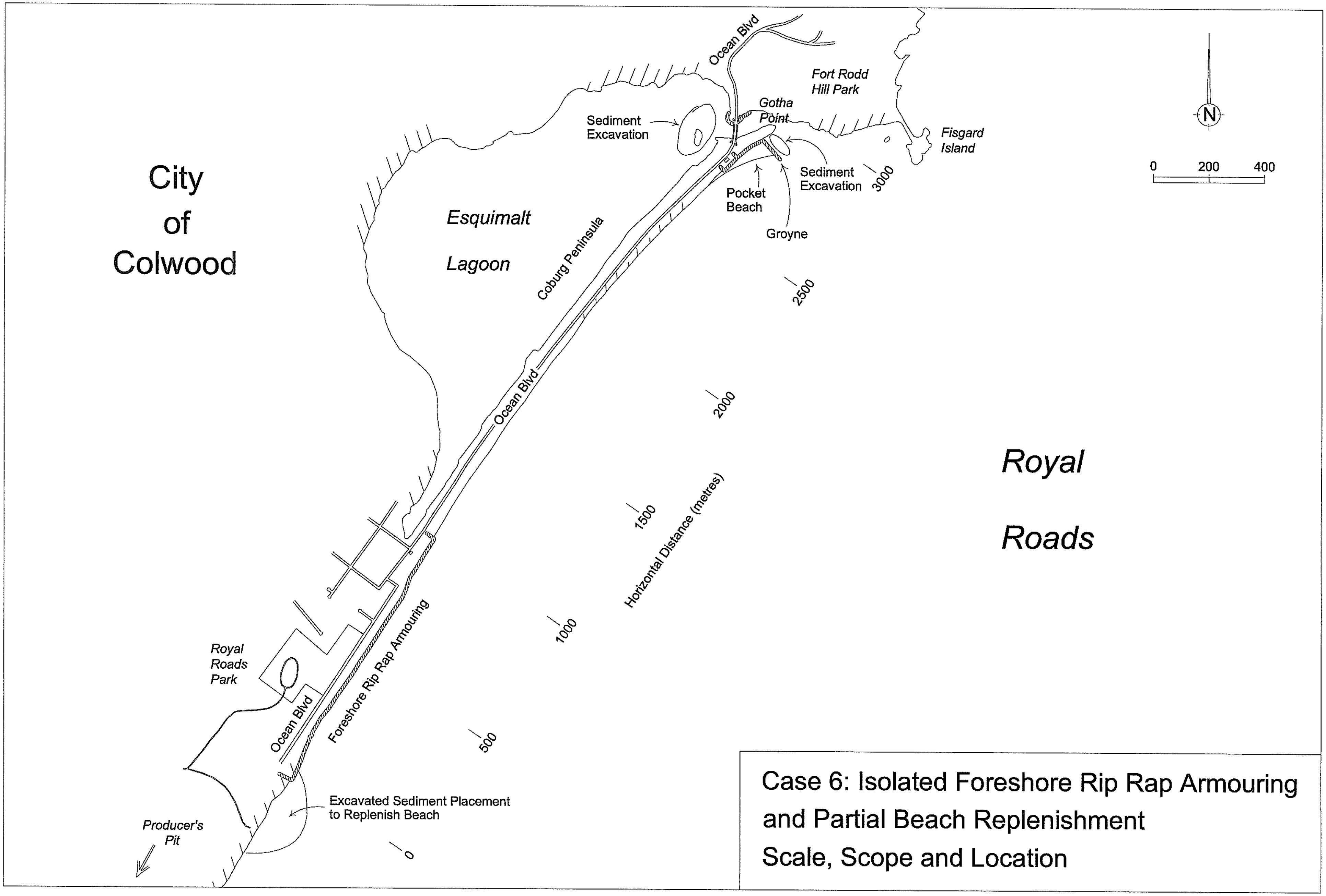
Case 3: Beach Replenishment
Scale, Scope and Location



Case 4: Array of Groynes
Scale, Scope and Location



Case 5: Array of Offshore Breakwaters
Scale, Scope and Location



Case 6: Isolated Foreshore Rip Rap Armouring and Partial Beach Replenishment Scale, Scope and Location

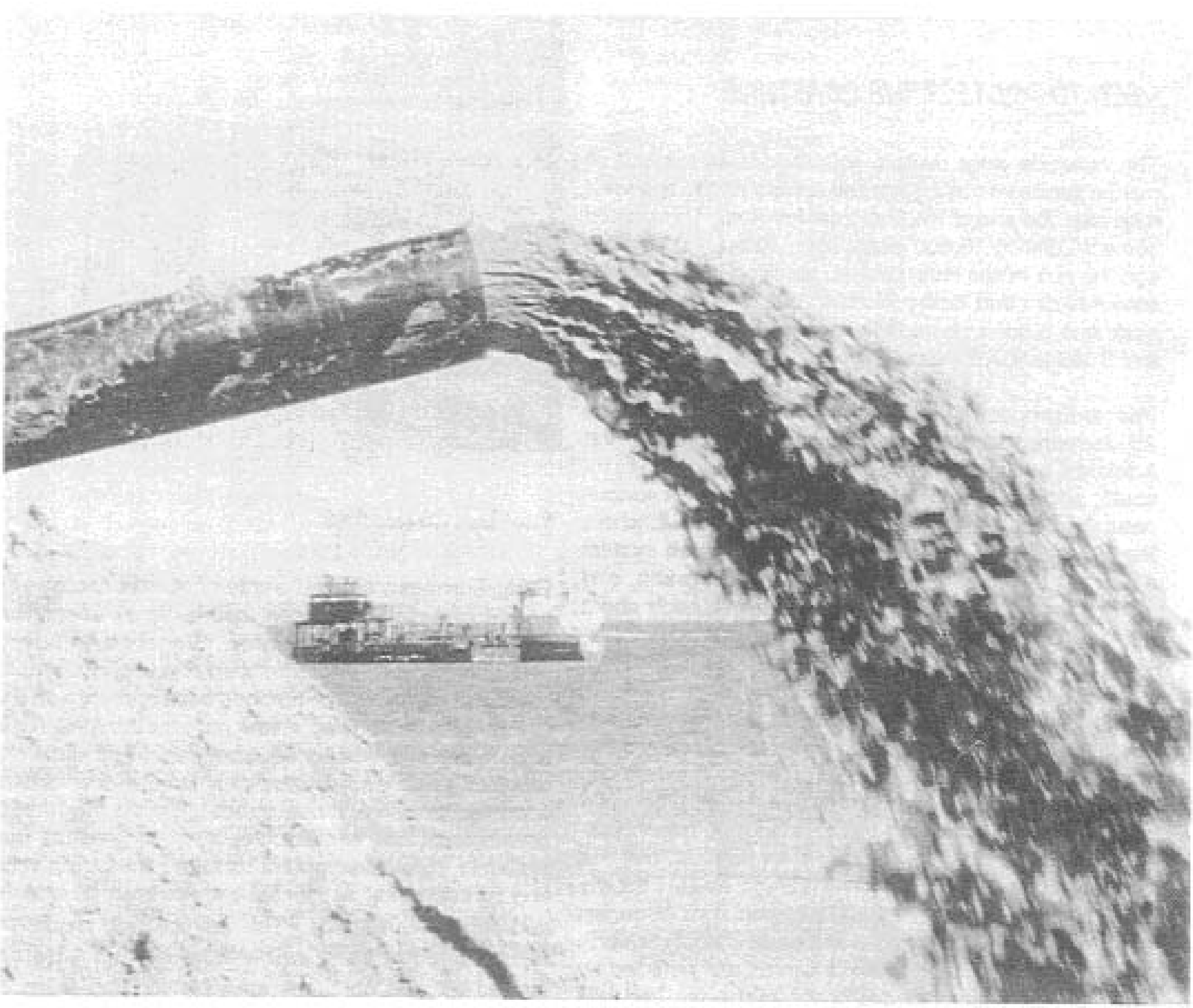
Appendix 14
Maintaining the Adelaide Coastline
South Australian Coast Protection Board

