

Peer Review

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of the Report for the Napier City Council

REVIEW OF THE WESTSHORE NOURISHMENT SCHEME — NAPIER CITY

prepared by

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The objective of this report prepared by Coastal Management Consultancy (CMC) has been to review the nourishment scheme for Westshore in order to improve its efficiency, effectiveness and sustainability. This nourishment scheme was initiated in January 1987, and after more than 15 years of operation it is time to undertake a review having those goals. It is important to guarantee the continued operation of the nourishment scheme and its sustainability through this century, prior to adoption of the reduced 2001 Coastal Hazard Zone that is dependent on a continuation of nourishment and an assurance that it will provide continued protection to Westshore from potential storm hazards and beach erosion.

Jeremy and Ann Gibb are to be commended for having completed a carefully prepared review of the Westshore nourishment scheme as commissioned by the Napier City Council. There are several components to this review, ranging from examinations of beach profiles obtained by the monitoring program, used to infer the decadal changes in sediment volumes on the beaches, to an attempt to assess the overall budget of sediments for the Hawke Bay beaches, which involves difficult evaluations of sediment volumes contributed by the rivers, losses to gravel-particle abrasion on the beaches, and estimates of rates at which the beach sediments are carried along the shore by waves. Results of those analyses are basic to the evaluation of the status of the nourishment scheme, and to recommendations that are directed toward potential improvements.

I have reviewed these aspects of the CMC Report, and discussions of each are provided below. In a couple of instances my discussions have gone beyond the intended scope of the CMC Report, especially where I believe that deficiencies remain in our understanding of the Hawke Bay shoreline, its sediment sources and beach processes, relevant to the long-term maintenance of the Westshore nourishment scheme and the protection of that community from potential erosion and flooding hazards.

Beach Sediment Volumes and the Effects of Nourishment

The best overall assessment of the efficiency and effectiveness of the Westshore nourishment scheme is derived from the "ground truth" provided by the monitoring profiles surveyed along the

length of the Hawke Bay shore. As pointed out the by CMC Report, there is a deficiency in the monitoring procedures in that the surveyed profiles are limited to above mean sea level, and therefore do not account for accumulations or losses of beach sediment in the offshore. This limitation can produce significant underestimates of the actual volume changes since they undoubtedly extend well below mean sea level into the offshore. In spite of this limitation, the beach-profile data collected over the duration of the nourishment scheme still provide the best documentation of the resulting beach changes.

A major portion of the CMC Report is devoted to a summary of the volumes of nourishment sediment deposited on the Westshore beach since January 1987 (Table 1). This was almost entirely fine gravel derived from Pacific Beach, with a small amount of sand included with the gravel when obtained from excavating the Wildlife Ponds. In total, the nourished volume since 1987 has been 233,800 m³, with about 40% placed at South Westshore between Whakaire Avenue and Fewick Street, and 60% along The Esplanade.

An interesting "state of health" assessment of the beaches and the role of the nourishment scheme is provided in Tables 4 and 5 based on the surveyed profiles along the entire Hawke Bay shore. At each profile site the earliest and most recent surveys are compared to calculate the net volume change (cubic meters of sediment volume) and the rate of change over the span of years. The patterns of net erosion and accretion are of special interest in that there has been a degree of continued erosion at South Westshore (profiles W-40 through W-51), in spite of the nourishment of this stretch of beach. The mean rate of beach volume loss has been -3,123 m³/yr, but one-third of that loss occurred at profile W-51; the cause of this localized erosion was not discussed in the report. Net beach volume accretion has been experienced along The Esplanade, generally at low rates (76 to 800 m³/yr). This accretion is attributed to the nourishment scheme, and perhaps also to the effects of dredged sand placement in disposal area "R", with the created shoal possibly damping the energy of the waves.

Table 5 gives the profile results for the South Napier System, extending from the Nagaruro River to Pacific Beach in Napier. In spite of gravel extraction by the commercial operation at Awatoto and the transfer of gravel from Pacific Beach to Westshore for nourishment, there is an overall positive balance of 11,357 m³/yr. This is encouraging in that it suggests this source of sediment from Pacific Beach for the nourishment scheme is sustainable at the present rates.

