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REVIEW OF THE WESTSHORE NOURISHMENT SCHEME – NAPIER CITY

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Report prepared for Napier City Council

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MARCH 2003

C.R. 2002/6

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EXECUTIVE SUMMARY

On 23 October 2002, Coastal Management Consultancy Ltd (CMCL) were commissioned by Napier City Council (NCC) to review the Westshore Nourishment Scheme to improve its efficiency, effectiveness and sustainability this century. The specific objectives of the review adopted previously by Council were to:

1. ***REVIEW*** *the current Westshore nourishment scheme to improve its effectiveness and sustainability during this century, with special reference both to mitigating coastal erosion between Scarpa Flow and Fenwick Street, and ensuring the sustainability of the Pacific Beach supply source and any other potential sources.*

2. ***INITIATE*** *steps to guarantee the operation of the Westshore nourishment scheme on a sustainable basis before considering the adoption and implementation of the much-reduced 2001 Coastal Hazard Zone for* ***Scenario 2*** *that assumes the continuation of the scheme.*

3. ***REVIEW*** *the current coastal monitoring programme of Hawke's Bay Regional Council between Ahuriri Entrance and Esk River mouth to ensure its effectiveness and sustainability at quantifying the effects of both coastal hazards and the Westshore nourishment scheme.*

The issue is a clear-cut example of sustainable management of a physical resource, namely the greywacke-derived sediments that are important for sustaining the Napier City beaches between the Ngaruroro and Esk River mouths. Whilst the South Napier barrier beach system between the Ngaruroro River mouth and Port of Napier is sustained by a net Northerly longshore drift of about 108,000m^3/year entering the system, the North Napier barrier beach system is in deficit and is entirely dependent on being sustained by both the existing Westshore Nourishment Scheme and the dumping of dredged sand inshore in Westshore Bay from time to time by the Port of Napier Ltd.

This review finds that the Westshore Nourishment Scheme has been successful but can be improved so that it is sustainable this century. Recommendations are made to achieve the improvements.

1. ***REVIEW*** *the current Westshore nourishment scheme to improve its effectiveness and sustainability during this century, with special reference both to mitigating coastal erosion between Scarpa Flow and Fenwick Street, and ensuring the sustainability of the Pacific Beach supply source and any other potential sources.*

RECOMMENDATIONS

i. The nearshore dumping programme on Dump Ground "R" Extended should formerly become part of the Westshore Nourishment Scheme and be managed and monitored accordingly.

ii. Condition 7 of Coastal permit No. CPA 0101 should be revised to allow dredgings of Sand to be dumped as close to the shore as possible within Dump Ground "R" Extended to form a shore-parallel offshore bar in 4 to 6m water depth off Westshore Beach.

iii. The most sustainable source area of suitable sediment for the Westshore Nourishment Scheme is Pacific Beach. Based on monitoring of beach volumes, Pacific Beach has the potential to supply between 12,000-13,000m^3/year, and up to about 20,000m^3/year after Southerly storms.

iv. The second sustainable beach source area is the barrier between Awatoto and the mouth of the Ngaruroro River which has the potential to supply about 15,000 to 20,000m^3/year of suitable sediment for the Westshore Nourishment Scheme. If this site was utilised then extraction from Awatoto must be reduced proportionately to ensure the continued trend of accretion of the South Napier barrier system and long-term protection of Napier City.

v. No gravel and coarse sand should be extracted from the shoreface along the South Napier barrier system between Pacific Beach and Awatoto.

vi. The preferred sustainable river source is the Ngaruroro riverbed at the Holcim Quarries extraction site where there is currently a stockpile of about 100,000m^3 of suitable fine gravel available.

vii. Both the Tukituki and Esk Rivers should be managed in such a way that promotes the maximum potential discharge of bedload to the coast to sustain the Napier City beaches. Current extraction of river bedload for commercial purposes should accommodate this important requirement and not be permitted to adversely affect bedload transport to the coast.

viii. The artificial beach ridge needs to be reconstructed at both Southern Westshore and The Esplanade according to the recommended parameters given in Tables 10 and 11 and shown in Figure 8.

ix. To fully utilise the net Northerly longshore drift and mitigate erosion the focus of dumping of nourishment sediment should be between HBRC Profiles W-40 and W-51C (Southern Westshore) at the rate of about 12,000m^3/year and 2,000 to 3,000m^3 every 2 years between HBRC Profiles E-6 and E-18 (The Esplanade). All 12,000 to 15,000m^3/year should be placed on the modified shoreface (Figure 8) to be distributed by wave action.

x. To mitigate coastal flooding, the crest of the re-positioned artificial barrier ridge needs to be raised about 0.05 to 1.0m, increasing in height Northwards, according to the recommended crest heights given in Tables 10 & 11.

xi. To improve both access and amenity of Westshore Beach the gradient of the seaward slope needs to be mechanically reduced and the sediment pushed landward to both increase the height of the artificial ridge and to raise the level of the swale behind as shown in Figure 8.

xii. Additional gravels will be required over and above the recommended annual nourishment volumes of 12,000-15,000m^3/year to raise the level of the swale behind the artificial beach ridge. The current stockpile of 100,000m^3 of pea gravel at the Holcim Quarries site may be a useful supply source.

Table 10: Recommended design parameters for the artificial beach ridge along Southern Westshore between HBRC Profiles W-40 and W-60. All horizontal measurements are in relation to the landward point of origin of the 2 December 2002 Profile survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m).

HBRC PROFILE	EXISTING CREST HEIGHT (m)	EXISTING DISTANCE TO TOP SEAWARD EDGE (m)	RECOMMENDED CREST HEIGHT (m)	RECOMMENDED DISTANCE (m)
W-40	13.61	30	13.6	21
W-41	13.82	40	13.8	27
W-42	13.65	42	13.8	30
W-44	13.95	61	14.0	50
W-45	14.15	55	14.0	44
W-46	14.07	49	14.0	39
W-48/HB-13	14.00	70	14.5	58
W-50	14.33	62	14.5	50
W-50C	14.49	26	14.5	16
W-51	13.88	27	14.5	15
W-51B	13.58	39	14.5	30
W-52	13.82	48	14.5	36
W-53	15.33	35	No change Required	
W-60	15.80	0	No change Required	

Table 11: Recommended design parameters for the artificial embankment along The Esplanade between HBRC Profiles EA and E24. All horizontal distances are in relation to the landward point of origin of the 2 December 2002 profile Survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m).

HBRC PROFILE	EXISTING CREST HEIGHT (m)	EXISTING DISTANCE TO TOP SEAWARD EDGE (m)	RECOMMENDED CREST HEIGHT (m)	RECOMMENDED DISTANCE (m)
E-A	16.15	19	16.0	10
E-2	16.10	20	16.0	15
E-4	15.99	18	16.0	14
E-6	15.95	16	16.0	15
E-8	15.85	19	16.0	16
E-10	15.56	19	16.0	15
E-12	15.53	17	16.0	11
E-14/HB-14	15.51	18	16.0	13
E-16	15.39	21	16.0	16
E-18	15.53	23	15.5	22
E-20	15.93	26	15.5	17
E-22	15.99	31	15.5	25
E-24	16.29	36	15.5	33

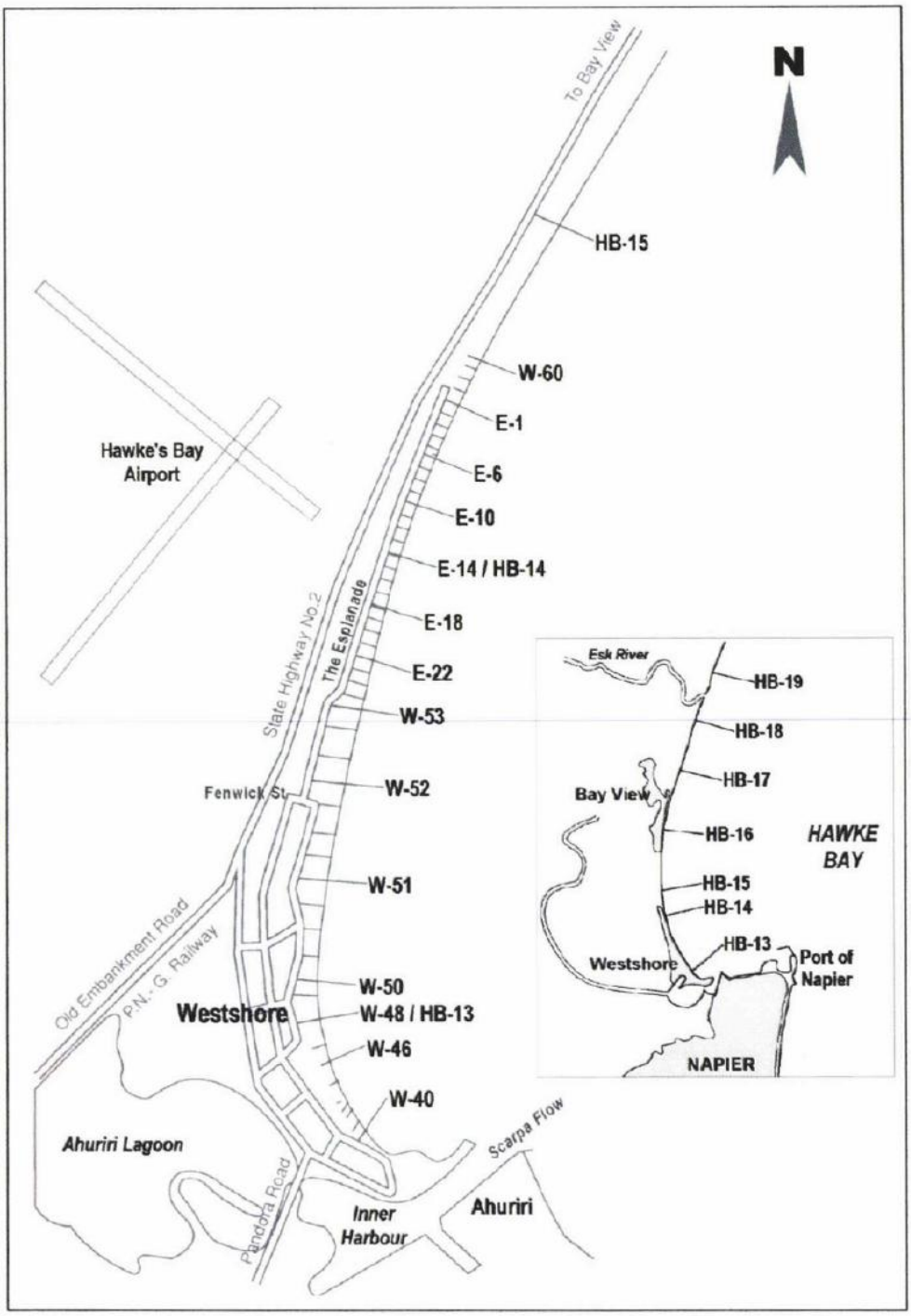
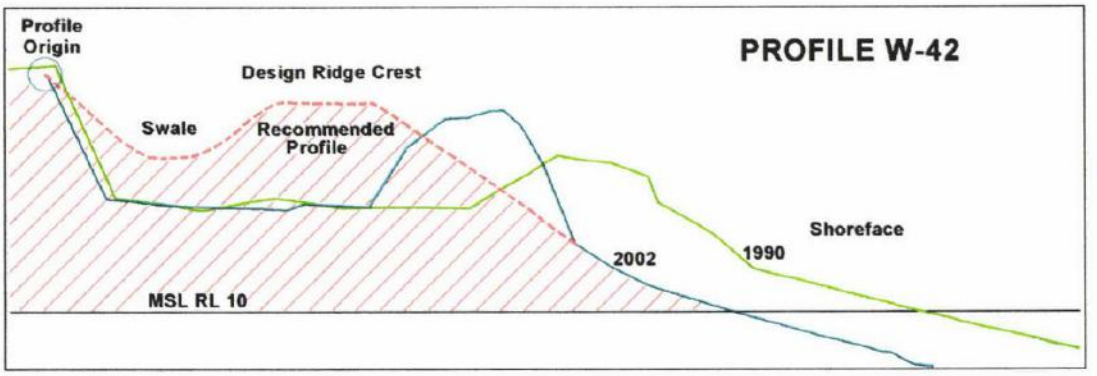
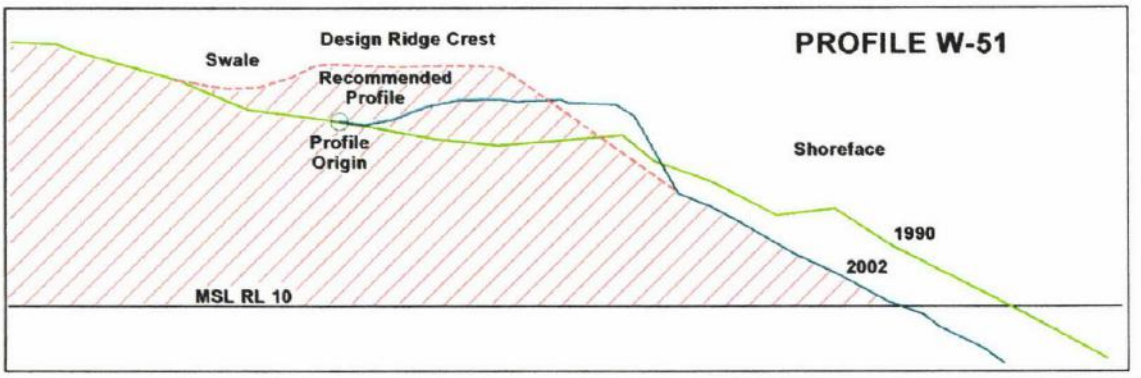