coastline

Maintaining the Adelaide Coastline

SOUTH AUSTRALIAN COAST PROTECTION BOARD

No. 28
September 1993



Dredging along the Adelaide Metropolitan Coastline

INTRODUCTION

The beaches between Kingston Park and Port Adelaide provide a natural resource which is used for recreation al purposes. They also afford protection to coastal development, particularly during storm attack, by reducing wave energies. However, the metropolitan dune system is slowly eroding due to the natural coastal processes, and it has become necessary to provide a management strategy to maintain the sandy beaches and protect the coastal development.

This "COASTLINE" provides a basic explanation of why* there is a need to maintain the coast, how the coast is monitored so that its problems can be better under stood, and what is being done to manage the situation. More detailed information can be obtained from the references listed at the end of this publication. "COAST LINE No. 27" provides a basic understanding of the geomorphological history of the Adelaide coast, the impact of European settlement on the dune system and the coastal processes at work on the coastline. "COASTLINE No. 29" provides information about the economic value of the Adelaide beaches and their significance to the Adelaide community.

NEED TO PROTECT THE COASTLINE

The Adelaide dune system was formed as a result of marine sediments being worked ashore as the sea level rose after the end of the last great Ice Age. This started some 10,000 to 15,000 years ago. About 7,000 years ago the rise in sea level slowed, resulting in diminishing amounts of sand being worked ashore into the dune system to a point where little has come ashore over the last 3,000 to 4,000 years.

Prior to European settlement of the Adelaide region, the 28 kilometre section of coast between Brighton and Port Adelaide had been formed into a continuous, north. south, silicious, Holocene sand dune system by various natural processes. It was broken only at Glenelg where the Patawalonga entered the sea. This dune system averaged between 200 and 300 metres; in width, and generally comprised 2 or 3 parallel ridges, each about 70 to 100 metres wide, separated by narrow depressions or swales.

The fact that sand is no longer being naturally added to the dune system would not be a major concern if the dune system was stable. However, the coastal processes occurring on the Adelaide coast produce a net northerly movement of sand along the beach system. The coastal processes are complex, but the biggest effect is from the predominant south westerly winds blowing across the Gulf St Vincent waters, generating waves which tend to advance in a north to north easterly direction. While these waves are distorted by various factors, such as the shape of the sea bed and **the different coastal** features, they generally strike the metropolitan coast at an oblique angle and have sufficient energy to work the sand grains along the beach in a net northerly direction. It is estimated that the northerly littoral drift is currently between 30,000 and 50,000 cubic metres per year. This leads to ongoing erosion of the dune system, particularly in the southern areas such as Brighton and North Glenelg.

With the coastal processes occurring, the sand dune system would erode in the southern areas and migrate northward. If allowed to continue, the beach system would attempt to maintain equilibrium using sand from the reserves stored in the dune system to compensate for the sand migrating northward along the beach. If the dune system provided an infinite sand supply, this natural process could continue virtually indefinitely, however, the dune system is now finite because it is not being naturally replenished. Without artificial replenishment the continuing coastal processes would erode the beaches until the sand veneer was removed to expose the underlying Hindmarsh clays and harder substrata. This natural phenomenon was not understood when European settlement occurred in the Adelaide region.

Sand Loss, Glenelg 1960

Early European coastal settlement was focussed at nodes of safe anchorage, primarily at Largs Bay, Semaphore, Grange, Henley, Glenelg and later at Brighton. These nodes tended to spread along the coast and dune system in ribbon development with links to the Adelaide square. It was not until the 1940's, particularly the post war period, when rapid infill of the metropolitan coast and development on the dune system occurred between these nodes. By the mid 1960's development had almost completely covered the dune system. This development included the public roads and infrastructure, residential and commercial property, and public open space. This unknowingly meant that the reserves of sand in the dune system were now "locked up" and no longer available to supplement the sand losses occurring due to the natural coastal processes.

Storm Damage, Brighton 1971

Development which has occurred on the dune system has required protection against storm damage. Early protective works had a short lifetime because of the limited understanding of the coastal processes at work during a storm. Expenditure on storm damage repairs and protection works has been considerable over the years. For example, 88,000 pounds (approx $14M in 1993 dollars) was expended on protective works after the 1948 storm; 230,000 pounds (approx $21M in 1993 dollars) after the 1953 storm; 88,000 pounds (approx $4M in 1993 dollars) after the 1960 storm. Sea walls now protect about 14 kilometres of the metropolitan coastline. These protection measures "locked up" the sand reserves and acted to accelerate the natural beach erosion on the metropolitan coastline.

In the 1960's the Metropolitan Seaside Councils Committee together with the State Government, commissioned the University of Adelaide to conduct a detailed study of the metropolitan coast to provide a better understanding of the coastal processes and problems of erosion of the metropolitan beaches. This detailed Erosion Report, published in 1970 and commonly called the "Culver Report" after its primary author Dr Bob Culver, concluded that the basic problem with the beach system was that there was no naturally continuing replenishment source of sand. When combined with the net northerly littoral drift, the ongoing increase in mean sea level and the development on the dune system, the long term effect is the need to artificially maintain the beaches, or eventually lose them.

The Culver Report recognised the need to act urgently to artificially maintain the metropolitan coast as well as provide adequate storm protection for properties constructed on the dune system. The Report recommended the establishment of the Coast Protection Board, which was constituted under the Coast Protection Act in 1972, to co-ordinate and facilitate these urgent activities. Since its formation, the Board has continued its role in maintaining and protecting the metropolitan coast with the technical and administrative assistance of the Coasts and Marine Section of the Environment Protection Agency of the Department for Environment, Heritage and Aboriginal Affairs.

MONITORING THE METROPOLITAN COASTLINE

Since its formation, the Coast Protection Board has placed a high priority on data collection and monitoring programs. This is primarily to enable a better under standing of the coastal problems, and provide a sound basis for making decisions about the most cost effective strategy available for resolving them. The beach profile monitoring program is an important aspect of managing the Adelaide coastline.

The profile network, which has been regularly surveyed since 1975, consists of a series of survey lines, spaced on average 500 metres apart between southern Kingston Park and the southern North Haven breakwater, and extend across the active beach zone to about 1 kilometre offshore. In 1989, modelling surveys were also undertaken utilising recent improvements in survey technology and GIS processing software. Contour and surface difference maps can be produced from the modelling surveys as well as more accurate estimates of sand volume changes.

It is possible to monitor the beach levels over time, or provide information about sand movements and rates of movements particularly after storm events and sand replenishment programs, or show areas of erosion and accretion, etc. Due to uncertainties attached to the actual data collected and the numerous variables associated with its acquisition and analysis, care must be taken when interpreting the results. Conclusions drawn from short term data can be misleading when dealing with coastal data, which is why long term data is, so valuable for decision- makers.

