Literature review on the effects of seawalls on beaches

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1 Introduction

This report was undertaken at the request of M Jacobson, Coastal Section, Planning and External Agencies, Department of Conservation. The report concerns a literature search and review of articles pertaining to the effects of seawalls on beaches. Particular consideration of articles relevant to the beach and coastal "protection" works at Wainui Beach, Gisborne was requested. Reports by Single (1993), and Peacock (1992 and 1993) were examined to gain an insight of the present situation and history of coastal protection works at Wainui.

The literature search was carried out in the libraries of the University of Canterbury. An initial search of two CD-ROM indexes was made before contents searches of the major relevant journals and conference proceedings.The bibliographical paper by Kraus (1988) gave starting points for further searches. The major journals included journal of Coastal Research, Shore and Beach, American Society of Civil Engineers Journal of Waterway Port Coastal and Ocean Engineering, Coastal Engineering Conference Proceedings, and the Proceedings of the Sixth Symposium on Coastal and Ocean Management - Coastal Zone '89. C.E.R.C technical reports were also checked. Work carried out by the University of Canterbury, Geography Department Coastal Group, and other post-graduate thesis work in New Zealand was also consulted. Only one relevant thesis (Dyer 1994) was found. Although some reports about seawalls have been written by the Coastal Group, copies were either unavailable or did not involve research of processes and beach response. Many of the articles noted in the search concerned the design and/or construction of seawalls, while others addressed wave run-up and overtopping criteria. These articles were not considered relevant for this report.

Of the articles surveyed regarding seawalls and their effects on beaches, twelve were found to be relevant for this review. The review is set out as an annotated bibliography. The order of presentation of the articles reviewed is chronological, with the latest article first. Five articles are considered to be of direct relevance to the Wainui situation, as they discuss the long term effects of rip rap revetments and seawalls on beaches. These are Griggs *et al* (1994), Basco (1991), Hall and Pilkey (1991), Magoon *et al* (1989) and Griggs and Fulton-Bennet (1988). These five articles plus papers by Dean (1987a, 1987b), Komar and McDougall (1988), MacDonald and Patterson (1985) have been copied and included with this report. The latter papers are not reviewed in this report but are included within the Kraus review (1988). A further report by Basco (1987) was requested but is an unpublished report prepared for the city of Virginia Beach, Virginia, U.S.A., and was not available. However the included Basco paper covers the same information, but without comments on specific applications.

2 Summary of Findings

Five major findings can be surmised from the literature. These are summarised as follows:

1. There does not appear to be any consensus within the literature as to whether a seawall can actively increase or decrease shoreline recession rates. Hall and Pilkey (1991) point out that there were three types of erosion associated with a seawalled beach: placement loss, passive erosion and active erosion. *Placement loss* occurs when a shore parallel structure is placed seaward of high tide line, thus substantially reducing the width of the beach. Loss of interaction between the dunes or cliffs and beach is also part of placement loss. *Passive erosion* occurs when the dune line is armoured or replaced by a permanent hard stabilisation structure, thereby causing the landward boundary of the beach to have a fixed location. *Active erosion* defines any process that accelerates erosion due to the presence of seawalls and other such structures. It involves the redistribution of sediment supply to a beach and/or any modification of shore zone processes due to the seawall.

2. It is more generally accepted that there are end effects of seawalls. 'End effect' occurs when a seawall acts like a groin, in that there may be some accretion on the updrift side but more often erosion or beach displacement on the downdrift side of the direction of wave approach. The end effect of a seawall is not as great as a groin, as seawalls do not protrude as far out into the surf zone, but the localised effect at the conjunction of the wall and the adjacent dune or cliff can extend to some distance away from the wall.

3. It is noted in the literature that no matter what type of shore protection put in place, the design and planning for such a structure must be comprehensive. Design parameters need to include the estimated maximum wave runup (for prevention of overtopping) and should also take into consideration the bathymetry and geological setting for the seawall. Many seawalls have been undermined or overtopped due to failure of the base material. Walls have also settled into the base material.