Figure 3: Sketch map showing the general location of the HBRC beach profile sites listed in Table 4, along the North Napier System.





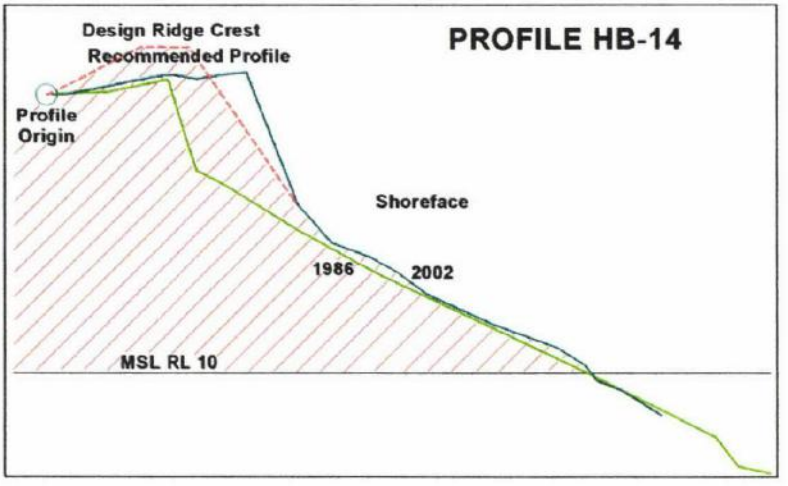


Figure 8: Recommended profiles at 3 representative sites along Westshore to improve the performance of the Westshore Nourishment Scheme.

2. ***INITIATE*** *steps to guarantee the operation of the Westshore nourishment scheme on a sustainable basis before considering the adoption and implementation of the much-reduced 2001 Coastal Hazard Zone for* ***Scenario 2*** *that assumes the continuation of the scheme.*

   Once the above recommendations have been considered and adopted by Council and implemented to achieve the improvements recommended then Council can consider adopting and implementing the much-reduced 2001 Coastal Hazard Zone for Scenario 2.

3. ***REVIEW*** *the current coastal monitoring programme of Hawke's Bay Regional Council between Ahuriri Entrance and Esk River mouth to ensure its effectiveness and sustainability at quantifying the effects of both coastal hazards and the Westshore nourishment scheme.*

Council needs to work closely with HBRC and Port of Napier Ltd who currently manage the coastal monitoring programmes along the Napier City coast to ensure that such programmes provide adequate information on the following issues for decision makers.

1. The long-term stability of both the North Napier and South Napier barrier beach systems.

2. The effects of dumping of sediment dredged from the Port Fairway and Ahuriri Inner Harbour on the bathymetry of Dump Ground "R" Extended (Figure 5) and on the long-term stability of Westshore Beach.

3. The effects of mining of beach sediment at Pacific Beach, Awatoto and the Ngaruroro River mouth on the long-term stability of the South Napier System.

4. The effects of the Westshore Nourishment Scheme on both the long-term stability of the North Napier System, and the composition and amenity of the beach.

5. The effects of severe wave storms on short-term barrier erosion and recovery, and flooding from storm wave runup.

6. The volume of bedload discharged at the mouths of the Tukituki and Esk Rivers during floods and the rate of distribution of these subtidal deltaic sediments along the coast.

RECOMMENDATION

i. Existing coastal monitoring programmes managed by both HBRC and Port of Napier Ltd., should be revised where appropriate, to provide quantitative information on the 6 issues listed above to the satisfaction of Napier City Council.

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- **Figure 8:** Recommended profiles at 3 representative sites along Westshore to improve the performance of the Westshore Nourishment Scheme. 33

TABLE CAPTIONS

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covering nourishment and survey periods; Column (D) net volume change to beach between Stations; Column (E) cumulative net volume change for the 4 beach compartments and for total system; Column (F) rates of change; Column (G) cumulative net rates of change for each of the 4 beach compartments and for the entire North Napier System (Data Source: Jones Zorn Surveying Ltd). Figures 1 & 3 show Station locations. 10

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- **Table 10**: Recommended design parameters for the artificial beach ridge along Southern Westshore between HBRC Profiles W-40 and W-60. All horizontal measurements are in relation to the landward point of origin of the 2 December 2002 Profile survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m). 32

- **Table 11**: Recommended design parameters for the artificial embankment along The Esplanade between HBRC Profiles EA and E24. All horizontal distances are in relation to the landward point of origin of the 2 December 2002 profile Survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m). 32

APPENDICES

APPENDIX 1: HBRC Profile Data

REVIEW OF THE WESTSHORE NOURISHMENT SCHEME

by
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1. INTRODUCTION

On 23 October 2002, Coastal Management Consultancy Limited (CMCL) were commissioned by Napier City Council (NCC) to review the Westshore Nourishment Scheme. The primary purpose of the review is to improve the "*efficiency, effectiveness and sustainability*" of the scheme which commenced in January 1987, and is expected to continue at least through this century. The specific objectives of the review are to:

4. **REVIEW** the current Westshore nourishment scheme to improve its effectiveness and sustainability during this century, with special reference both to mitigating coastal erosion between Scarpa Flow and Fenwick Street, and ensuring the sustainability of the Pacific Beach supply source and any other potential sources.

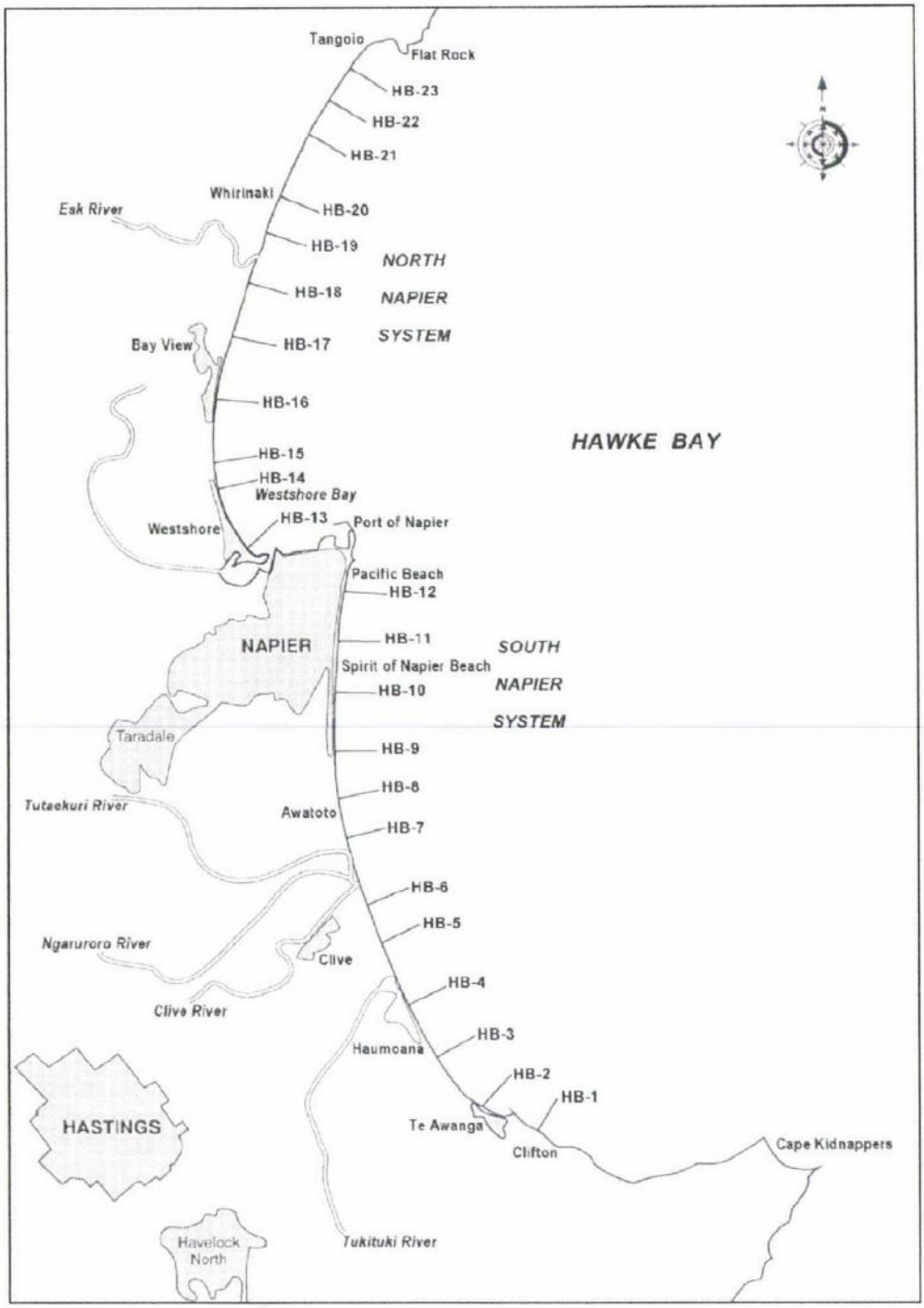
5. **INITIATE** steps to guarantee the operation of the Westshore nourishment scheme on a sustainable basis before considering the adoption and implementation of the much-reduced 2001 Coastal Hazard Zone for **Scenario 2** that assumes the continuation of the scheme.