It is difficult to provide a summary of the results from the monitoring program because it is dependent on what information is required and what problem needs to be resolved. For example, it is possible to use the data to determine the extent of erosion or accretion at specific locations over certain periods, or, at the other extreme, to determine the impacts to the total metropolitan sys tem over a period. As an example, the 1977 and 1989 data has been used in Figures 1 and 2 to illustrate how the metropolitan coast has varied over this period. It should be noted that the data used includes the effects of the sand replenishment programs undertaken during this period.

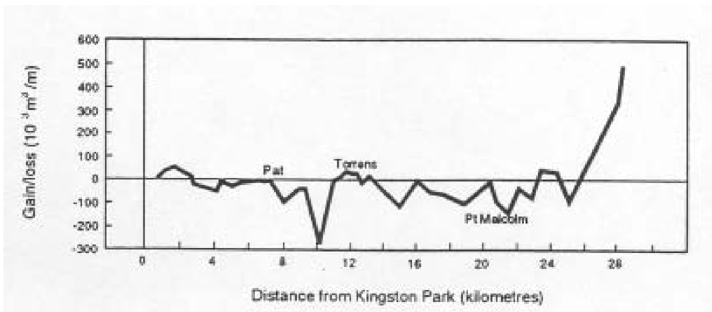
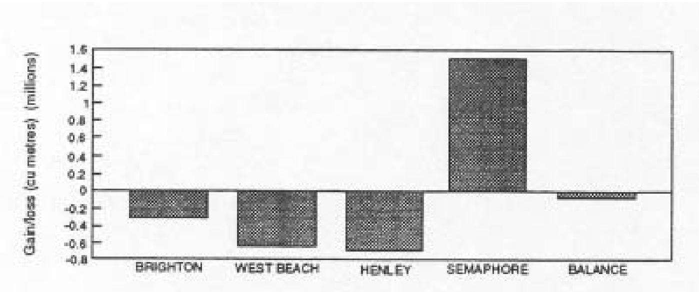


Figure 1
Sand Volume Changes 1977-1989

Figure 1 provides an estimate of the sand volume change along the metropolitan coast between 1977 and 1989. It can be seen that most of the coast has suffered a loss of sand. The exceptions being at the northern end of the system at Largs Bay to North Haven (due to the net northerly littoral drift effect), the Torrens Outlet (due to the hydraulic barrier effect of the outflows on the sand migrating northwards), and at Kingston Park (due to the beach replenishment program).



Brighton region = Kingston Park to Glenelg Breakwater
West Beach = Glenelg to Torrens Outlet
Henley = Torrens to Pt Malcolm
Semaphore = Pt Malcolm to North Haven

Figure 2
Regional Volume Loss/Gain 1977-1989

Figure 2 divides the metropolitan coast into four compartments to illustrate the regional gains and losses of sand along the metropolitan beaches between 1977 and 1989. The Brighton, West Beach and Henley regions all show a net loss of sand during this period, while the Semaphore region shows a net gain. Overall the losses appear to be in balance with the gains in the total system.

While these two examples give a brief insight into how the data can be used, of more importance is the fact that the data has been collected since 1975, and with the assistance of computer technology can be relatively easily processed to provide a good scientific basis for resolving problems.

MANAGEMENT STRATEGIES AVAILABLE FOR THE METROPOLITAN COASTLINE

The "Culver Report" in 1970 recommended that sand replenishment be undertaken as a matter of urgency, in addition to other protective works, and that other sources of sand should be investigated for future replenishment programs. In response to these recommendations, the Coast Protection Board established a sand replenishment strategy using sand collected from northern beaches and trucked to southern beaches and vulnerable foreshore sites. Beach replenishment has continued to be the Board's preferred management strategy, although since 1989 the replenishment has been by dredging sand ashore from offshore sand sources. Figure 3 shows the annual expenditure on sand replenishment for the metropolitan coast.

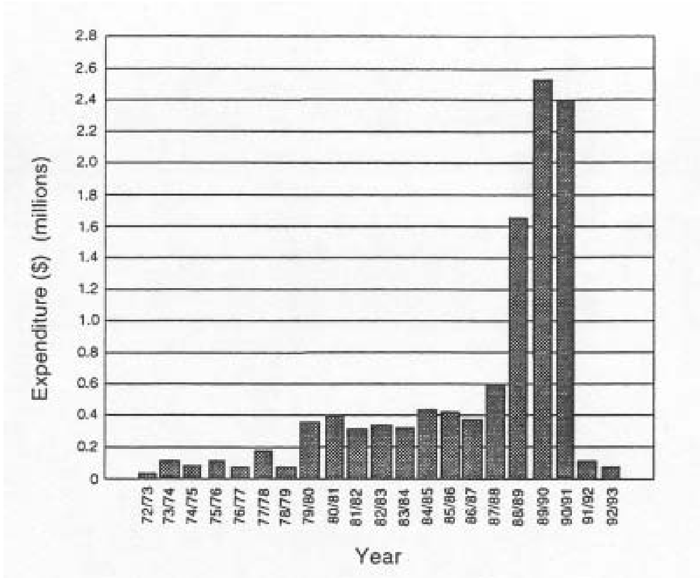


Figure 3
Metropolitan Beach Replenishment
Actual Annual Expenditure

The Board has periodically investigated alternative strategies for maintaining the metropolitan coast in an attempt to provide the most cost effective solution available. Major study reports were prepared by the Coastal Management Branch in 1984 and 1992 for the Board. The Board considers this an important task because of the changing technology and costs of the available alternatives, the ongoing research which is providing a better understanding of the coastal processes, and the need to conserve the natural coastal resource for as many future generations as possible at an affordable cost to the present community.

Coast protection strategies can be categorised into the following three fundamental philosophies.

a. Let the natural processes continue unobstructed. This involves the retreat of all coastal development to a point where the natural coastal processes can proceed uninhibited by manmade obstacles. In effect, this "unlocks" the sand reserves in the dune system, and permits natural erosion to occur while sand is continually transported in a net northerly direction.

b. Provide solutions which alter the rate of erosion of the coastline. This could be achieved by supplying erosion material through a beach replenishment program to counteract or retard the natural losses, or providing structures which dissipate the wave energy such as sea walls or breakwaters. This philosophy enables development to be retained on the dune system.

c. Provide solutions which obstruct or retard the littoral drift process. This could be achieved by constructing groynes across the active beach zone, or offshore breakwaters to alter the wave patterns, or constructing artificial headlands. These solutions enable selective accretion and erosion at predetermined locations along the coastline.