4. A vigorous inspection programme during and after construction should be carried out. Monitoring should also be a requirement, to incorporate any and all maintenance into the overall protection programme. It is through the adoption of strict design parameters and planning and monitoring procedures that the satisfactory performance of a seawall in protecting a beach and the property behind it can be ensured.

5. A major finding indicated by the literature search is the relative paucity of work carried out on the effects to the beach of the presence of seawalls. This is a direction of research that has not been widely addressed in New Zealand, but is a necessity with the advent of the RMA consent process.

3 Annotated Bibliography

Griggs, Gary B., Tait, James F., and Corona, Wendy, 1994, "The Interaction of Seawalls and Beaches: Seven Years of Monitoring, Monterey Bay, California". in Shore and Beach, Vol. 67, No. 3, pp 21-28.

In discussing the question of whether coastal structures cause or accelerate erosion, the authors have analysed seven years of bi-weekly to monthly monitoring of beaches adjacent to and fronting seawalls. The seven years of data was evaluated for any seasonal or long term patterns or effects. The result of this analysis was that there are some seasonal changes between the summer and winter profiles on both the adjacent and seawalled beaches. However once the summer berm on the adjacent beach had retreated back to or landward of the seawall, there was very little difference between the profile fronting the seawall and that of the adjacent beach. The authors stated that there were no significant long term effects or impacts shown from the seven years of data collection.

Dyer, Mitchell J., 1994, Beach profile change at St Clair beach, Dunedin, Unpublished Masters of Science Thesis in Geography, University of Canterbury, 210 pp.

Aim of the thesis is to record, observe and quantify coastal process elements and assess their potential influence on geomorphic change. Erosion of beaches is measured by retreat of the high water mark and by removal of sediment volume. Erosion of volume was concentrated at the seawall at St Clair, while retreat of the beach was more pronounced at non-stabilised areas. Recovery of the beach occurred at each site but was quicker in front of the wall. Dyer notes that more research is required on local processes and geomorphic change. The thesis includes photos and descriptions of beach change in front of the St Clair seawall, but no in-depth interpretations are made.

Basco, David R., Bellomo, Douglas A., and Pollock, Cheryl 1993, "Statistically Significant Beach Profile Change With and Without the Presence of Seawalls" in Proceedings of the 23rd Coastal Engineering Conference, American Society of Civil Engineers, pp 1924 - 1937.

In an attempt to shed some light on the question of the interaction between beaches and seawalls, the authors have statistically analysed field data from Sandbridge, Virginia. They examined the quantitative change in beach profile through profile section volumes, berm elevation, and shoreline position. This analysis revealed that there is no strong evidence to support the claim that the seawalls of Sandbridge have caused higher shoreline recession rates. Although the seaward sediment loss was higher on the seawalled beach, the landward loss of sediment was less than on the adjacent beach. Thus the total amount of sediment lost was less on the seawalled beach due to the volume of sand retained behind the wall.

Basco, David R., 1991, "The Effects of Seawalls on Long-term Shoreline Change Rates for the Southern Virginia Ocean Coastline". in Proceedings of the 22nd Coastal Engineering Conference, American Society of Civil Engineers, pp 1292 - 1305.

This article examines the relationship between offshore bathymetry, wave climate, shore boundary conditions, and shoreline response over a lengthy time period. Approximately 120 years of shoreline recession rates were examined to discover whether the 50 year presence of seawalls on the Virginian coastline had altered the rate of shoreline recession. It was found that the seawalls had not increased the rate of recession of the adjacent shoreline, while inhibiting retreat at the seawall positions. The offshore bathymetry of the area, deep water and high energy wave environment, had a major influence on erosion along this coastline. Thus the authors call for field studies to include the offshore boundary conditions so that no errors in judgement will be made in relation to building a seawall.

Hall, Mary Jo, and Pilkey, Orrin H., 1991, "Effects of Hard Stabilization on Dry Beach Width for New Jersey". in Journal of Coastal Research, Vol. 7, No. 3, pp 771 - 785.