6. **REVIEW** the current coastal monitoring programme of Hawke's Bay Regional Council between Ahuriri Entrance and Esk River mouth to ensure its effectiveness and sustainability at quantifying the effects of both coastal hazards and the Westshore nourishment scheme.

According to NCC, the objectives of the Westshore Nourishment Scheme in order of importance are to:

1. Mitigate the hazard of long-term coastal erosion along Westshore.
2. Maintain and enhance the amenity of the Westshore coastal environment.
3. Remedy the hazard of occasional flooding from the sea.

(John O'Shaughnessy & Bill McWatt, NCC, pers. comm., Nov. 2002)



• **Figure 1:** Sketch map showing the review area along the Napier City coastline between the Ngaruroro River mouth and the Esk River mouth and the location of the HBRC HB Series profiles utilised in this review between HB-7 and HB-23.

The co-operation of Jones Zorn Surveying Ltd, Port of Napier (Port), Hawke's Bay Regional Council (HBRC), NCC and Kamen Ganev, Consulting Engineer, with respect to either providing data or feedback on drafts of this report is much appreciated. Reports and papers referred to in this study are listed in the References at the back of the report. Figure 1 shows the area encompassed by this review.

2. METHODS

The conceptual framework adopted for this review is the sediment budget approach developed and published by Adams and Gibb (1982). These authors developed sediment budgets for the 220km-long coast between Oamaru and Banks Peninsula. The 220km was split into 2 compartments, the 84km-long Waitaki System and the 136km-long Canterbury System.

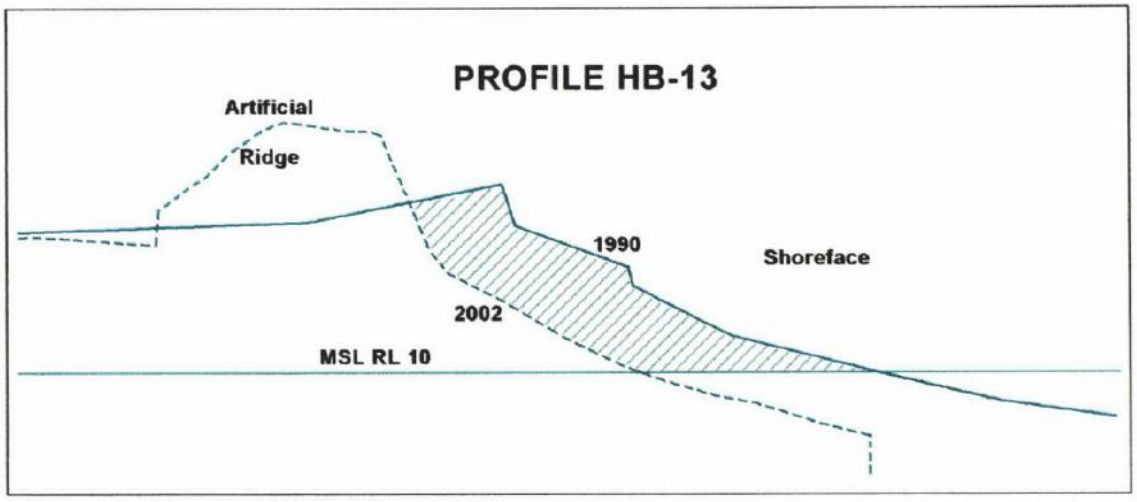
Both the Waitaki and Canterbury Systems have much in common with the study area. Within both systems, the mixed greywacke Gravel and Sand beaches are supplied from eroding seacliffs and from rivers. There is a strong net Northerly Longshore drift toward Banks Peninsula generated by prevailing high-energy ocean swells from the Southerly quarter. Both systems are separated by Port of Timaru, an artificial breakwater harbour similar to Port of Napier that was constructed between 1874 and 1906 (Adams and Gibb 1982).

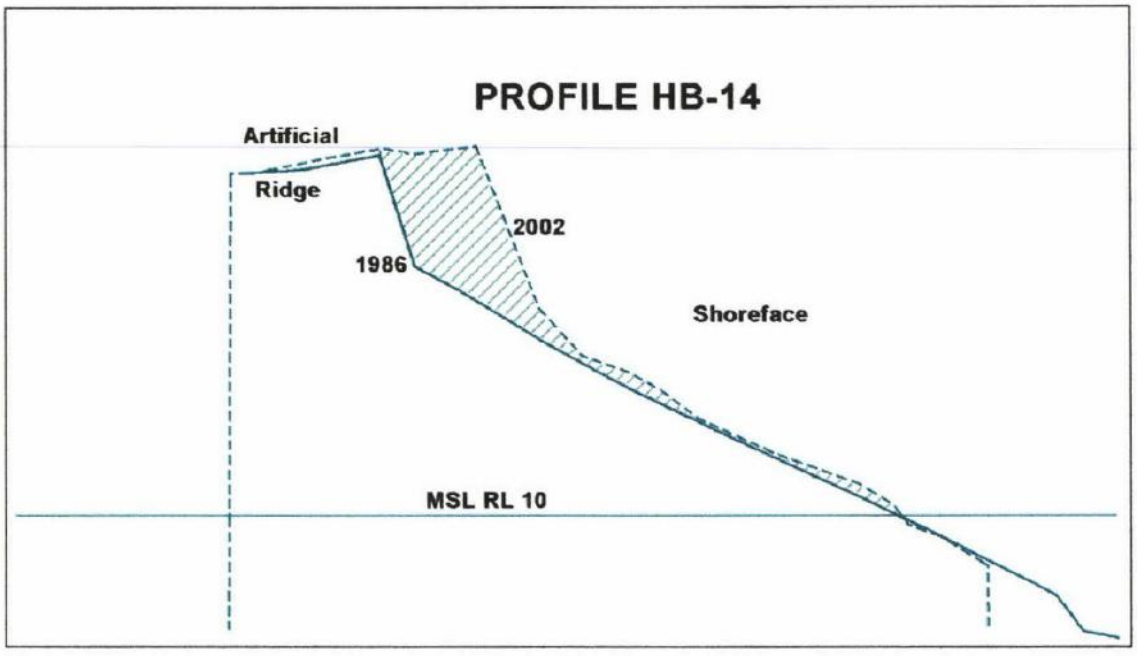
For the purposes of this review, the Napier City barrier beach systems are divided into 2 systems, the South Napier System between the Ngaruroro River mouth and Port of Napier, and the North Napier System between the Ahuriri Entrance and Esk River mouth. Both coastal systems are about 10km in length. Sediment budgets are developed for each system involving quantifying both sediment inputs and outputs. The sediment budgets are confined to the shoreface above MSL (Figure 2) and to the relatively coarse sediment transported as bedload in this dynamic zone. Owing to a lack of survey data the sediment budget beach components do not extend below MSL to the beach closure depth. Inputs and outputs were quantified as follows:

- ***Net Northerly Longshore Transport Rates***:- Inferred where possible from previous work, and the sediment budget analytical process in this study. These rates are regarded here as best estimates within the constraints of the other data.

- ***River inputs***:- Quantified from HBRC reports supplied by Graham Edmondson, Senior Engineering Officer, HBRC, and his best estimate for the Esk River. These volumes are regarded as best estimates as they are not direct measurements of volumes discharged to the sea at the river mouths.

- ***Barrier Shoreface Erosion and Accretion Volume Changes***:- Quantified from HBRC beach profiles re-surveyed in this study by Jones Zorn Surveying Ltd in December 2002, for a common starting survey period for each profile generally covering the beach nourishment programme (1986-2002) along the North Napier System and the last 10years (1992-2002) along the South Napier System. Figure 2 indicates the shoreface area adopted for the analysis to achieve internal consistency. Volumes are regarded here as minimal best estimates owing to survey limitations such as varying survey periods, random distances apart of profiles, and survey coverage across each profile.





- **Figure 2:** Shaded zone on HBRC Profiles HB-13 (Southern Westshore) and HB-14 (the Esplanade) indicates the area of shoreface quantified for sediment budget purposes. The selected zone is regarded here as a minimum as it does not take account of changes along the entire profile below MSL due to survey limitations.

- ***Offshore Dump Site "R" Volume Changes***:- Quantified from bathymetric surveys supplied by Keith Rodel, Engineering Services Manager, Port of Napier Ltd., and analysed by both Kamen Ganev, Consulting Engineer and Craig Goodier, Design Engineer, HBRC, for the period 1988-1998. Like beach volumes, seabed volumes are regarded here as minimum best estimates for Dump Site "R" owing to variations in survey. The changes recorded may or may not be indicative of changes occurring over the entire seafloor of Westshore Bay.

- ***Mining Volumes***:- Quantified from annual records held by HBRC, for the period 1993-2002 for Pacific Beach and 1973-2002 for Awatoto. The volumes for Awatoto are regarded here as minimum as the values supplied by the company have not been independently verified. The volumes for Pacific Beach are regarded as reliable.

- ***Nourishment Volumes***:- Quantified from annual records held by HBRC, NCC, Port of Napier, and Gibb (2002, table 6), for the period 1987-2002 (onshore) and 1982-2000 (offshore). These volumes are regarded as reliable.

- ***Coarse Sediment Abrasion volumes***:- Inferred from the sediment budget analytical process in this study using the findings of Adams and Gibb (1982) as a guideline. These volumes are regarded as best estimates within the constraints of the other data.

Derivation of the above parameters provided the basis for satisfying the objectives of this review.

3. SEDIMENT BUDGET PARAMETERS

In this section of the report the various parameters to quantify sediment budgets for both the South Napier System and North Napier System are quantified.