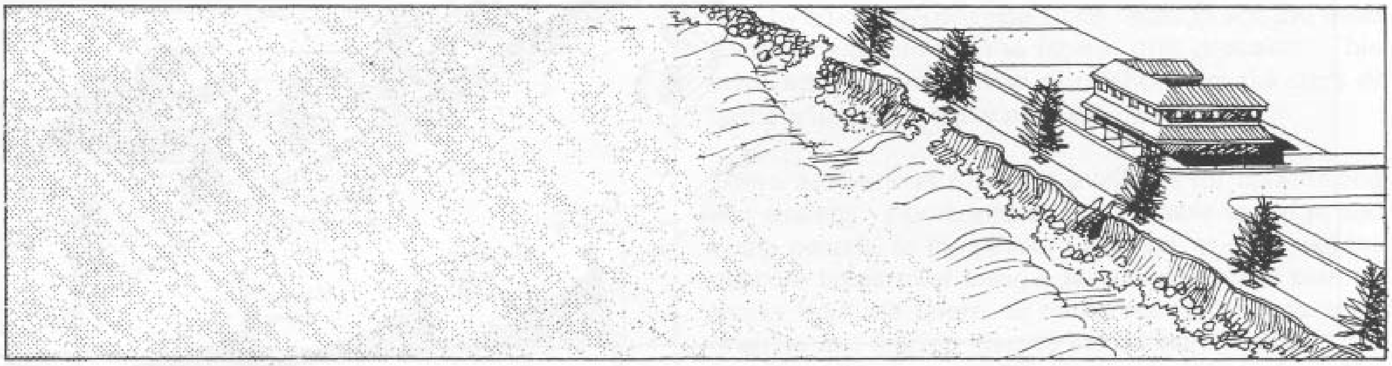


Figure 4
Natural Retreat

It should be noted that on the metropolitan coast, the last two philosophies are not entirely separable, because anything which affects the wave energy must also change the littoral drift rate which is driven by this energy.

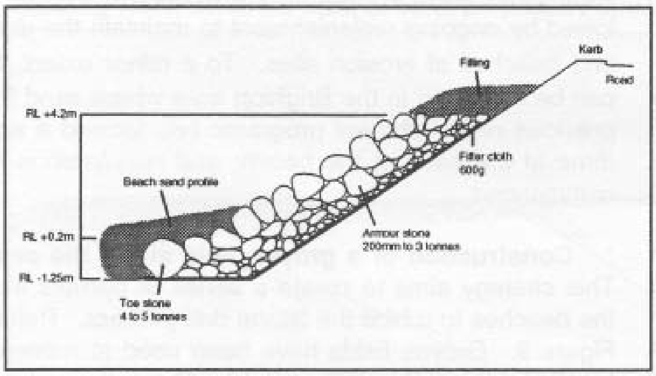


Figure 5
Seawall Defense

While it is possible to determine the economic cost of relocating the existing development back from the coast, this option has never been considered a viable option because of the social impact such a strategy would have on the community. In addition, when costed over normal planning periods such a community cost could not be justified. The cost of this option could be expected to be in the 100's of millions of dollars. However, in terms of good planning, it is important to recognise that the development fronting the coast is in a high risk area and steps should be taken through planning legislation, such as Supplementary Development. Plans (SDP's), to ensure development does not encroach further seaward.

It is, therefore, necessary to consider engineering solutions which will provide protection to existing coastal development and maintain the sandy beaches. There are a number of options available, with different meth-ods being available for each option. The following list outlines the basic options:

* **Sea wall defense:** This strategy involves constructing sea walls, such as a rip rap wall, along the coast. Refer to Figure 5.

Examples of these are numerous, such as north of the Patawalonga Outlet at North Glenelg. Sea walls are primarily employed to protect property and development. Without supplementary beach replenishment on the metropolitan coast, they will not prevent the beaches eroding because of the littoral drift problem. They should not be considered as a total solution unless the beach can be sacrificed.

There is currently about 14 kilometres of sea wall along the metropolitan coast, but it is important to note that much of this is now a "last line of defense" in the event of major storms because of the success of the beach replenishment program.

* **Ongoing beach replenishment:** This strategy involves the replacement of sand at erosion locations on the metropolitan coast to counteract the ongoing coastal processes. It aims to maintain the amenity of the beaches at, a particular level, and reduce storm

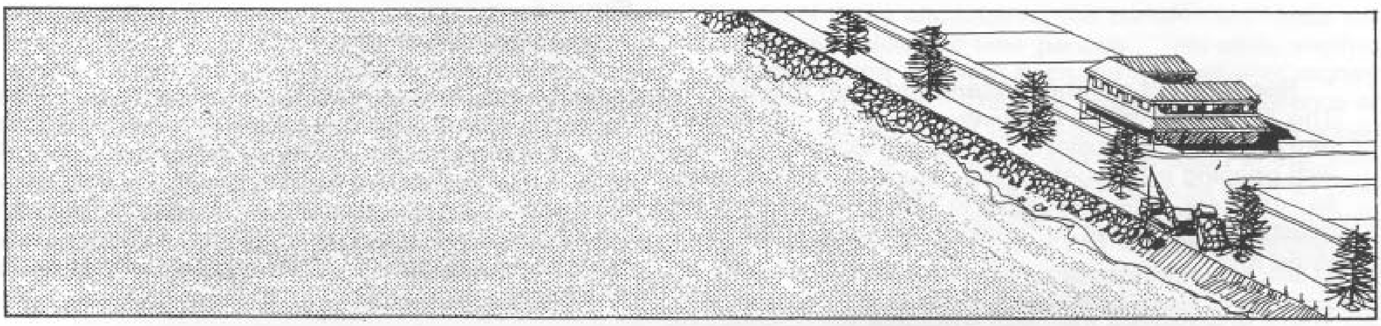


Figure 6
Rock Seawalls Only

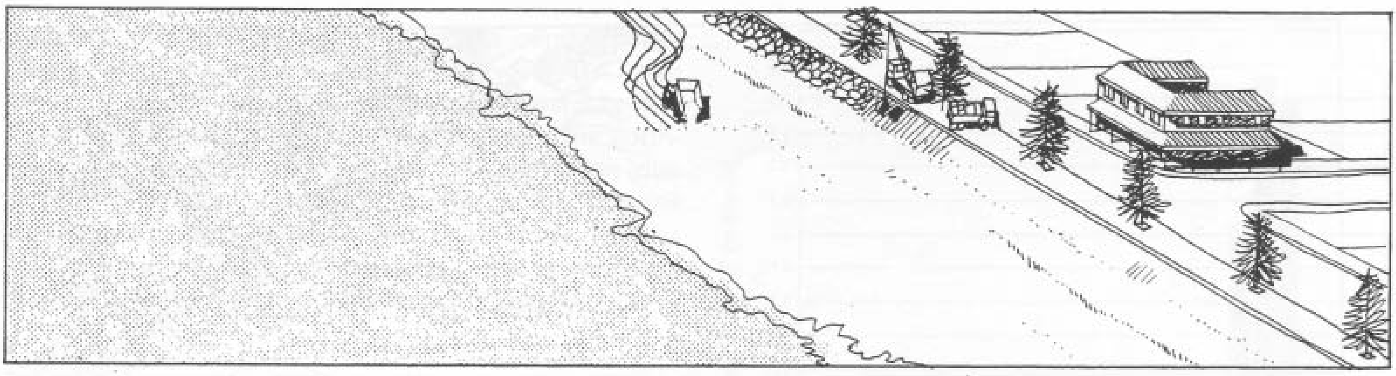


Figure 7
Trucking /dredging Sand

damage to properties and development by attenuating wave energy. However, it should be remembered that during major storms the beach replenishment strategy combines with the existing sea wall defenses to protect the vulnerable coastal properties.