This article examines the impact of hard stabilization structures on beaches regardless of the mechanism of beach degradation. Three types of erosion are defined: placement loss, passive erosion, and active erosion. The first two involve building a seawall and where it is on the beach, while the last is more controversial and describes any process that accelerates erosion or beach degradation due to the presence of the seawall. The authors measured the dry beach width for the open coast of New Jersey in order to determine whether there was a relationship between the presence of a hard stabilization structure and the width of the dry beach. They discovered that beaches with stabilization structures were statistically narrower than those beaches without such structures. The width of the dry beach appears to be a function of the density of the hard stabilization structure - the greater the density the narrower the beach. Of those sections of the coastline with seawalls 51% had no beach whatsoever, unless sediment had been trapped by a groin. The authors concluded that the seawalls were more responsible for the lack of beach than the groins, and that in general those beaches without hard stabilization structures are wider than adjacent stabilised beaches.

Toue, Takao, and Wang, Hsiang, 1991, "Three Dimensional Effects of Seawalls on the Adjacent Beach", in Proceedings of the 22nd Coastal Engineering Conference, American Society for Civil Engineers, pp 2782 - 2795.

The authors have examined the three-dimensional effects a seawall may have on an adjacent beach by using a physical model test. It was found that in the model tank, under normal incident waves, the rate of volumetric erosion together with the total eroded volume in front of the seawall was smaller than that of a natural beach. When oblique waves were applied, groin effects were noticed as the beach receded past the seawall which started to act as a large groin. These effects were localised to a region spanning up to 3 to 4 times the seawalls length.

Barnett, Michael R., and Wang, Hsiang, 1989 "Effects of a Vertical Seawall on Profile Response" in Proceedings of the 21st Coastal Engineering Conference, American Society of Civil Engineers, pp 1493 - 1507.

This article examines the response of a beach profile to the presence of a vertical seawall and to explain differences between the response to normal incident wave attack of both natural and seawalled-backed beaches, through experiments in a wave tank. It was found that scour occurred to a greater extent on the seawalled beaches, but the volume of sand that was retained upland of the wall was greater than on a natural beach which eroded past the point of the seawall. A bar-trough system was found to be the prominent system in play, with a bar forming in the proximity of the wave breaking point and the trough occurring near the still water shoreline. The presence of the seawall accentuated the trough as a scour hole in front of the wall, as opposed to the trough forming along the whole of the swash zone. Wave reflection was not found to be a major contributor in the development of the scour. Water depth was found to be important, with the greater depth came an increase in erosion. The seawalled beach exhibited greater recovery, however the majority of the volume of sand returned to the beach was at the structure's toe. There was not sufficient evidence to construe whether the placement of a seawall on an eroded beach would promote recovery.

Griggs, Gary B., and Tait, James F., 1989, "Observations of the End Effects of Seawalls" in Shore and Beach, Vol. 57, No. 1, pp 25-26.

Through the monitoring of beach changes over two years in the vicinity of various types of seawalls, visual observations of the end section of the walls indicated that when they were under direct wave attack that wave reflection was occurring. The extent to which this reflection had an impact downcoast appears to be dependent on wave height and wave period. Other factors which appear to have an influence on the end effect of seawalls are the angle of wave approach and the geometry and permeability of the end section. A lowered beach profile was observed up to 150 metres from the downdrift end of the seawall. It was also noted that the extension of the structure seaward was also a factor in determining the amount of scour or erosion.

Magoon, Orville T., Pope, Joan L., Sloan, Robert L., and Treadwell, Donald D., 1989 "Long Term Experience with Seawalls on an Exposed Coast". in Proceedings of the 21st Coastal Engineering Conference, American Society of Civil Engineers, pp 2455 - 2468.

This article examines the performance of seawalls along the shoreline of Santa Cruz California, which were built in the early 1960s. Major erosion of the predominantly mudstone and sandstone cliffs and beaches had occurred prior to this. The majority of the cliffs were protected by a sand beach at the toe. Two major rubble mound seawalls were constructed of 4700 feet and 870 feet in length. An inspection some twenty-five years after construction found that over 91% of the seawalls and revetments were in a 'very serviceable or nearly as-built condition'. Those that had failed were the result of a lack of understanding of various factors which the authors feel should be used when designing and maintaining a seawall. These are: the oceanographic and geological design parameters, a vigorous inspection programme during construction, and continued observation and maintenance of the structure. Using these factors would ensure satisfactory performance from a seawall.