3.1. NOURISHMENT AND MINING VOLUMES

For this review, sediment volumes for the Westshore Nourishment Scheme placed within the North Napier System are given for both above Mean Sea Level (MSL) (Table 1) and below MSL (Table 2). Table 1 also provides volumes of sediment mined from both Pacific Beach and Spirit of Napier Beach (South Napier System) for the Westshore Nourishment Scheme. Volumes of sediment mined from Awatoto (South Napier System) are provided in Table 3. For Tables 1 and 3, information was kindly provided by Hawke's Bay Regional Council (Graham Edmondson, Senior Engineering Officer, pers. comm., 2002). For Table 2, information was kindly provided by Port of Napier Ltd (Keith Rodel, Engineering Services Manager, pers. comm., 2002).

Table 1 reveals that since the Westshore Nourishment Scheme began in January 1987, a total volume of 233,800m^3 of predominantly Fine Gravel has been placed on the beach above MSL at Westshore between January 1987 and October 2002. Of this volume, an estimated 155,100m^3 was placed on the foreshore and 78,100m^3 was used to construct an artificial gravel barrier ridge (Kamen Ganev, pers. comm. 2001). Of the 233,800m^3, about 94,700m^3 (40%) was placed along Southern Westshore between Whakarire Avenue and about Fenwick Street at 7,892m^3/year (Table 1), and 139,100m^3 (60%) was placed along The Esplanade at 8,694m^3/year (Table 1).

Table 2 reveals that both prior to and during the Westshore Nourishment Scheme, a total volume of 304,007m^3 of predominantly Fine Sand has been dumped on the nearshore seabed off Westshore between MSL and about –7m water depth, at an average rate of 16,889m^3/year. Of this volume, 77,230m^3 was dredged from the Ahuriri Inner Harbour at an average rate of 4,291m^3/year (1982-2000), and 226,777m^3 was dredged from the Fairway to Port of Napier at an average rate of 28,347m^3/year (1989-1997).

Most, if not all, of the Fine Sand was of recent deposition along the Eastern sides of both harbour channels and was dredged to maintain safe navigable depths (Peter Frizzell, Coastal Zone Management Consultant, pers. comm. 2002). As noted later in this report, the dredged sand is unlikely to be recycled sediment in Westshore Bay but is continually bypassing the Port of Napier into the Bay by mass transport from sources South of the Port.

Table 3 reveals that between 1973 and 2002 inclusive, about 1,510,606m^3 of coarse sediment have been mined from the Awatoto foreshore at an average rate of 50,354m^3/year. Average extraction rates per decade have ranged from 45,149m^3/year (1983-1992) up to 57,970m^3/year (1973-1982) (Table 3). Further north, 12,500m^3 were extracted from Spirit of Napier Beach in October 1999. At Pacific Beach, 146,300m^3 were extracted between 1993 and 2002 at an average rate of 16,256m^3/year, ranging from 41,000m^3 in 1993 to 12,000m^3 in other years (Table 1).

The sediment mined from Awatoto was used for industrial-commercial purposes, the sediment mined from Spirit of Napier and Pacific Beaches was used for the Westshore Nourishment Scheme. Over the last 5 years, the average annual extraction rate in total from the 10km-long South Napier System foreshore was about 65,000m^3/year (Tables 1 & 3).

• **Table 1:** Sediment deposited above MSL that contributed to the Westshore Nourishment Scheme since its inception in January 1987. (Info. Sources: Table 6, Gibb 2002; Graham Edmondson, HBRC, pers. comm. Nov 2002). Note that an estimated total of 66% was placed on the active foreshore and 34% out of reach of the waves on the back barrier to form an artificial beach ridge (Info. Source: Kamen Ganev, Dec. 2001).

LOCATION	DATE	VOLUME (m^3)	SOURCE AREA	SEDIMENT GRADE	PLACEMENT AREA	
					FORESHORE	BACK BARRIER
The Esplanade North (E1-E15)	January 1987	22,000	Wildlife Ponds	Mixed Fine Gravel, Silt and Sand	50%	50%
The Esplanade (E1-E25)	November 1987	20,000	Wildlife Ponds	Mixed Fine Gravel, Silt and Sand	50%	50%
The Esplanade South (E15-W53)	November 1988	27,000	Wildlife Ponds	Mixed Fine Gravel, Silt and Sand	50%	50%
Charles St to The Esplanade (W40-W53)	March 1991	6,000	Wildlife Ponds	Mixed Fine Gravel, Silt and Sand	100%	
Charles St to Fenwick St (W40-W51C)	March 1993	16,500	Pacific Beach	Medium Size Gravel	20%	80%
The Esplanade (E3-E25)	December 1993	24,500	Pacific Beach	Fine Gravel	80%	20%
Charles St to Gardiner St (W40-W51)	November 1994	12,000	Pacific Beach	Fine Gravel	50%	50%
Whakarire Ave	October 1995	4,500	Pacific Beach	Fine Gravel	100%	-
The Esplanade (E1-E25)	October 1995	12,000	Pacific Beach	Fine Gravel	80%	20%
Whakarire Ave to Alfred St (W40-W50C)	October 1996	8,500	Pacific Beach	Fine Gravel	60%	40%
Whakarire Ave	October 1996	3,500	Pacific Beach	Fine Gravel	100%	-
Whakarire Ave to Tareha St (W40-W44)	September 1997	2,600	Pacific Beach	Fine Gravel	100%	-
Ferguson Ave (W50A-W51)	September 1997	1,800	Pacific Beach	Fine Gravel	80%	20%
The Esplanade (EB-E21)	September 1997	10,600	Pacific Beach	Fine Gravel	70%	30%
Whakarire Ave to Alfred St (W39-W50C)	October 1998	13,000	Pacific Beach	Fine Gravel	80%	20%
Ferguson Ave (W50A-W50C)	October 1999	1,500	Spirit of Napier Statue	Fine Gravel	100%	-
The Esplanade (EA-E20)	October 1999	11,000	Spirit of Napier Statue	Fine Gravel	80%	20%
James St to The Esplanade (W41-W52A)	November 2000	12,000	Pacific Beach	Fine Gravel	70%	30%
The Esplanade (EA-E20)	October 2001	12,000	Pacific Beach	Fine Gravel	80%	20%
Alfred St (W50A-W50C)	May 2002	2,000	Pacific Beach	Fine Gravel	100%	-
Whakarire Ave to The Esplanade (W40-W52A)	October 2002	10,800	Pacific Beach	Fine Gravel	100%	-
TOTALS:		**233,800**			**155,100m^3**	**78,700m^3**

- **Table 2:** Sediment deposited between MSL and about -7m water depth that contributed to the Westshore Nourishment Scheme both prior to and after its inception in January 1987. Port Fairway refers to the dredged shipping channel leading into Port of Napier and Inner Harbour refers generally to the Ahuriri Entrance. All sediments are maintenance dredgings. Depth dumped is metres below Chart Datum (CD). Areas K, L, M, P are located off Charles Street and Ferguson Avenue in approximately 4-5m depth, Area Q off Ferguson Avenue in approximately 4-5m water depth, and Area R off Ferguson Avenue and The Esplanade in approximately 5-7m water depth. The mid-point of all dump grounds is about 0.4 nautical miles offshore. (Info. Sources; Keith Rodel & Peter Frizzell, Port of Napier, pers. comm., Nov. 2002; Paul Dunford, Napier City Council, pers. comm., Nov. 2002).

DUMP GROUND	SOURCE AREA	EVENT DATE	VOLUME DUMPED (m^3)	DEPTH DUMPED (m CD)	SEDIMENT GRADE
Area K	Inner Harbour	1982	1,700	4-5	Fine Sand and Mud
Area L	Inner Harbour	1984	9,920	4-5	Sand, Gravel, Mud
Area M	Inner Harbour	1985	2,559	4-5	Sand, Gravel, Mud
Area P	Inner Harbour	1985	4,556	4-5	Sand, Gravel, Mud
Area P	Inner Harbour	1988/89	5,165	4-5	Sand and Mud
Area R	Port Fairway	March 1989	96,000	5-7	Fine Sand
Area Q	Inner Harbour	1991	8,000	4-5	Fine Sand and Mud
Area R	Port Fairway	May 1993	56,131	5-7	Fine Sand
Area Q	Inner Harbour	November 1993	12,530	4-5	Fine Sand and Mud
Area R	Port Fairway	March 1995	44,305	5-7	Fine Sand
Area Q	Inner Harbour	April 1995	2,800	4-5	Sand, Gravel, Mud
Lower Foreshore	Inner Harbour	July 1995	19,000	0-2	Fine to Very Fine Sand
Area R	Port Fairway	December 1997	30,341	5-7	Fine Sand
Area Q	Inner Harbour	June/August 2000	11,000	3-5	Fine to Very Fine Sand
			304,007		

- **Table 3:** Annual volumes of coarse sediment mined from the foreshore at Awatoto over the last 30 years inclusive (1973-2002) (Info. Source: HBRC, 2002).

YEAR	(m^3)	DECADAL AMOUNT (m^3)	RATE (m^3/year)	YEAR	(m^3)	DECADAL AMOUNT (m^3)	RATE (m^3/year)	YEAR	(m^3)	DECADAL AMOUNT (m^3)	RATE (m^3/year)
1973	54,700			1983	58,900			1993	71,157		
1974	80,600			1984	43,900			1994	22,818		
1975	55,600			1985	51,100			1995	50,128		
1976	56,400			1986	54,300			1996	51,435		
1977	52,600			1987	39,700			1997	47,288		
1978	48,900			1988	39,000			1998	52,024		
1979	60,300			1989	40,764			1999	48,431		
1980	45,000			1990	43,996			2000	48,024		
1981	45,600			1991	47,068			2001	42,556		
1982	80,000			1992	32,765			2002	45,552		
		579,700	57,970			451,493	45,149			479,413	47,941
								Total Mined 1973-2002:		**1,510,606**	**50,354**

3.2. BARRIER EROSION-ACCRETION VOLUME CHANGES

Tables 4 and 5 provide changes in shoreface volume above MSL between HBRC beach profile sites for the North Napier and South Napier Systems, respectively. Because of the variability in survey intervals between the HBRC profile series (Column C, Tables 4 & 5) it was necessary to express all changes in rates of cubic metres per year (m^3/y). In the following discussion, average rates determined in Tables 4 and 5 are rounded upwards to the nearest $500m^3$ to allow for unknown changes below MSL. Although the North Napier System finishes at the Napier City boundary at Esk River mouth, it was decided to continue the analysis to Tangoio as the 17km-long barrier beach is all part of a continuous, interdependent system. Figures 3 and 4 show the location of the HBRC Profile sites listed in Tables 4 and 5, respectively.

Notwithstanding the effects of beach nourishment since about 1987, the North Napier System is found to be in net deficit and to be losing coarse sediment at an average rate of approximately $-13,500m^3$/year over the 17km length over the 7-16 year survey interval analysed (Table 4). In direct contrast and notwithstanding the effects of beach mining at both ends, the South Napier System is found to be in net surplus and to be gaining coarse sediment at an average rate of approximately $11,500m^3$/year over the 8.7km length over the 8-10 year survey interval analysed (Table 5).