Replenishment can be undertaken using sand from within the beach system or external to the beach system. The advantage of an external source is that it enables additional sand to be added to the finite supply onshore which would have benefits in the long term against beach loss due to sea level rise. The currently used offshore source also provides a coarser sand to be input into the system. This can act to retard the littoral drift process and hence over time reduce the volume of sand required for replenishment. There are various methods available for undertaking. beach replenishment. These include trucking sand from land sources and accreting beaches, dredging sand from offshore sources, and pumping sand through a pipeline from a source to the erosion sites.

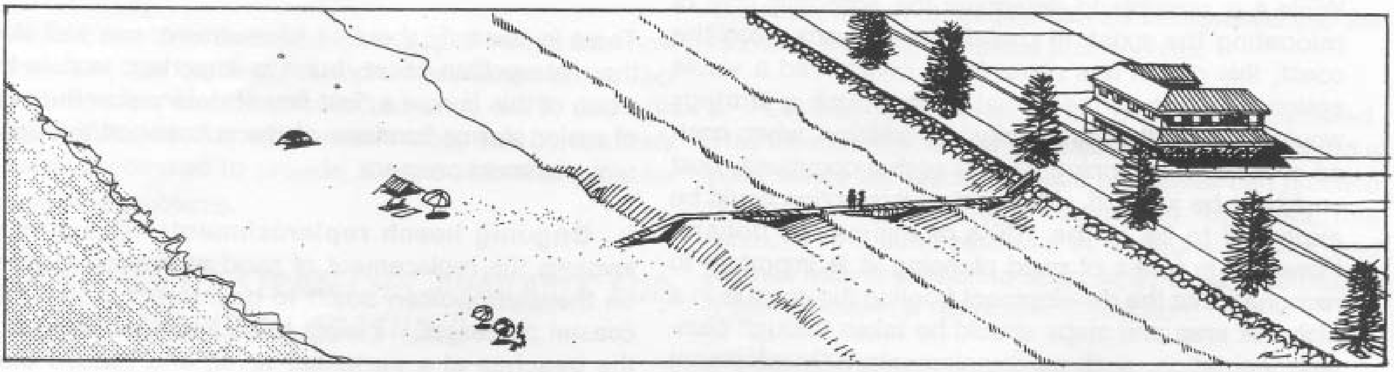


Figure 8
Major Beach Replenishment

* **Reconstruct a dune system and then maintain it:** This strategy involves artificially recreating a dune system in front of the existing coastal development so that, with ongoing maintenance, the natural coastal processes can occur. The alternative to this is moving back the coastal development to "unlock" the sand in the dune system.

There are various methods available for undertaking this strategy. These include dredging sand from off shore sources, barging sand from more distant sources, trucking sand from land sources, and pumping sand through a pipeline from a source. The reconstruction of a dune system is reliant on sufficient sand being avail able from external sources and dune stabilisation techniques, such as vegetating the dune. The strategy would involve a major replenishment program initially to establish a dune system on the existing beaches, followed by ongoing replenishment to maintain the dunes and beaches at erosion sites. To a minor extent, this can be observed in the Brighton area where sand from previous replenishment programs has formed a small dune at the back of the beach, and revegetation has commenced.

* **Construction of a groyne field along the coast:** This strategy aims to create a series of barriers along the beaches to inhibit the littoral drift process. Refer to Figure 9. Groyne fields have been used at numerous locations throughout the world. The influence of a groyne on the metropolitan coast can be observed at the Patawalonga outlet. A groyne or barrier placed across a beach system will cause accretion to the coast on the upstream side and erosion on the downstream side. It is therefore necessary to determine the spacing of these barriers so that the changes to the coast do not adversely affect the coastal properties. Groyne fields will alter the appearance of the coast, and the aesthetic value of the coastline must be considered prior to constructing a groyne field.

There are various methods available for undertaking this strategy. It is possible to use different materials to

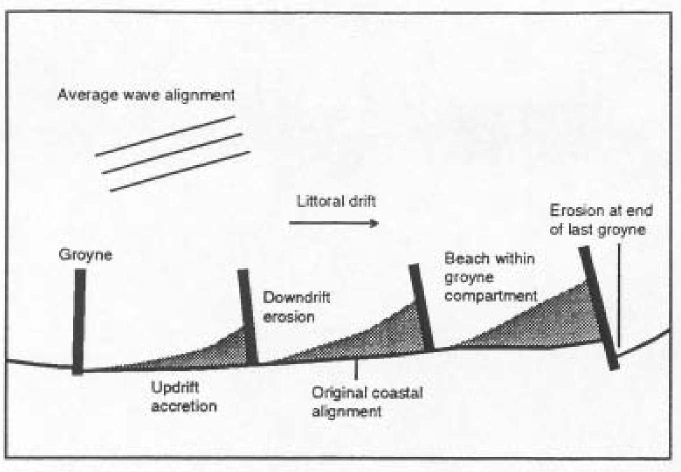


Figure 9
Conventional Groyne Field

construct the barriers in a groyne field. For example, they could be constructed as rock groynes, timber retaining walls, concrete walls or other proprietary structures; such as sand filled geotextile bags, or rock filled gabions. On the Adelaide coast suitable rock is readily obtainable close to the coast, and the cost of constructing rock groynes is estimated to be the cheapest method currently available. It should also be remembered that groyne fields alter the shape of the coastline, and as part of the construction process in establishing a groyne field on the metropolitan coast it would be necessary to supplement the existing beach with a replenishment program to prevent loss of coastal property. Once established there would also be a need to continue a sand replenishment program, because sand will continue to migrate in a net northerly direction, albeit at a slower rate to that presently observed, due to the coastal processes. This ongoing replenishment process would supplement the leakages of sand from one groyne to the next.

* **Offshore breakwaters:** This strategy aims to attenuate or reduce the wave energy reaching the beaches and, by so doing, minimise storm damage and the wave energy available for the littoral drift process. This involves the construction of offshore breakwaters or barriers running roughly parallel to the coast.

There are various methods available for undertaking this strategy. For example, it is possible to barge and dump material to the offshore location, or construct the offshore breakwater using a temporary access path for trucks from the shore, or constructing caissons units onshore and floating them to the offshore location. It is also possible to use different materials to form the breakwaters. For example, quarried rock, or manufactured concrete armour units, or concrete or steel caisson units, or proprietary structures such as sand filled geotextile fabric bags or rock filled gabions. Floating breakwaters have been suggested from time to time, but experience elsewhere in the world indicates that they would not be suitable for the metropolitan coast because of the large period swell component of the local waves. Various configurations of offshore breakwaters can be designed to impact differently on the metropolitan coast. This would be a very expensive strategy when compared to the other alternatives, primarily because of the quantity of material involved and the high construction costs.