The net balance for the entire North Napier System, given in Table 4, is -112,780 m³ or -13,168 m³/yr. The negative balance indicates a condition of long-term net erosion, in spite of the addition of the nourishment sediment at Westshore. The net loss is likely even greater than these values obtained by the CMC Report. Simply adding the profile results listed in Table 4 to obtain a net balance is misleading, due to the irregular spacing of the profiles which range from about 90 to 100 meters along The Esplanade to 1.5 to 1.7 km at the north end of this stretch of shore. The large number of profiles at close spacings for The Esplanade has the effect of over-weighting the accretion experienced there in calculating the net balance, so it is likely that the correct assessment of the net balance is more negative than given in Table 4, that is, there has been a greater degree of net erosion within the North Napier System than calculated by the CMC Report.

The Budget of Beach Sediments

The development of a sediment budget for a beach involves assessments of the various sediment sources or "credits", compared with its losses or "debits", with the difference between the credits and debits yielding the "net balance" which is reflected in either progressive erosion or accretion of the beach (Komar, 1996, 1998). The above evaluations of the net sediment volume changes in the South and North Napier Systems constitute the balances in the sediment budgets for those two stretches of the Hawke Bay shore. The CMC Report (Section 4) attempts in Tables 8 and 9 to expand those results to full sediment budgets for the South and North Napier Systems through assessments of the sediment sources (credits) and losses (debits). The main significance of this development of a more complete sediment budget is its potential to provide a clearer picture of the sustainability of the

Westshore nourishment scheme, since sustainability depends on the natural sources of the beach gravel versus the losses.

The development of a sediment budget is challenging, since it is generally difficult to arrive at satisfactory quantitative assessments of all of the beach sediment sources and losses (Komar, 1996, 1998). Often the best established part of the budget is its balance, the net erosion or accretion of the beach, and that is true in this application to the Hawke Bay beaches. Furthermore, the components of these budgets are particularly difficult to assess. The primary sources of beach sediments (sand and gravel) are the rivers, principally the Tukituki River which is evaluated in the budget (Table 8) as contributing 28,000 m³/yr; this undoubtedly is a very approximate "average" value, since it is always difficult to accurately determine the coarse bed-load contributions of large rivers. The main debit of sediment for the South Napier System is the mining of beach sediment, the commercial operation (-50,500 m³/yr) plus the removal at Pacific Beach (-13,000 m³/yr) for Westshore nourishment (where it becomes a sediment credit in the budget for the North Napier System).

An unusual debit in the budgets for both the South and North Napier Systems is the loss of gravel by abrasion, caused by the collisions and grinding together of the greywacke particles by the action of the surf. The only sediment budgets I have seen where this is included are those formulated for New Zealand beaches. Unfortunately, there has been relatively little research undertaken concerning abrasion processes, insufficient to permit accurate assessments of the rates and losses of beach gravel through abrasion. In the present application by CMC the evaluation is based on the work of Adams and Gibb (1982) and their development of sediment budgets for beaches on the east coast of the South Island. More recent measurements of greywacke abrasion rates have been obtained by Hemmingson (2000), research that is still underway, showing that the rates differ significantly for greywacke gravel on different New Zealand beaches; it is also likely that wide ranges of values will be found for different particle sizes and different wave energies. Kirk and Single (1999) have used the abrasion rates measured by Hemmingson (2000) in their development of sediment budgets for the Napier Systems, with very different results from those presented in the CMC Report. This disagreement is a reflection of honest differences, which can result from the imperfect development of sediment budgets.

In spite of such differences, the development of sediment budgets is still extremely helpful, since it forces one to think about the many factors and processes that affect the availability of beach sediments, and in the present application the potential sustainability of beach nourishment for Westshore. We have already seen that in order to improve the assessment of this sustainability, we need to know more about the quantities of sediment derived from the rivers and the rate of loss to grain abrasion once the sediment reaches the beaches; this can come only from additional research. The budget as developed by CMC has other components that are directly relevant to the sustainability of the nourishment scheme. Foremost is the 80,000 m³/yr credit for the inferred net northward drift of sediment on the beach immediately south of the Tukituki River, the first item in Table 8 for the South Napier System budget. This value is derived from the volume of gravel initially trapped by the Haumoana groyne when it was constructed, but that trapped volume has been doubled in the CMC budget to include the transport that presumably occurs beyond the 400-meter length of the groyne. In itself this is obviously an approximate assessment, but its magnitude does suggest the existence of a major sediment source to the south of the Tukituki River mouth. The actual nature of this source is not discussed in the CMC Report. Part of it could be derived from the erosion of Cape Kidnappers, but the erosion of resistant headlands generally do not represent significant sediment sources (unfortunately, I do not have direct familiarity with Cape Kidnappers to assess it as a possible sediment source). Pervasive beach and property erosion has occurred along this stretch of shore south of the Tukituki River, with the eroded material being transported northward by the waves, some of it trapped by the Haumoana groyne where CMC assessed its volume and arrived at the 80,000 m³/yr rate. This erosion may be a continued response to the 1931 earthquake in that this stretch of coast subsided at the time of the earthquake, whereas that to the north experienced uplift. Subsidence can be expected to result in a prolonged period of shoreline retreat, until a new equilibrium is achieved. The implication is that this erosion contributing to the 80,000 m³/yr credit in the sediment budget will progressively decrease as an equilibrium is approached. Even before that happens, the increased construction of shore-protection structures to halt the erosion and loss of properties south of Haumoana would result