3.2.1. North Napier System

Within the Northern barrier beach system, the average net loss does not occur everywhere (Table 4). Along The Esplanade (1,706m) and Bay View (2,358m) there has been net deposition at average rates of approximately $3,500m^3/y$ and $3,000m^3$/year between 1986 and 2002, respectively. The net deposition trend is believed here to be entirely due to the combined effects of the Westshore Nourishment Scheme since January 1987 and offshore dumping of dredgings since 1982. There is little doubt that the Scheme has directly helped to reverse a long-term erosion trend in both areas.

In contrast, along Southern Westshore (1,192m), from Bay View to the Esk River mouth (4,517m), and from the river mouth to Tangoio (7,112m), there has been net erosion at approximately $-3,500m^3$/year (1990-2002), $-7,500m^3$/year (1991/95-2002), and $-9,000m^3$/year (1991-2002), respectively (Table 4). Despite beach replenishment along Southern Westshore the beach profile has continued to retreat, owing to the shoreline curve being slightly seaward of its natural alignment in this area (Kamen Ganev, pers. comm. 2003). For the 3 eroding areas, a net deficit in supply rates and swash-backwash abrasion of coarse sediment have contributed significantly to the erosion trend.

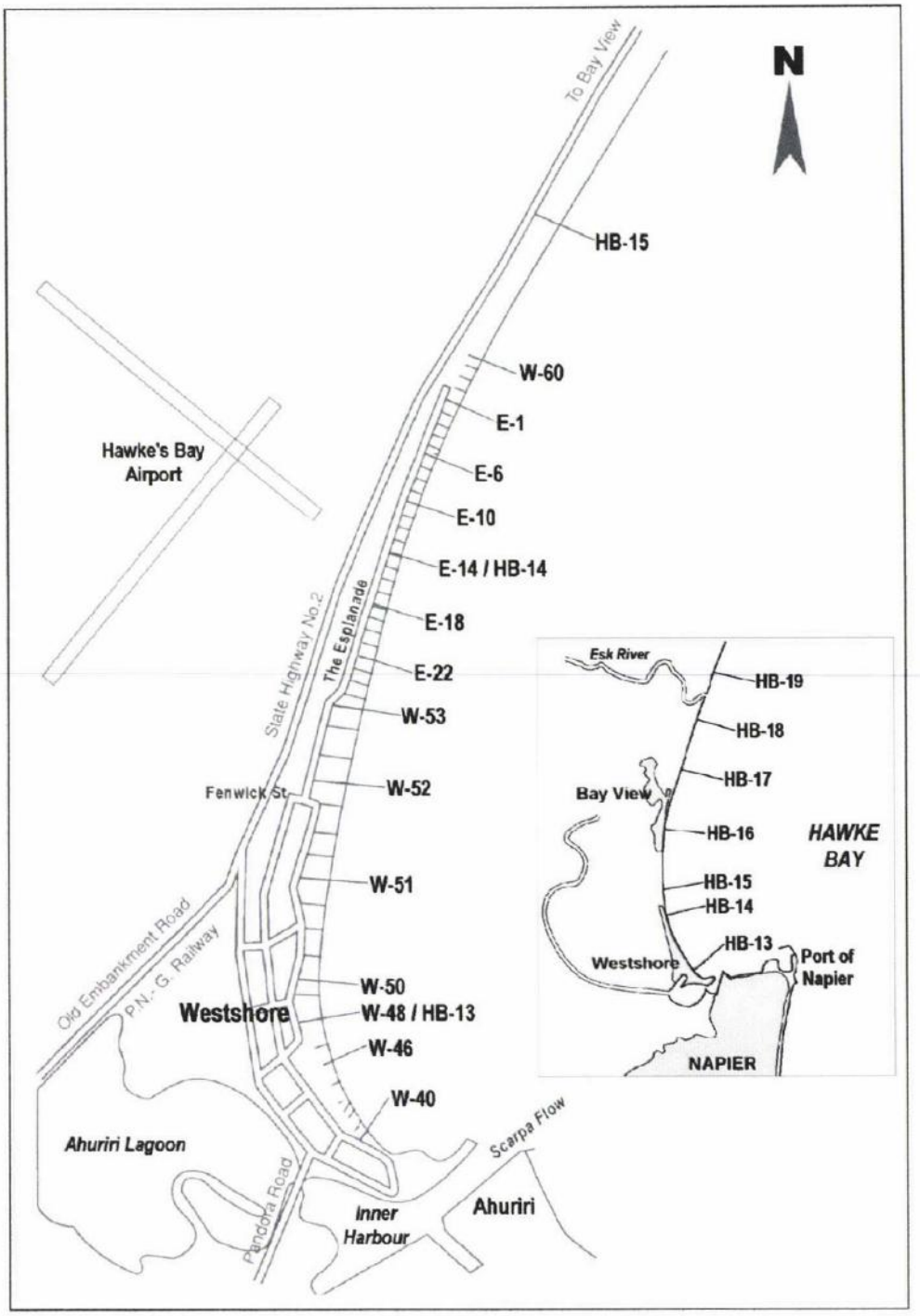
3.2.2. South Napier System

Within the South Napier System, the average net gain diminishes Northwards from about $6,000m^3$/year at Awatoto (1,450m), to about $5,000m^3$/year along the Mid-Beach Domain area (6,270m), to about $1,500m^3$/year along Pacific Beach (970m) (Table 5). The reduction in net accretion rates Northwards of Awatoto over the last decade or so, is believed here to be due to the combination of beach mining at both Awatoto and Pacific Beach, swash-backwash abrasion, and an overall reduction in the rate of the net Northerly longshore drift toward Port of Napier in proportion to a reduction Northwards of the angle of incidence of breaking waves to the beach as shown by wave refraction analysis (Gibb 1962).

- **Table 4:** Volumes of coarse sediment deposited (+) or lost (-) from the shoreface above MSL along the North Napier System since the Westshore Nourishment Scheme began in January-November 1987 along The Esplanade (Stations W-52 to E-A) and in March 1991-1993 along Ferguson Avenue-Charles Street (Stations W-40 to W-51). Column (A) are HBRC profiles and street names; Column (B) cumulative horizontal distances between profile bench marks North of profile W-40; Column (C) survey interval covering nourishment and survey periods; Column (D) net volume change to beach between Stations; Column (E) cumulative net volume change for the 4 beach compartments and for total system; Column (F) rates of change; Column (G) cumulative net rates of change for each of the 4 beach compartments and for the entire North Napier System (Data Source: Jones Zorn Surveying Ltd). Figures 1 & 3 show Station locations.

A		B	C	D	E	F	G
STATION		DISTANCE (m)	SURVEY INTERVAL	NET VOLUME CHANGE (m^3)	CUMULATIVE NET VOLUME (m^3)	RATES (m^3/y)	CUMULATIVE NET RATES (m^3/y)
W-40	Charles St	0	1990-2002				
W-42	Charles St	67.55	1990-2002	-1,536.8		-128.1	
W-45	Charles St	206.33	1990-2002	-3,219.7		-268.3	
W-46	Charles St	305.71	1990-2002	-2,111.8		-176.0	
W-48 / HB-13	North Terrace	479.34	1990-2002	-5,764.5		-480.4	
W-50	Ferguson Ave	649.13	1990-2002	-8,251.8		-687.7	
W-51	Ferguson Ave	1,011.24	1990-2002	-14,683.6		-1,223.6	
Mid-profile distance		1,192.36		-1,901.7	-37469.9	-158.5	-3,123
W-52	The Esplanade	1,373.47	1986-2002	1,131.9		70.7	
W-53	The Esplanade	1,686.33	1986-2002	12,842.9		802.7	
E-24	The Esplanade	1,786.33	1986-2002	7,555.0		472.2	
E-22	The Esplanade	1,886.33	1986-2002	6,700.0		418.8	
E-20	The Esplanade	1,986.33	1986-2002	4,730.0		295.6	
E-18	The Esplanade	2,086.33	1986-2002	3,015.0		188.4	
E-16	The Esplanade	2,186.33	1986-2002	2,065.0		129.1	
E-14 / HB-14	The Esplanade	2,286.33	1986-2002	2,250.0		140.6	
E-12	The Esplanade	2,386.33	1986-2002	2,475.0		154.7	
E-10	The Esplanade	2,481.33	1986-2002	2,161.3		135.1	
E-8	The Esplanade	2,573.83	1986-2002	1,618.8		101.2	
E-6	The Esplanade	2,666.33	1986-2002	1,225.6		76.6	
E-4	The Esplanade	2,760.33	1986-2002	1,222.0		76.4	
E-2	The Esplanade	2,853.33	1986-2002	1,957.7		122.4	
E-A	The Esplanade	2,952.33	1986-2002	2,866.0	53,816.2	179.1	3,364
W-60	Reserve	3,095.33	1986-2002	1,901.9		118.9	
HB-15	Airport Beacons	3,690.33	1986-2002	9,728.3		608.0	
HB-16	Fannin St	5,310.33	1986-2002	30,456.0	42,086.2	1,903.5	2,630
HB-17	Rogers Rd	6,885.33	1995-2002	-9,135.0		-1,305.0	
HB-18	Le Quesne Rd	8,462.33	1991-2002	-63,710.7		-5,791.9	
	Esk River Mouth	9,927.33			-72,845.7		-7,097
HB-19	North Shore Rd	10,616.33	1991-2002	-153,566.4		-13,960.6	
HB-20	Whirinaki	11,863.80	1991-2002	-47,620.6		-4,329.1	
HB-21	Whirinaki Bluff	13,663.90	1991-2002	20,791.1		1,890.1	
HB-22	Pakuratahi	15,322.50	1991-2002	47,684.8		4,335.0	
HB-23	Tangoio	17,039.70	1991-2002	34,344.0	-98,367.1	3,122.2	-8,942
Total cumulative net beach volume change for North Napier Barrier System:					**-112,780.4**		**-13,168**

Explain



• **Figure 3**: Sketch map showing the general location of the HBRC beach profile sites listed in Table 4, along the North Napier System.