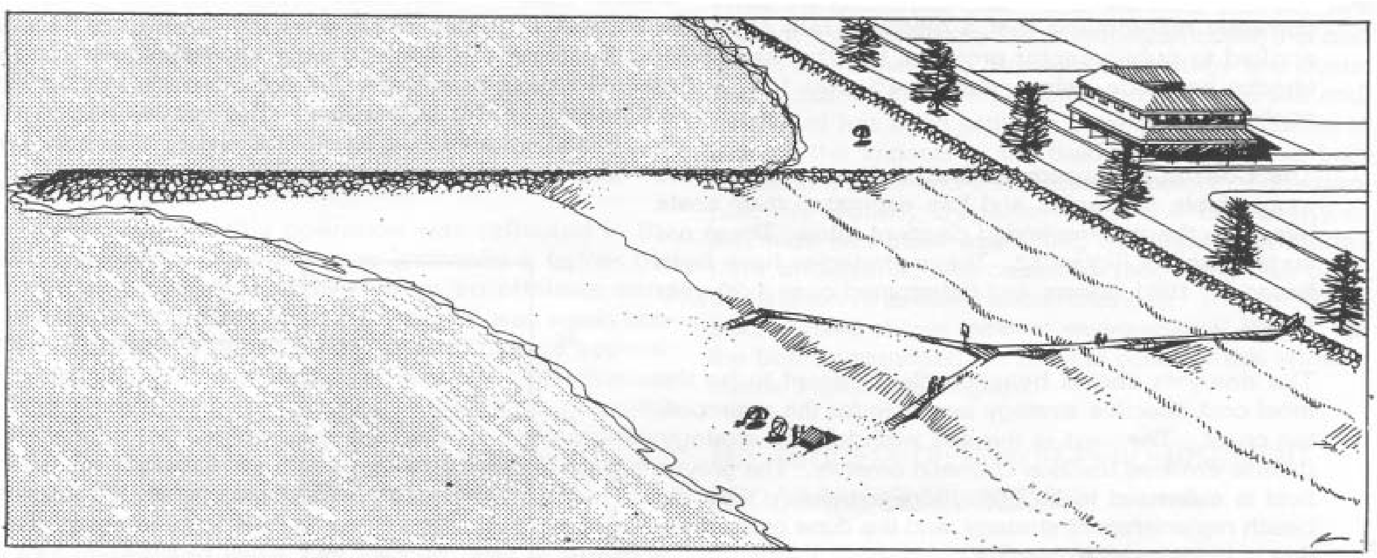


Figure 10
Groynes

For all of these alternatives, the benefits and costs will accrue over different time periods. This adds another variable to the problem because the value of money changes over time. This is a result of the existence of real interest rates, that is, the difference between actual interest rates and inflation, and is reflected in the community's preference to receive benefits as soon as possible, and pay costs as late as possible. A commonly used method for eliminating this variable is to convert all the costs and benefits to an equivalent dollar value at a particular point in time. It is usual to convert the costs to todays dollars and call the result "the present value". To achieve this, a "discount rate" is applied to future benefits and costs of projects. State Treasury

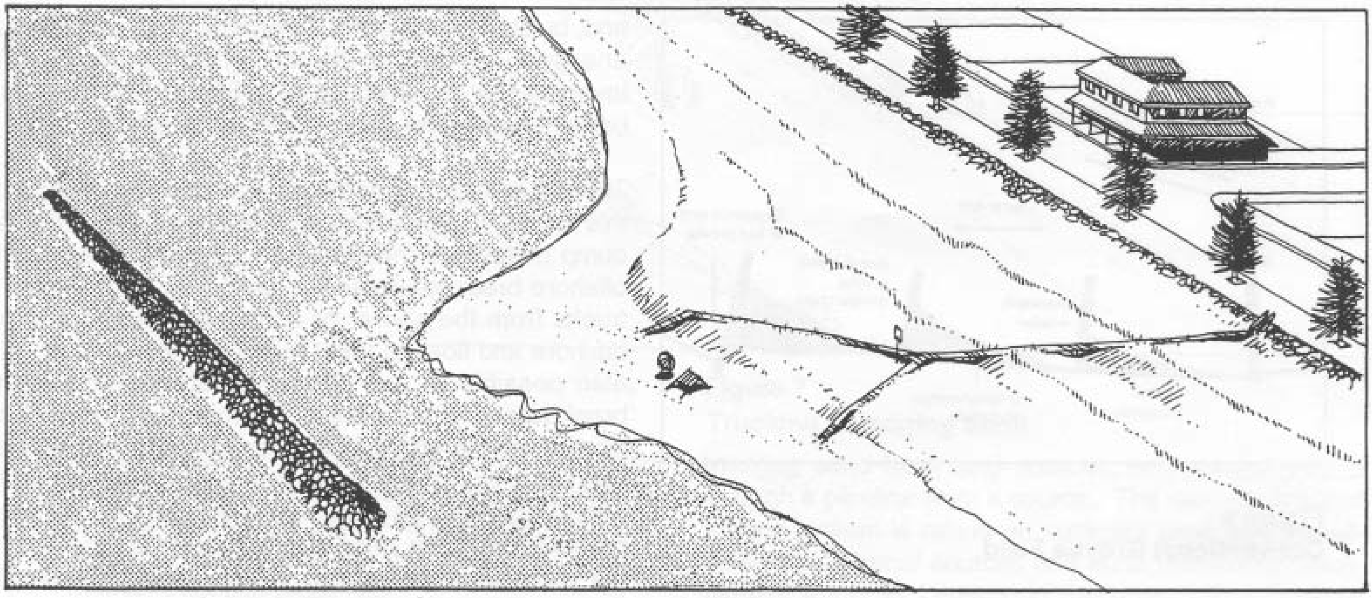


Figure 11
Break Waters

currently recommend that a discount rate of 7% be applied to public sector projects, but that sensitivity checks be made using rates of 4% and 10% in the analysis.

The Coasts and Marine Section, Environment Protection Agency has assessed the more viable strategies and has estimated their costs based on the recommended discount rates. These are summarised in Figure 12. These strategies have been based on 1991 dollars and determined over a 20 year period.

The analysis shows beach replenishment to be the most cost effective strategy available for the metropolitan coast. The next is the sea wall defense strategy, but this involves the loss of beach amenity. The groyne field is estimated to be 60% more expensive than the beach replenishment strategy, and the dune reconstruction is 112% more expensive.

BEACH REPLENISHMENT - THE MOST COST EFFECTIVE OPTION CURRENTLY AVAILABLE

Since its formation, the Coast Protection Board has maintained the beach replenishment strategy as the primary metropolitan coast protection strategy. Between 1972 and 1988 the Board maintained a replenishment program which averaged about 100,000 cubic metres of sand per year. During this period the method of replenishment was by trucking sand from northern beaches to the vulnerable southern locations. The cost of this method is dependent on the haul distance, but ranges from $2 to $5 per cubic metre of sand trucked.

In 1988, the Board obtained approval from State Cabinet and the South Australian Planning Commission to undertake an increased 3 year replenishment pro gram using a sand source on Torrens Island and an off shore source at North Haven instead of taking sand off the northern beaches. The purpose was to supplement vulnerable locations deemed to be at high risk in the event of major storm attack. The beach levels at Somerton and North Glenelg were extremely low and if left without remedial action could have led to the under mining of the sea walls. The sand dunes at West Beach were eroding at an unacceptable rate and were also in need of replenishment.