in the progressive decline of this credit in the sediment budget for the South Napier System. In Table 5 the CMC Report found an overall positive balance of 11,357 m³/yr in the sediment budget for the South Napier System based on the profile surveys; with the loss of the 80,000 m³/yr sediment credit derived from sources south of Haumoana, the balance in the budget would shift to about -69,000 m³/yr, a net erosion of the beach that opens to question the sustainability of the Westshore nourishment scheme based on mining at Pacific Beach as the primary source.

As documented by the CMC Report, there are potential alternative sources of sediment for the Westshore nourishment. It is concluded that the Ngaruroro River is the most suitable potential source, specifically derived from the Holcim Quarries which has a sizable stockpile. Use of this source is particularly appropriate in that the lower reaches of the Ngaruroro were diverted in 1960, temporarily eliminating it as a source of coarse sand and gravel to the beach of the South Napier System. The gravel in the bed of this river is slowly moving toward the river's mouth and beach, but is not expected to reach there until A.D. 2400 according to the CMC Report. Using the Ngaruroro River as a source of nourishment sediment would in effect speed up this process, re-entering it as a credit into the sediment budget.

The sediment budgets presented in the CMC Report are "steady state", that is, the components are expressed as long-term averages and therefore do not reflect variations from year to year, the "unsteady" reality of Nature. This unsteadiness is particularly relevant to the river contributions. While the credit from the Tukituki River is entered into the budget for the South Napier System (Table 8) as a fixed 28,000 m³/yr average, it is recognized that the actual contribution of sediment occurs primarily during episodic floods, with the largest forming a temporary delta at the mouth of the river. With time the delta sediments are driven onshore by the waves to add material to the beach, which then slowly moves northward along the shore as a "slug" of sediment. A number of years could pass before this slug of abundant sediment reaches Napier and Pacific Beach, at which time increased mining for the nourishment of Westshore would be appropriate. Of more concern are the periods of low discharges on the Tukituki River and the reduced sediment supplies, which in the cycles of Nature could represent periods of several years to decades. With some time lag, this decrease would produce reduced quantities of sediment reaching Pacific Beach, temporarily reducing it as a potential source for the Westshore nourishment scheme. With the development of an "unsteady" sediment budget to account for these natural variations in sediment "credits", the effects on the nourishment scheme could be anticipated. With a recognized decrease in sediment supply from the Tukituki River, smaller quantities of sediment could be commercially extracted from the beach to mitigate the reduction, or the nourishment scheme could shift to the Ngaruroro River as its primary source.

Dredged Sand Disposal

While there is evidence that gravel does not bypasses the breakwater of the Port of Napier, suspended fine sand does, and it is then deposited in the Port Fairway. This sand is dredged and in part is disposed of in dump site "R" offshore from Westshore. The volumes are significant, estimated to be a total of 304,000 m³ since 1982, an average rate of 16,900 m³/yr (Table 2 in the CMC Report). Dump site "R" extends from mean sea level to a water depth of about -7 meters (Figure 5). The disposed volumes are measured by bathymetric surveys (which likely underestimate the total volumes), and the surveys provide some documentation of the rate and directions of the dispersal of this fine sand by the waves and currents.

This disposal of sand at site "R" is credited in the CMC Report (page 19) with the documented accretion of the beach along The Esplanade, although the gravel accumulation itself is due to the nourishment operation. One should think in terms of the shoal created by sand disposal at site "R" as acting to dissipate the energy of the waves, so the alongshore dispersal of the nourished sediment on the beach is reduced, resulting in a prolonged period of accretion following the nourishment operation.