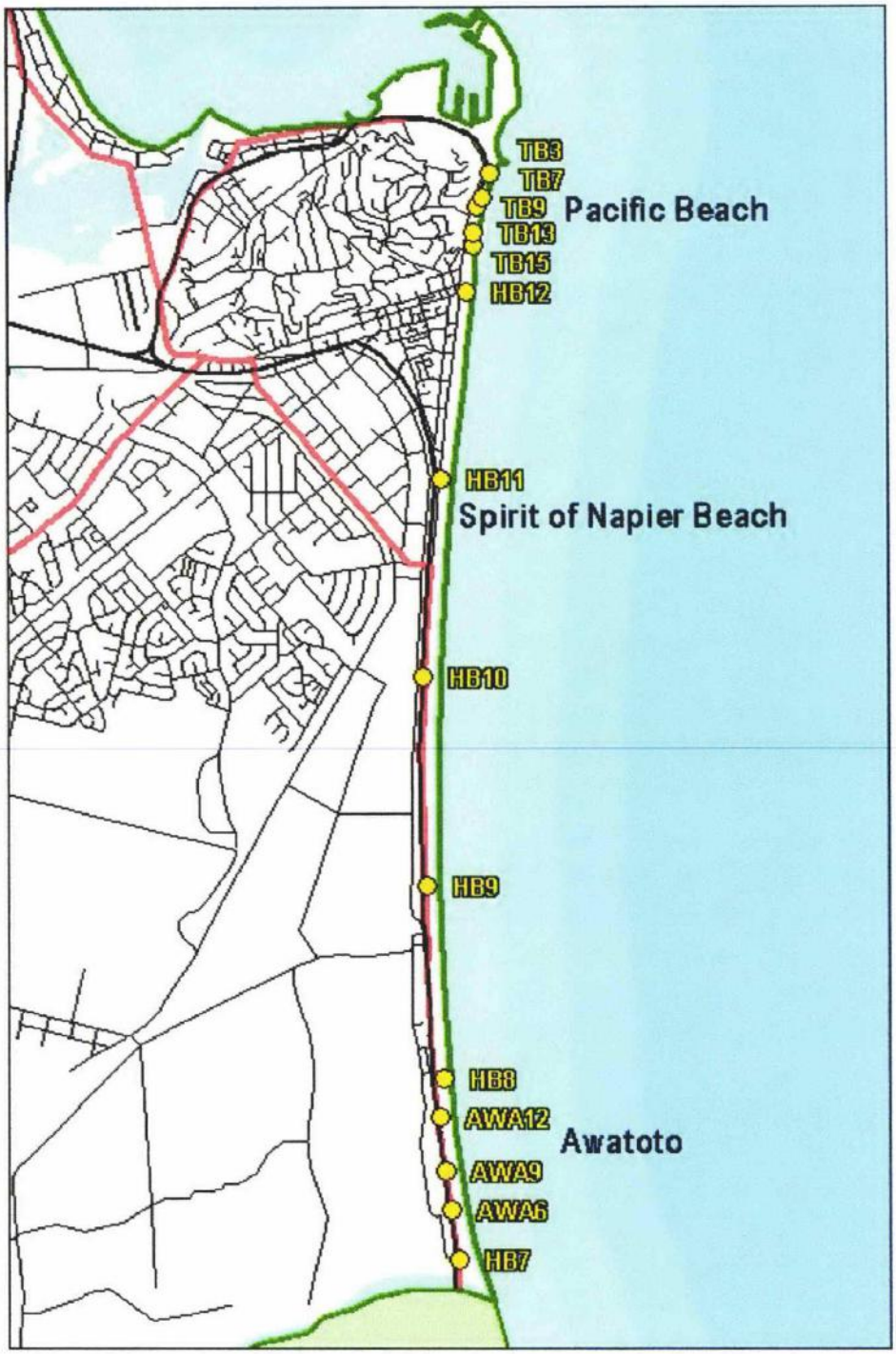
• **Table 5:** Volumes of coarse sediment deposited (+) or lost (-) from the shoreface above MSL along the South Napier System over the last decade since sediment was extracted for the Westshore Nourishment Scheme. Column (A) are HBRC profiles and location names; Column (B) cumulative horizontal distances between profile bench marks North of profile HB-7; Column (C) survey interval covering extraction and survey period; Column (D) volume change to beach between Stations; Column (E) cumulative net volume change for the 3 beach compartments and for total system; Column (F) rates of change per annum; Column (G) cumulative net rates of change for each of the 3 beach compartments and for the entire South Napier System (Data Source: Jones Zorn Surveying Ltd.). Figure 4 shows station locations.

A		B	C	D	E	F	G
STATION		DISTANCE (m)	SURVEY INTERVAL	VOLUME CHANGE (m^3)	CUMULATIVE NET VOLUME (m^3)	RATES (m^3/y)	CUMULATIVE NET RATE (m^3/y)
AWA-2 / HB-7	Ngaruroro River North	0	1992-2002	-		-	
AWA-6	Waitangi Rd	399.7	1992-2002	20,784		2,078.4	
AWA-9	Awatoto	712.3	1992-2002	12,254		1,225.4	
AWA-12	Awatoto	1,146.9	1992-2002	15,472		1,547.2	
AWA-15 / HB-8	Normanby St	1,448.6	1992-2002	7,724	56,234	772.4	5,623
HB-9	Beach Domain	2,981.7	1992-2002	2,530		253.0	
HB-10	Beach Domain	4,648.7	1992-2002	-83		-8.3	
HB-11	Spirit of Napier	6,217.9	1992-2002	33,895		3,389.4	
HB-12	Napier Beach	7,721.4	1992-2002	9,021	45,363	902.1	4,536
TB-15	Pacific Beach	8,084.3	1993-2002	-7,222		-802.4	
TB-13	Pacific Beach	8,199.4	1994-2002	-1,421		-177.6	
TB-9	Pacific Beach	8,394.1	1993-2002	3,719		413.2	
TB-7	Pacific Beach	8,492.6	1993-2002	4,792		532.4	
TB-3	Pacific Beach	8,692.1	1993-2002	11,092	10,960	1,232.4	1,198
Total cumulative net beach volume change for South Napier System:					**112,556**		**11,357**

3.3. RIVER CONTRIBUTIONS

Table 6 summarises the estimated bedload contributions of rivers to the Napier barrier beaches. The volume of river bedload discharged to the coast is directly related to the frequency of floods of sufficient magnitude to transport gravel and coarse sand (Gary Clode, pers. comm. 2003). Of the 4 rivers, the Tutaekuri and Ngaruroro discharge only Fine Sand and Mud to the sea as suspended load. Since the lower reaches of the Ngaruroro were diverted in 1960, the gravel bed has migrated about 600m downstream at 14m/year. At its current rate of migration and distance from the coast of 5,700m (Kamen Ganev, pers. comm., Dec. 2002), the gravel front is unlikely to reach the coast for about 400 years.

Only the Tukituki and Esk Rivers contribute bedload to the coast (Table 6). The best estimate for the Esk River is an average discharge of approximately 2,000m^3/year (Graham Edmondson, pers. comm. 2003). Coarse sediment discharged by the Tukituki River into the coastal system during episodic floods forms a temporary sub-tidal delta at the mouth. The delta is quickly driven onshore by breaking waves to coalesce with the beach as a visible bulge in the shore adjacent to the mouth. Depending on the frequency and magnitude of South-Southeasterly swells the Tukituki-derived bedload is then quickly transported away by the net Northerly longshore drift over periods of weeks or months. Although not observed, the same distribution process can be expected to apply to the Esk



• **Figure 4:** Sketch map showing the general location of the HBRC Beach profile sites listed in Table 5, along the South Napier System (Map provided by Simon Nitz, GIS Analyst, NCC pers. comm., Dec. 2002).

River which last saw a decent flood in 1988 (Graham Edmondson, pers. comm. 2003). Clearly, an accurate way of recording the amount of bedload discharged at the coast is to measure the volume of sediment in the delta deposited immediately after a flood.

• **Table 6:** Estimated bedload transport in lower reaches of the 4 rivers with potential to supply the Napier barrier beach systems plus estimated supply of bedload to the coast [Info. Sources: HBRC Reports by McBryde (1989); Williams (1997); Edmondson (2000, 2001, 2001) and pers. comm. 2003; and Kamen Ganev, pers. comm. 2002].

RIVER	Long-Term Supply to Lower Reach (m^3/year)	Coastal Output (m^3/year)	Barrier Beach System Affected
Esk	4,000	2,000	North Napier
Tutaekuri	28,000	0	South Napier
Ngaruroro	50,000	0	South Napier
Tukituki	43,000	28,000	South Napier

3.4. NET NORTHERLY LONGSHORE TRANSPORT RATES

When breaking waves strike the shoreline at an angle they induce a longshore current by which water plus sediment placed in suspension by the breaking wave, moves along parallel to the shoreline in the forward direction of the breaking wave. In addition, coarse sediment is pushed and rolled along the nearshore seabed and across the shoreface as bedload, tracing a sawtooth path in the direction of wave travel. Both suspended load and bedload sediment transported alongshore in the surf-zone by wave action are collectively termed *longshore drift*. As the angle of incidence of waves to the shore reduces so does the *longshore transport rate* (Gibb 1980).

The longshore transport rate is indicated by the symbol **Q**, and is given in cubic metres per year (m^3/year). The *gross longshore transport rate* (**Qg**) is the total amount of sediment moving in either direction each year within a beach system (Gibb 1980) and is expressed by the equation:

$$Qg = (a + b)\, y^{-1} \qquad \text{Eqn [1]}$$

Where: **a** = sediment volume moving downdrift from source.
b = sediment volume moving updrift from source.

The *net longshore transport rate* (**Qn**) is the difference between the amounts moving updrift (**b**) and downdrift (**a**) each year (Gibb 1980) and is expressed by the equation:

$$Qn = (a - b)\, y^{-1} \qquad \text{Eqn [2]}$$

Within the Hawke's Bay region generally, and the study area specifically, there is compelling evidence for a *net Northerly longshore drift* generated by deep-water waves from the South-Southeast quarter (Marshall 1927, 1929; Gibb 1962, 1980, 1996, 2002; Smith 1984). What this means in practice is that the predominant effects of either extracting or depositing sediment on the beach or blocking sediment transport by placing structures across the surf-zone, will mostly be felt downdrift or North of the site of activity.

Little is known of the proportion of net Northerly longshore drift to the gross longshore drift in the study area. Looking seaward from the beach, the net Northerly drift requires most waves to approach from the right. At Marine Parade, observations of wave directions between 1975 and 1980 revealed that about 55% of all waves approached the beach from the right and 42% from the left (Gibb 1996). Daily observations of wave directions at the same area between August 1998 and March 2001 revealed that 53% of all waves approached from the right and 47% from the left (Kamen Ganev, pers. comm., Dec. 2002).

In contrast, at Westshore daily observations between August 1998 and March 2001 revealed that 73% of all waves approached from the right and 27% from the left (Kamen Ganev, pers. comm., Dec. 2002). The short-duration of these observations means that the results must be treated with caution when quantifying net longshore transport rates. Notwithstanding, these observations are entirely consistent with the geological evidence for a net Northerly longshore drift at various rates along the barrier system.

3.4.1. South Napier System Net Longshore Transport Rates

For the South Napier system construction of rock groynes at East Clive in the early 1990s and Haumoana in February 1999 provide an opportunity to determine transport rates from gravel accumulation on the updrift (South) side of the groynes. The Haumoana groyne initially trapped the net Northerly longshore drift at 110m^3/day (c.40,000m^3/year) (Kamen Ganev, pers. comm., 2002) before the resumption of the net Northerly drift along the coast. Downdrift, across the mouth of the Tukituki River, the barrier retreated rapidly from erosion until the new shoreline equilibrium was established.