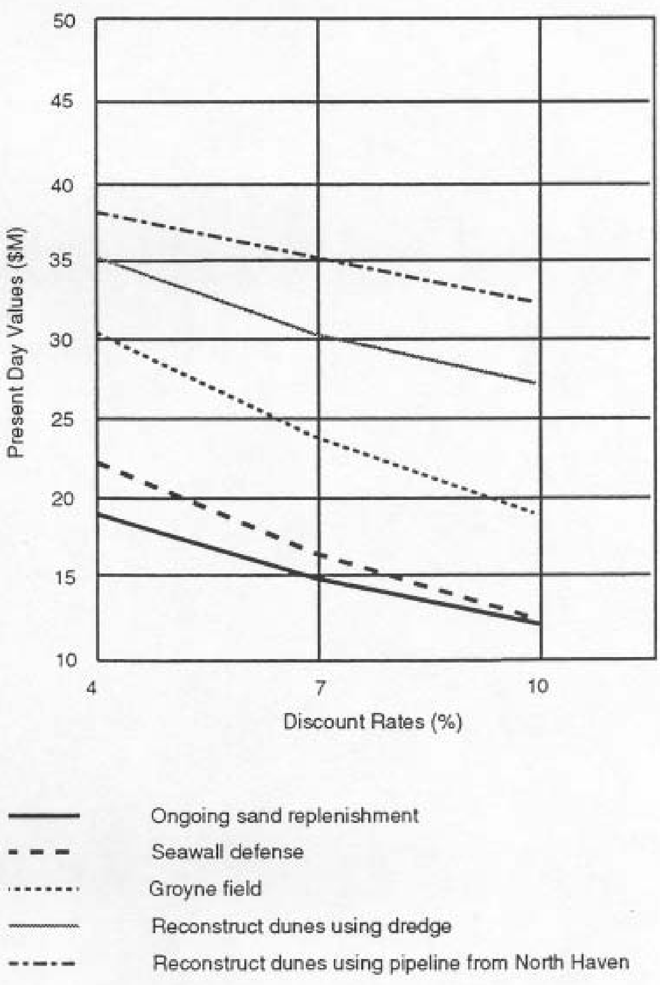


Figure 12
Summary of Alternative Strategies

From 1988 to 1990, approximately 190,000 cubic metres of sand was excavated and trucked from Torrens Island to North Gleneig at a cost of about $7 per cubic metre, and approximately 100,000 cubic metres of sand was pumped ashore at North Haven by a small cutter suction dredge and then trucked to Somerton at a cost of about $8 per cubic metre.

In 1990, State Cabinet approved a further Board recommendation that a trial dredging operation be undertaken in lieu of the previously used trucking operation. This had the advantage of being able to input coarser sand into the beach system from offshore sand sources, and minimise the trucking hazard from the beaches. Approximately 100,000 cubic metres of sand was dredged by Australian Dredging and General Works Pty Ltd, from the offshore sand source at North Haven using a split hopper dredge called "the Pelican" and pumped ashore at North GleneIg. From the tenders received for this work, this small dredge with a hopper capacity of almost 1,000 cubic metres, was the most economic dredge for the volume of sand to be moved and the conditions prevailing on the metropolitan coast. The cost was about $12 per cubic metre (including mobilisation costs for the dredge, that is getting the dredge to the site) or about $9 per cubic metre if mobilisation costs are excluded.

The success of this operation was reflected in the Government's endorsement to undertake a further trial dredging operation in 1991 from an offshore sand source at Port Stanvac. "The Pelican" was again contracted, after a public tender call, to dredge approximately 100,000 cubic metres of sand from Port Stanvac and discharge it onto the beach at Brighton. Towards the end of the contract, the dredging company indicated that the Government could make a potential saving Of about $0.5M on mobilisation costs if the programmed 1991/92 metropolitan beach replenishment program was undertaken while "the Pelican" was in Adelaide. After an assessment was made of the dredging opera tion and costs, the Minister for Environment and Planning agreed to an extension to the contract based on the contractor's offer. A further 100,000 cubic metres was dredged from the Port Stanvac site. The cost of this 200,000 cubic metre dredging program was about $11 per cubic metre (including mobilisation costs) or $8 per cubic metre if mobilisation costs are excluded. The beach replenishment program averaged about 200,000 cubic metres per year in the three year period from 1988.

The Board has assessed the beach replenishment program since this period, and has now determined that to maintain the beach amenity at its current level, and provide adequate protection to the coastal property, it is necessary to provide an annual replenishment program of about 160,000 cubic metres. To achieve this, it is necessary to undertake a biennial dredging program and a supplementary trucking program. This is estimated to cost about $2.5M biennially, with the dredging contract being about $2.1 M. The next scheduled dredging replenishment contract is expected to be

The Pelican Dredge used on the Adelaide Coastline

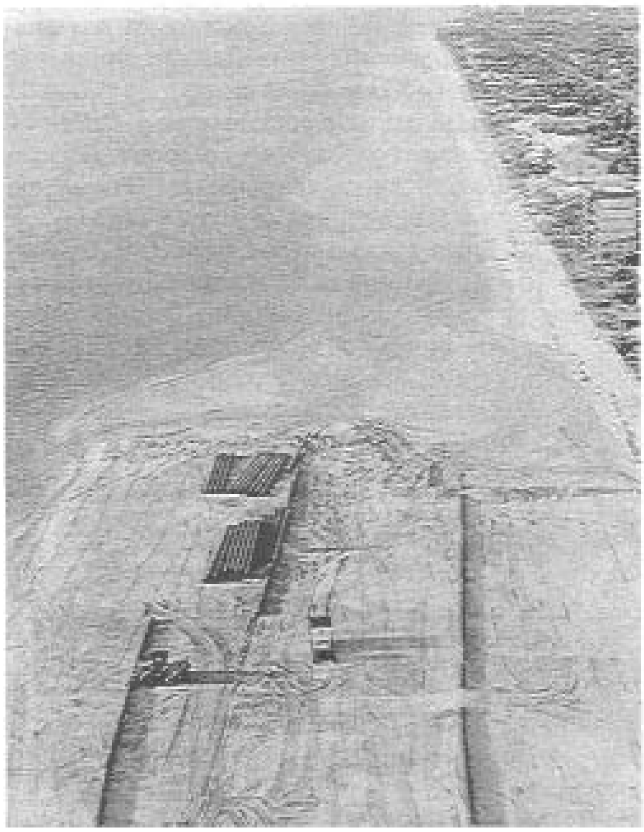
undertaken early in 1994.

While the Board has determined the most cost effective strategy for maintaining the metropolitan coast, it is also aware of the need to monitor the strategy and costs, and to assess the environmental impacts. To this end, the Board has been active in commissioning studies to monitor the impacts of the dredging program, at both the sand source and the discharge points. For example, the Botany Department of the University of Adelaide has been examining the impact on marine flora and fauna, and coastline modelling has been undertaken to assess coastal changes. To date, these studies have shown minimal environmental impact, but the Board recognises the need to continue this environmental monitoring program.

THE SUCCESS OF BEACH REPLENISHMENT PROGRAMS ELSEWHERE

It is important to note that the Board's beach replenish ment strategy is not unique. In fact, it is estimated that over 70% of the world's sandy coastlines are eroding, and the soft engineering option of beach replenishment is used throughout the world as a solution to this problem. This solution has gained increasing acceptance over the last 30 years. The following examples have been chosen to indicate the extent of use of the beach replenishment method, but it should be noted that numerous other examples exist and could be cited.