The CMC Report recommends that the fine sand dredged from the harbor and disposed of in "R" be placed as a shore-parallel offshore bar in 4 to 6 meters water depth, rather than being spread evenly

over the disposal area as is now required. If the disposed sand is able to persist in this bar configuration for a significant period of time, it would enhance the protection of the gravel beach by increasing the degree of wave-energy dissipation. The CMC Report envisions that this bar would progressively migrate shoreward and eventually weld onto to the beach, but this is uncertain as this fine sand may not be stable in the active swash zone of the otherwise coarse sand and gravel beach at Westshore. It may also not be desirable, as field studies of gravel and cobble beaches have demonstrated that the introduction of sand decreases the permeability of the uprush of the waves into the gravel and cobbles, so the strength of the backwash is increased and acts to cut back the beach slope (Everts et al., 2000). However, in balance the suggestion in the CMC Report to construct an offshore bar of the disposed sand has merit if it is sufficiently stable to dissipate the energy of the waves and to promote stability of the gravel beach. It is noteworthy that ASR makes a similar recommendation in their report (Mead, Black and McComb, 2001), based on a detailed study of the fine-grained sand. They also suggest that the disposed sand be placed as a wedge that widens toward the south in order rotate the waves by refraction, thereby decreasing the rate at which beach sediment is transported to the north out of the disposal area. Furthermore, the ASR report recommends the construction of a reef consisting of sand-filled geotextile bags to block the sand dispersal route. Their proposals are discussed at greater length in my review of their report. What ever decisions are made concerning an altered scheme of fine-sand disposal, it could be attempted as a one year "experiment" with an increased level of monitoring, and if demonstrated to have a positive effect it could then be implemented as standard practice.

Physical Improvements

Sections 5.3.2 and 5.3.3 of the CMC Report make recommendations for "physical improvements" to the backshore, including recontouring the topography as diagrammed in Figure 8, and increasing the elevation of the artificial beach ridge along South Westshore and the embankment along The Esplanade. The main objectives appear to be to improve beach access and/or reduce flooding during storms. There may also be improvements in the beach responses to storms, for example by reducing wave reflection. These proposed changes go beyond the scope of the intended review of the nourishment scheme, and only marginally relate to beach nourishment. Any efforts directed toward recontouring the beach and backshore should include detailed assessments of ocean processes such as potential extreme combinations of tides, storm surge and storm-wave runup, and perhaps rarer events such as tsunami. As presented in the CMC Report, the selection of the increased elevations of the beach ridges and embankments are based on the desire to achieve an elevation that would prevent flooding like that on 3 April 2002. There is no assessment of that particular event in the report in terms of whether it has a probability of occurrence once in 5 years or once in 100 years. Analyses need to be undertaken of expected combinations of tides, storm surges and swash runup levels of waves generated by major storms, with quantitative assessments of the total water levels that might be exceeded once in 50 to 100 years. The design of these physical improvements and the specific selection of their elevations should be based on such analyses, so the degree of protection offered by the improvements is better established.

The same types of analyses should be undertaken for Pacific Beach, since it provides the natural line of defense for the city from storm-induced erosion and flooding. The CMC Report indicates that the developed park grounds west of Marine Parade are currently within reach of wave runup during severe storms, so there is the potential for damage by extreme 50 to 100-year events. Analyses of combinations of ocean processes that might lead to unacceptable erosion or flooding could focus on the minimum beach conditions (widths, elevations, etc.) required to maintain the desired level of protection, with the results serving as a guide in the monitoring of Pacific Beach to insure that sediment mining does not reduce the beach to a condition that could endanger the city.

Recommended Revisions in the Nourishment Scheme

The main recommendation in the CMC Report for the improvement of the Westshore nourishment scheme is that the nourished gravel be placed mainly along South Westshore between HBRC Profiles

W-40 and W-51C. The Report further recommends that 12,000 m³ be placed each year at South Westshore, and 2,000 to 3,000 m³ every two years along The Esplanade. The rationale for this change is that if the nourishment sediment is placed primarily at Westshore, the use of the sediment is both more effective and efficient in protecting the North Napier shoreline from erosion and flooding, in that it would first protect South Westshore and would then be transported northward by the waves to The Esplanade shore, to protect that area. This represents the commonly used concept of a "feeder beach" in nourishment projects, used where there is a dominant direction of net longshore sediment transport on the nourished beach. This is the case at Westshore, so this recommendation by the CMC Report is reasonable and should be adopted.