Mossa, Joann, and Nakashima, Lindsay D., 1989 "Changes Along a Seawall and Natural Beaches: Fourchon, LA., in Coastal Zone '89". American Society of Civil Engineers, pp 3723 - 3737.

The authors compare the shoreline and beach morphology changes and responses to storms from 1985 to 1988 along sections of a rapidly eroding coast. This shoreline consists mainly of delta headlands and barrier islands. A beach consisting of a cement-filled bag seawall and nourishment was compared to the natural beaches at either end of the project. Surveys were undertaken quarterly and included the monitoring of the effects of Hurricane Gilbert and long term performance of the seawall. It was found that the seawalled beach experienced greater volumetric losses and greater recovery than the natural beaches, especially in relation to the impacts of the hurricane. However most of the sediment replaced in front of the seawall filled the scoured toe of the structure. Although greater erosion occurred to the east of the seawall, it was concluded that this was related more to the shoreline curvature and geological factors rather than to the presence of the seawall.

van de Graaf, Jan, and Bijker, Eco W., 1989, "Seawalls and Shoreline Protection". in Proceedings of the 21st Coastal Engineering Conference, American Society of Civil Engineers, pp 2090-2101.

This article discusses hypothetical situations regarding the placement of seawalls on a beach, and it is unclear whether the authors were using a physical or numerical model in their study. It is the authors' belief that many of the seawalls around the world are built in places where they shouldn't be, in that they do not interact with processes such as the long-shore transportation of sediment which effects erosion rates. The authors believe that seawalls should only be used where they are absolutely necessary, and that the use of beach nourishment should be encouraged as this approach can be applied anywhere. In general the authors believe that seawalls do not destroy beaches, but rather it is their design and often placement which is at fault.

Wright, Howard, and Pilkey, Orrin, 1989, "The Effect of Hard Stabilization Upon Dry Beach Width". in Coastal Zone `89, American Society of Civil Engineers, pp 776-790.

The authors report the results of a dry beach width survey of the developed shoreline of New Jersey, North Carolina and South Carolina. Dry beach width is defined as the distance between the high water line and active dune line or the onset of stabilization. This section of a beach represents the width of a beach that is available for recreational use and is often used as a quality measure for a beach. A detrimental effect of hard stabilization to the dry beach width was defined at the loss of width, or the narrowing of the dry beach. In general the authors found that an unstabilised beach had a dry beach width in the order of 10 to 25 metres, while the model dry beach width for a stabilised beach was zero, that is no beach. They concluded that on the open coast developed shoreline of their study area that dry beach width decreases as the density of shore parallel hard stabilization increases. This decrease in dry beach width is a function of placement loss, passive erosion and possibly active erosion.

Griggs, Gary B., and Fulton-Bennet, Kim, 1988, "Rip Rap Revetments and Seawalls and Their Effectiveness Along the Central Californian Coast". in Shore and Beach, Vol. 56, No. 2, pp 3-11.

This article examines the effectiveness of protective structures regarding reductions in storm damage and minimising or halting shoreline erosion. Effectiveness is based on the failure of and within the structure rather than the good or bad impacts of the structure on the beach. The assessment was based on the case histories of 32 sites along the central Californian coast which included a variety of coastal environments, rip rap revetments and seawalls. It was found that the success rate of many of the rip rap revetments was often marred by the relatively high maintenance requirements, and that significant damage to property could occur even if there was only partial failure in the rip rap. A well maintained rip rap revetment was found to have a proven effectiveness in slowing erosion, but the costs of maintenance were high. Concrete seawalls were found to have better durability than rip raps, and often lower maintenance costs. However the construction costs of a concrete seawall are substantially higher than those of a rip rap revetment. The authors conclude by stressing the need for continuous, coherent structures be they rip raps or seawalls, as a combination of various types of protective structures is only as strong as the weakest link.

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