The most active nations have been the Netherlands, Germany, Great Britain, Denmark, United States and Australia. Arguably, the Dutch have been the leaders in the use of beach replenishment and in scientific advances that have led to cost reductions. The Dutch rely on natural and artificially reinforced sand dunes, combined with nourishment of berms and levees, to provide their major coastal defenses. Between 1952 and 1989, about 60M cubic metres of material has been used for Dutch replenishment programs. For example, In the United States, over 600km (450km on the Atlantic seaboard and over 150km on the Gulf and Pacific seaboard) of the coastline have been replenished at a cost in excess of $US8 billion. The majority of this work has been undertaken since 1970, during which time significant advances have been made in planning, monitor ing and maintenance of the programs. The beach replenishment programs commenced primarily as a result of the severe damage and erosion along the US East Coast caused by major hurricanes in the 1950's. By far the largest and most successful beach nourishment undertaken was the Miami Beach project completed in 1980. Over 1OM cubic metres of sand was placed along 17km of coast at a cost of approx $US64M. More recently, the Hollywood and Hallandale beach replenishment project in Florida was completed in 1991. This project involved placing approximately 1 M cubic metres of dredged sand on the beaches at a cost of about$US9.5M.



Sand Key, Florida Replenishment Project

In Great Britain, the widespread natural occurrence of gravel beaches has led to increasing and successful use of replenishment programs, especially the south eastern coastline such as Hampshire and Sussex. The scale of projects is tending to increase, for example, at Seaford 1.5M cubic metres of sea dredged gravel was placed in the late 1980's at a cost of 12M pounds. Sand replenishment has also been successfully prac ticed at other locations, particularly at Bournemouth. The use of gravel replenishment has also been used in Vancouver, Canada to abate erosion of unconsolidated Cliffs.

Sand replenishment has been satisfactorily used in France at Moulin Blanc, Cannes, Monaco and Marseille, and in Portugal at Praia da Rocha along the Mediterranean Coast. In Belgium, at Zeebrugge, about 8.5M cubic metres of sand was dredged offshore and placed along an 8km section of beach in the 1980's. In New Zealand sand replenishment has been used in the Wellington Harbour, Tauranga Harbour, Pohara Beach and Washdyke Lagoon. A beach replenishment program has proved to be very successful in Durban, South Africa after over 30 years of implementation, and in Varadero, Cuba for over two decades to maintain prime tourist infrastructure. Other examples exist at Copacabana Beach in Brazil, Singapore, Bora Bora, and Bar Beach-in Nigeria.

Since the early 1980's other nations have endorsed the use of beach replenishment. Most notably, the Soviet Union which moved away from hard engineering structures in 1981 and undertook 6 beach replenishment programs along the Black Sea Coast accounting for 70ha of additional beach along 48km of coast.

The Japanese Government has joined the growing trend to create and replenish beaches, primarily due to increased desires by the Japanese community for recreational amenities and beachfront access. Since the early 1970's nine beach replenishment projects supporting seaside parks have been constructed in Tokyo Bay, and by 1990 twenty one beaches had been replenished throughout Japan, with a further sixty six planned projects awaiting commencement or underway.

In Australia, between 1975 and 1987, approximately 20km along the shore of Port Phillip Bay in Victoria were successfully replenished. Probably the best known beach replenishment program in Australia is at the Gold Coast (Kirra/Bilinga Beaches) in Queensland. The first major beach replenishment program commenced at the Gold Coast in the mid 1970's and until 1990 about 5M cubic metres of sand had been used for the beach replenishment program. In 1990, a major replenishment program was undertaken at the Gold Coast during which over 3M cubic metres of sand was dredged ashore. This project received an excellence award in 1991 from the Queensland Division of the Institution of Engineers, Australia.

These few examples demonstrate the widespread use of beach replenishment for maintaining the beach amenity and protecting the coast. Beach replenishment is an internationally recognised soft engineering solution for coastal recession problems, and its application has proved successful and popular throughout the world.

CONCLUSIONS

The Coast Protection Board has been given the task of maintaining the amenity of the metropolitan beaches and protecting the coastal property from storm damage. It initially commenced the beach replenishment strategy in 1972 based on the recommendations of the "Culver Report". Since then, it has actively investigated and assessed the various strategies available for achieving the most cost effective solution to the communities problem, and has always sought to maximise the beach amenity and minimise potential storm damage.

The beach replenishment program, combined with the established sea wall defenses, provides the best engineering solution and least cost, long term strategy. The ultimate test for this strategy is in its performance during major storm events. In hindsight, we know what storm damage can occur, based on the events in the 1940's, 50's and 60's. However, by comparison storm damage since undertaking the beach replenishment strategy has been much less significant. For example, the storms in the 1980's, while estimated to be of similar intensity to previous events, did not result in the same level of dam age as the previous ones.

It is easy to become complacent by this significant improvement, but it must always be remembered that the Adelaide coast is artificially maintained, and without the ongoing efforts of the Coast Protection Board, the Coasts and Marine Section, and the State and Local Governments, the beaches would be quickly lost, leaving the community with a huge investment in vulnerable coastal property which would be at a high risk of dam age.

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For further information contact the Coasts and Marine Section of the Environment Protection Agency of the Department for Environment, Heritage and Aboriginal Affairs.

Appendix 15
Example of Offshore Breakwaters

Appendix 15 – Example of Offshore Breakwaters

Offshore Breakwaters, Presque Isle, Pennsylvania
Excerpt from US Army Corps of Engineers Coastal Engineering Manual, Report EM 1110-2-1100
EM 1110-2-1100 (Part V), 1 Jun 06, Figure V-3-19

Appendix 16
Summary of Engineered Shoreline Treatments

Appendix 16: Comparison of Engineered Shoreline Treatments: Coburg Peninsula

Case	Description	Time Frame	Visitor Experience	Benefits	Issues/ Impacts/ Risks	Magnitude Cost ($ M)	Study Requirements
1	Foreshore Armouring Coburg Peninsula, Distance Approx. 3 km	Long Term	Not an enhancement	Existing infrastructure protected from erosion	Beach deflation likely to continue, beach will be inaccessible during high tides	$2.1	Rip rap slope design
2	Beach Replenishment 250,000 m^3 With Dredge Deployment	Short Term – Perhaps 5 to 10 years	Enhancement	Existing infrastructure protected from erosion, beach restored	Requirement to maintain sediment trap on lagoon, beach deflation will continue, future replenishment required to maintain beach	$2.5	Dredging plan required, environmental assessment
3	Coastal Structure – Array of 16 Groynes Along Coburg Peninsula, Distance Approx. 3 km	Long Term	Generally regarded as an enhancement	Existing infrastructure protected from erosion, pocket beaches created	Significant cost, sediment trapped creating pocket beaches	$4.8	Major design study required
4	Coastal Structure – Array of 9 Offshore Breakwaters Along Coburg Peninsula, Distance Approx. 3 km	Long term	Generally regarded as an enhancement	Existing infrastructure protected from erosion, pocket beaches created	Significant cost, tumbolo formation behind breakwater creating pocket beaches	$11.5	Major design study required
5	Isolated Foreshore Armouring at South Ocean Bvld and Tip of Peninsula With Small Scale Land Based Beach Replenishment	Medium Term	Not an enhancement	Existing infrastructure protected from erosion	Periodic beach replenishment work required, isolated armouring may impact adjacent unprotected beach	$0.90	Rip rap slope design
6	North Bridge Abutment Only, Reconstruct About 50 m Abutment Armouring	Long Term	Not an enhancement	Immediately issue of north bridge abutment addressed, protection from erosion	Rest of peninsula unprotected and likely to experience further erosion	$0.035	Rip rap slope design
7	Do Nothing	Long term	Not an Enhancement		Beach deflation likely to continue, risk to infrastructure continues and likely will get worse	$0.0	None