Summary of Review Comments and Recommendations

The overall objective of the CMC Report was to review the nourishment scheme for Westshore in order to improve its efficiency, effectiveness and sustainability. The contents of the Report are for the most part suitably directed toward that objective, with the analyses of the beach sediment volumes determined by the monitoring profiles addressing the issue of the efficiency and effectiveness of the nourishment scheme, while the development of a full sediment budget considers its sustainability as a means to protect Westshore from long-term erosion and the potential of flooding during storms. While I have made a number of comments and suggestions regarding the contents of the CMC Report, overall I consider it to be a good contribution toward addressing the role of continued beach nourishment as the primary means for the protection of Westshore.

Specific comments and suggestions concerning the contents of the Report have included:

- I agree that the principal source of nourishment sediment should continue to be Pacific Beach, which has the potential for a sustainable supply between 12,000 and 13,000 m³/yr as concluded by the Report;
- The sediment budget for the South Napier System demonstrates the present existence of a healthy positive balance, reflecting a net gain in beach sediment, indicating that Pacific Beach can continue to be the source of sediment for the nourishment of Westshore; however, in my review I have raised questions concerning the nature and the potential longevity of the sediment contribution derived from erosion of the beach and properties south of Haumoana, the concern being that this source will decrease with time as the beach approaches equilibrium and increased measures are taken for shore protection, at which time the Pacific Beach source might not be sustainable;
- While the budget of sediments developed by the CMC Report is a good first estimate based on what is presently known about the sediment sources and losses, it does not account for the natural variations in sediment sources, the "unsteadiness" of Nature; I therefore recommend that more advanced budgets be developed to assess the variability of sediment supplies from the Tukituki River that will affect the quantities of sediment available at Pacific Beach to be mined in the nourishment scheme;
- While the placement of dredged fine-grained sand in the disposal site "R" does not make a contribution to the budget of beach sediments, evidence suggests that the shoal created by this disposal is effective in dissipating the energy of the waves and in part accounts for the net beach-volume increase along The Esplanade; the recommendation in the CMC report that this disposal be in the form of a shore-parallel bar in order to increase the wave dissipation is reasonable, and could be attempted on an experimental basis after consideration is also given to the recommendations made by the ASR study concerning the disposal of the fine sand;
- Improvements to raise elevations of beach ridges and embankments along South Westshore and The Esplanade are necessary to provide greater protection from erosion and flooding, but the recommendations provided by the CMC Report are inadequate in that they do not account for the actual processes (tides, storm surge, wave runup) through assessments of their extreme 50- to 100-year elevations; such analyses need to be completed to the same extent as would be employed in the design of a seawall or revetment for shore protection;

- Similar analyses should be undertaken for the Pacific Beach gravel extraction site, analyses of the processes and their extreme combinations that determine total waters, in order to prevent adverse impacts to the city during the 50- to 100-year storm events that could result from excessive mining;
- I concur with the report's recommendation that the nourished gravel be placed mainly along South Westshore between HBRC Profiles W-40 and W-51C, in order to serve as a feeder beach with the subsequent movement of the gravel northward along The Esplanade.

The CMC Report has also made a contribution by demonstrating the limitations in our understanding of the Hawke Bay beaches, in particular the remaining uncertainties in the components of the sediment budgets and therefore whether the nourishment of Westshore is sustainable. Those limitations in the sediment budgets, and suggestions for physical improvements for the protection of Westshore from extreme episodes of erosion and flooding, point to the need for additional investigations. I recommend that priority be given to the following studies:

- The development of a much refined budget of beach sediments that takes into account annual variations in sediments derived from the Tukituki River, the effects of sediment mining from the river channel as well as from the beach, the sediment contributions south of the Haumoana groyne, and more detailed analyses of the losses of beach sediments through abrasion of the greywacke particles;
- Surveys be undertaken of sediment deltas formed at the mouth of the Tukituki River at times of floods to establish the volumes of sediment contributed, and the development of model analyses of the longshore sediment movement to assess the migration of this "slug" of sediment northward and the time delay in its arrival at Pacific Beach;
- Detailed analyses be undertaken of extreme storm-wave heights, their runup levels on beaches, the heights of generated storm surges, and the total water levels achieved by these storm-related processes plus the tides to determine the extreme total water levels that pose an erosion and flooding threat to Westshore and Pacific Beach.

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