This volume, however, falls far short of the actual volume trapped as it only relates to accumulation above low tide level and is restricted to a distance 400m South of the structure. It is known that the total accumulation extended below Low Tide level and further South by several hundred metres. A more likely accumulation rate may be of the order of 70-80,000m^3/year boosted by outputs from the Tukituki River, which would be entering the South Napier System at Awatoto to sustain the barrier system.

According to Smith (1984), net Northerly transport rates decrease from about 57,000m^3/year near Awatoto to about 6,000m^3/year near the Port of Napier weather breakwater. From sediment accumulations against the weather breakwater following construction, Gibb (1980; 1996) calculated accumulation rates of 20,300m^3/year for the net Northerly drift. There was a significant reduction in accumulation rates against the weather breakwater after 1959 (Gibb 1996, fig.4) as the coast completed adjustments to the displacements from the 1931 Hawke's Bay earthquake.

Lindup (1948) found no evidence of gravel bypassing the breakwater, which has also been recently confirmed by the Port of Napier from periodic examination of maintenance dredgings from the Fairway (Peter Frizzell, pers. comm., 1996 & 2002). Others believe that small amounts of gravel are bypassing but not reaching Westshore as they are trapped in the Fairway (Kamen Ganev, pers. comm. 2003). It is quite reasonable to expect a reduction in net Northerly longshore transport rates between Awatoto and the Port as the prevailing waves become increasingly parallel to the shore Northwards and swash-backwash abrasion processes steadily predominate.

Although minimal coarse sediment bedload bypasses the Port weather breakwater, Fine to Very Fine Sand suspended load continually bypasses the structure, a portion of which is

deposited in the Port Fairway. Following extensions to the weather breakwater in 1940, 120,000m^3/year of fine sediment accumulated in the lee of the breakwater (Lindup 1948). Between 1978 and 1995, 52,700m^3/year of sand accumulated in the Fairway of which 91% accumulated along the Eastern edge and the remainder along the Western edge (Gibb 1996).

Modelling by ASR (2001) suggests that 124,300m^3/year of sediment bypasses the Port "*to be dredged or carried into and across Westshore Bay each year*". A possible explanation for the difference by a factor of 2 in rates is that a portion is trapped in the Fairway and a portion crosses the Fairway into Westshore Bay.

Although the weather breakwater has effectively blocked the net Northerly longshore drift of gravel and coarse sand from reaching Westshore it has had a significant positive updrift benefit. The shoreline position for the South Napier barrier has built out against the structure increasing the relative width and volume of the barrier in front of Napier City. Without the breakwater, the shoreline would be aligned with Scinde Island and development seaward of Marine Parade would have a greater exposure to risk from coastal hazards.

3.4.2. North Napier Net Longshore Transport Rates

At the Ahuriri Entrance, Gibb (1996) estimated a net Northerly transport rate of 24,000m^3/year of coarse sediment from initial accumulations against the East Mole prior to construction effects of the Port of Napier being felt at Ahuriri. There is scant evidence today of the net Northerly longshore drift of coarse sediment bypassing either Port of Napier or the Ahuriri Entrance to reach Southern Westshore.

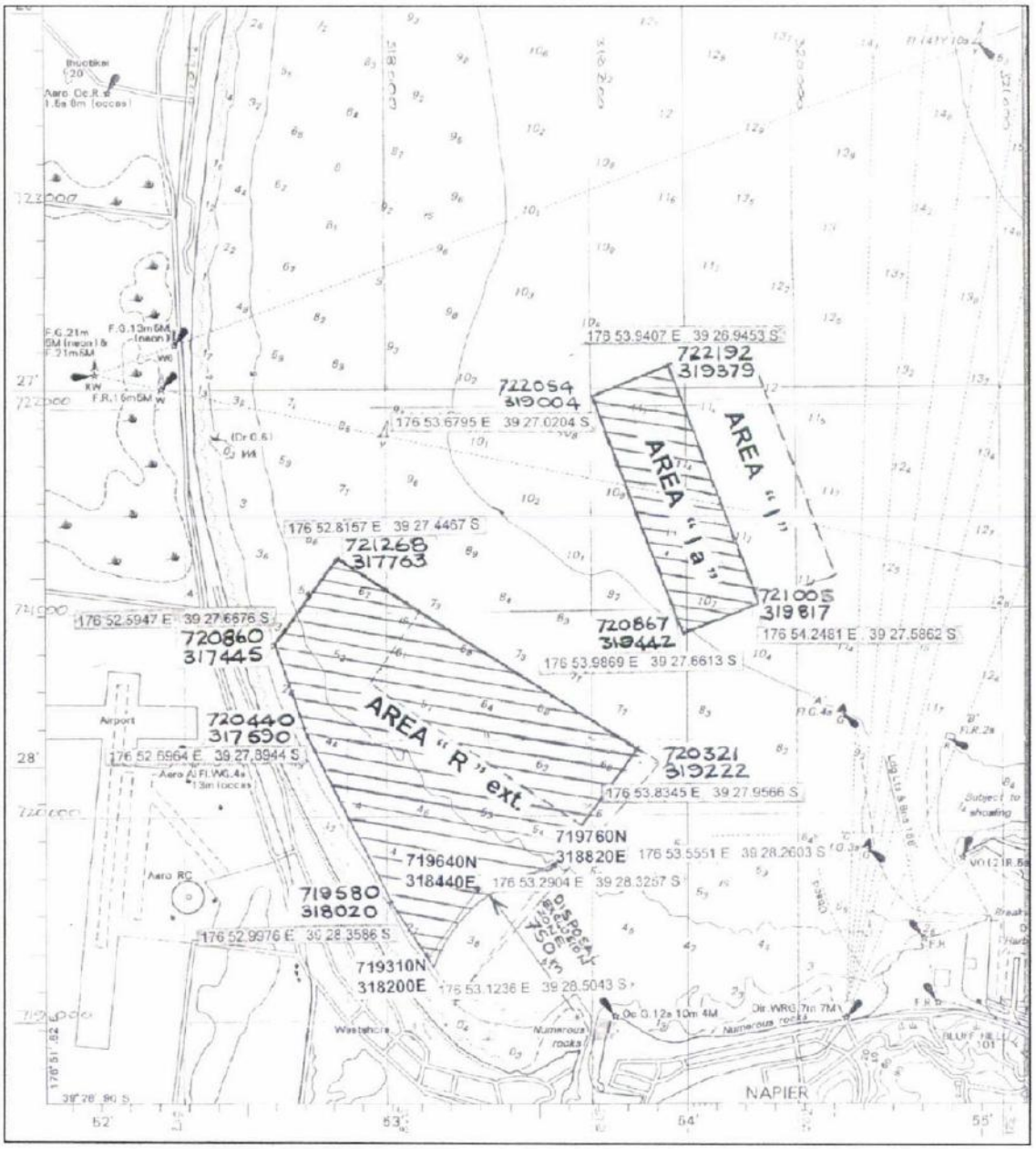
Since the 1931 Hawke's Bay earthquake and accompanying tectonic uplift, Ahuriri Harbour has acted as a sink trapping about 4,500m^3/year of Fine to Very Fine Sand (Table 2). The trapped sand mostly accumulates along the East side of the Entrance near the Iron Pot (Peter Frizzell, pers. comm., Nov. 2002), suggesting mass transport from the East of sand bypassing the Port of Napier weather breakwater. The pattern of sediment deposition in both the Port Fairway and Ahuriri Entrance is consistent with a net Southwesterly mass transport direction of Fine Sand across Westshore Bay.

For Westshore, O'Callaghan (1986) theoretically calculated potential net Northerly transport rates of 20,000m^3/year by Domain Road reducing to 14,000m^3/year by the Air Gap. Gibb (2002) determined rates of net Northerly longshore above MSL of about 10,000m^3/year along Southern Westshore, increasing to about 12,000m^3/year along The Esplanade, progressively decreasing toward Bay View as the prevailing swell increasingly paralleled the shore Northwards. For Westshore North, ASR Ltd (2001) calculated a net Northward sediment loss of about 30,000m^3/year between the -0.5 and -4.0m depth contours, equating to a probable net Northerly longshore transport rate below approximate low tide level.

3.5. MASS TRANSPORT IN WESTSHORE BAY

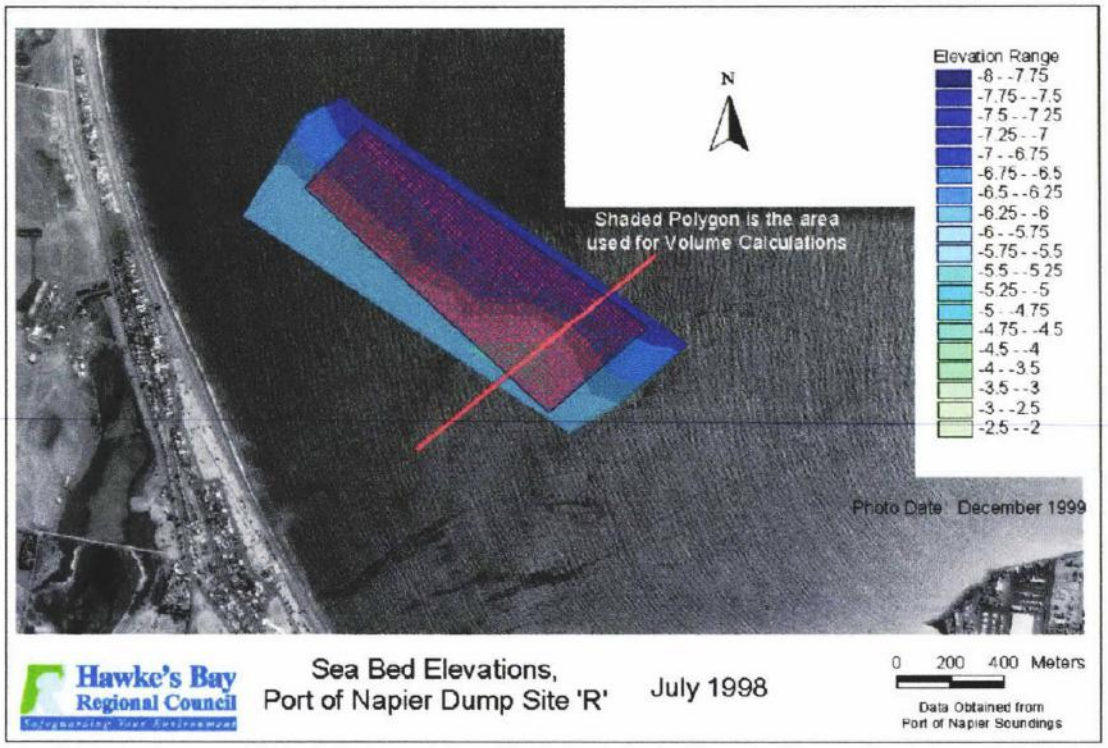
Fine Sand bypassing the Port of Napier weather breakwater at about 125,000m^3/year mostly accumulates along the Eastern sides of both the Port Fairway and Ahuriri Entrance. The consistent pattern of accumulation indicates mass transport of Fine Sand from the weather breakwater area to the Southwest into Westshore Bay. At Dump Ground "R" which is located directly off Westshore in about –3 to –7m water depth below Chart

Datum (Figure 5), the dispersal of dredgings also provides compelling evidence of the pattern of mass transport of Fine Sand in Westshore Bay.



• **Figure 5:** Chart showing location of dredge disposal grounds used by Port of Napier Ltd (Source: Port of Napier Ltd 2002).

Between December 1988 and August 1998, there have been 12 high-resolution sounding surveys of Dump Ground "R" to a vertical accuracy of ±0.1m (Peter Frizzell, pers. comm., Nov. 2002). Unfortunately, the sounding surveys vary significantly in coverage of the dredge spoil disposal site so that it is not possible to compare changes with time over the entire Dump Ground. For this review a representative polygon was selected for volumetric analysis that covered a sizeable part of the disposal site. The location of the polygon adopted is shown in Figure 6 and the results of the volumetric analysis are summarised in Table 7. In addition, a representative cross-section (Figure 6) was adopted to investigate the net direction of sediment transport that bisected the bulk of the dumped dredgings on the seabed.



• **Figure 6:** Photomap showing the location of the polygon on Dump Ground "R" used to derive volumetric changes to the seabed 1988-1998 and location of representative profile to derive sediment dispersal direction (Info. Source: Craig Goodier, HBRC).

Table 7 reveals that between December 1988 and August 1998, there has been a net accumulation of Fine Sand at about 6,300m^3/year on most of Dump Ground "R". Between March 1989 and December 1997, Table 2 reveals that 226,777m^3 of Fine Sand dredged from the Port Fairway was dumped on the disposal site at an average rate of 28,350m^3/year. Notwithstanding net accumulation at 6,300m^3/year, there is also clear evidence that dumped sediment is dispersed at rates up to and exceeding 35,000m^3/year (Table 7). The results suggest that between approximately –5 and –7m below Chart Datum, about 75-80% of dumped dredgings are dispersed by mass transport and about 20-25% have remained in situ resulting in a net shallowing of the seabed at the disposal site from 1988 to 1998.

• **Table 7:** Volumetric changes at Dump Ground "R" between December 1988 and August 1998. Volumes were determined over an area of seabed of 490,000m² with respect to –10m below Chart Datum. * Rate not calculated as period less than one year (Info. Source: Craig Goodier, HBRC, pers. comm., Dec. 2002).

SURVEY DATE	VOLUME (m^3)	DIFFERENCE (m^3)	CUMULATIVE CHANGE (m^3)	RATE (m^3/year)
December 1988	1,729,414	-	-	-
July 1991	1,804,647	72,233	72,233	27,864
May 1993	1,740,189	-64,458	10,775	-35,810
September 1993	1,776,201	36,012	46,787	*
October 1994	1,787,119	10,918	57,705	10,918
July 1996	1,782,381	-4,738	52,967	-2,632
November 1997	1,733,897	-48,484	4,483	-37,295
December 1997	1,754,922	21,025	25,508	*
July 1998	1,778,358	23,436	48,944	*
August 1998	1,791,119	12,761	61,705	*
Net rate of deposition between 1988 and 1998:				**6,296m^3/year**

The profile analysis provides evidence of the dispersal direction of the sediment. The crest height of the dump mound and distance from a fixed point were measured between dumping episodes. All measurements recorded an upslope (landward) migration of the dump mounds at rates between 35.3m/year (March 1989-July 1991) and 88.6m/year (May 1993-October 1994). There was a general flattening in gradient of the seaward slope of the mound and concomitant steepening of the landward slope. A comparison of depth contours on the 10 hydrographic survey plans (Table 7) confirmed the landward migration of sediment.

On this basis it is concluded that there is a net Southwesterly mass transport of Fine Sand in water depths of –5 to –7m below Chart Datum toward the shore. This observation is consistent with the observations from the Port Fairway and Ahuriri Entrance which substantiate a net Southwesterly mass transport of Fine Sand across Westshore Bay toward the shore in the direction of wave travel.

These observations are contrary to the findings of ASR Ltd (2001) who concluded that Dump Ground "R" was eroding at -23,490m^3/year and that mass transport of Fine Sand in Westshore Bay was to the East toward the Fairway. If this was so, then the sand being dredged from the Fairway and to a lesser extent, Inner Harbour would be recycled sand. Based on available evidence of sediment transport patterns we do not believe that the sand currently being dredged from the Fairway and Inner Harbour is sand recycled from Dump Ground "R".

Adjacent to the major spoil disposal site on Dump Ground "R" is a significant seaward bulge in beach widths adjacent to the Southern end of The Esplanade (Figure 6). This part of Westshore is now remarkably stable since the Westshore Nourishment Scheme began in January 1987. The bulge is located in the immediate direction of predominant wave travel from the dumpsite. We believe that part of the stability of this beach is due to the effects of offshore dumping at Dump Ground "R" since March 1989, reducing the erosive effects of waves on this part of Westshore. These observations in total indicate that dumping of Fine Sand on Dump Ground "R" is providing a net benefit to Westshore by

both helping to sustain the sandy beach along Westshore and mitigating any potential long-term erosion of the nearshore seabed.

3.6. SWASH-BACKWASH ABRASION

For both the North and South Napier barrier beach systems most, if not all, transport of coarse sediment occurs in the swash-backwash zone where sediment particles are pushed and rolled across the beach face, tracing a sawtooth path in the direction of wave travel. Thus, all particles are subjected to constant swash-backwash abrasion during transport across the foreshore. Adams and Gibb (1982) found that brown gravels of sandstone from slightly weathered cliff gravels (c.f. Cape Kidnappers) abraded 40% faster than fresh greywacke sandstone gravels free of defects supplied by the rivers (c.f. Tukituki River). They found that of the total coarse sediment input into the Waitaki and Canterbury Systems, about 87% and 95% by volume, respectively, were destroyed by abrasion.

Adams and Gibb (1982), found that beach Gravels generally wear by abrasion rather than by fracture. Abrasion of cobbles produced mainly Mud, which was washed offshore, and pebbles that remained on the beach undergoing further abrasion. Only small amounts of Sand were found to be produced by abrasion of greywacke gravels, and the Sand produced, if not swept off the beach was further abraded by the "*ball mill*" effect of the mobile Gravel. If there are low or reducing rates of gravel input into a system then one can expect an overall reduction in gravel textures with time toward pea gravel size from abrasion, with much of the resultant silt percolating into the barrier structure.

For the Canterbury System, Adams and Gibb determined a loss from abrasion of about 7,500m^3 of gravel annually per kilometre length of beach (7.5m^3/m/year). This rate is likely to represent an absolute upper limit for the study area beaches as they are less exposed to the prevailing South-Southeasterly swells, especially at Westshore, than the more open exposed beaches of the Canterbury-Waitaki Systems. Despite the probable lesser abrasion rates in the study area, swash-backwash abrasion is an important and often overlooked coastal process that is continually reducing the volume of the Napier barrier beach systems.

4. SEDIMENT BUDGET

Table 8 provides a beach sediment budget for the South Napier System and Table 9 for the North Napier System. Each system is subdivided into various compartments and the input and output of bedload within each compartment assessed. The parameters for the budgets are derived from data in Section 3 of this report. Each budget is regarded here as a "*best estimate*", with regard to the limitations of available data set out in Section 2 of this report.

4.1. SOUTH NAPIER SYSTEM

The beach sediment budget for the South Napier System is subdivided into 3 compartments (Table 8). The net Northerly drift entering this system of 108,000m^3/year (Table 8) is inferred from balancing the outputs in the Awatoto compartment (Table 8) and from potential accumulations at Haumoana. For the 1450m-long Awatoto compartment, most of the input of 108,000m^3/year is accounted for by beach mining (47%) for commercial-industrial purposes and the net Northerly longshore drift (44%) out of this

compartment. Loss by abrasion and storage by accretion account for only 9% of the total input (Table 8) within this compartment

For the 6,270m-long Mid Beach Domain compartment, most of the input of 48,000m^3/year is accounted for by the net Northerly drift out of this compartment (43%) and abrasion (44%) within the compartment (Table 8). Minor loss from once-off mining (3%) for the Westshore Nourishment Scheme at the Spirit of Napier beach in October 1999 (Table 1) and from storage by accretion (10%), account for the balance remaining of the input.

For the 970m-long Pacific Beach compartment, most of the input of 20,500m^3/year is accounted for by beach mining (64%) for the Westshore Nourishment Scheme and abrasion (29%) within the compartment (Table 8). A minor amount is stored in barrier accretion (7%) and there is no net Northerly longshore drift of coarse sediment out of the compartment to bypass the Port of Napier weather breakwater.

The minor accretion largely occurred during Southerly wave storms on 6 February and 3 April 2002 during which time there was considerable transport by the net Northerly drift (Kamen Ganev, pers. comm. 2002). Prior to the 2002 accretion, Pacific Beach was subject to a net loss of about -1,600m^3/year (1993-2000) when mining at 12,000 to 41,000m^3/year, averaging about 15,200m^3/year, must have exceeded the natural rate of supply.

Of the 108,000m^3/year of coarse sediment entering the 8.7km-long South Napier System at Awatoto from the net Northerly longshore drift, about 65,000m^3/year (60%) is removed by beach mining, about 30,500m^3/year (28%) is destroyed by swash-backwash abrasion, and about 12,500m^3/year (12%) is stored as accretion. The abrasion product is mostly Silt which is washed offshore to eventually be deposited in deeper water on the continental shelf (Table 8). At this point in time there is scant evidence of any coarse sediment being transported Northwards out of the South Napier System around the Port of Napier weather breakwater

4.2. NORTH NAPIER SYSTEM

The beach sediment budget for the North Napier System is subdivided into 5 compartments (Table 9). For the 1,192m-long Westshore South compartment there are zero inputs of coarse sediment from the 2 potential sources of the net Northerly longshore drift bypassing Ahuriri Entrance plus Ahuriri Harbour. This situation contrasts with the South Napier System where similar sources contribute 108,000m/year of coarse sediment into this system via the net Northerly drift.

The total input of about 11,500m^3/year to the Westshore South compartment is derived entirely from the Westshore Nourishment Scheme (70%) and barrier erosion (30%) within the compartment. Most of the input of 11,500m^3/year is accounted for by the net Northerly drift out of the compartment (48%) and barrier accretion (48%), artificially stored as a beach ridge (see Figure 2). Only a minor amount (4%) is lost by abrasion (Table 9) owing to relatively smaller wave heights and larger wave angles at the shore as a result of wave refraction around the Port of Napier.

- **Table 8:** Beach sediment budget estimated for the South Napier barrier beach system above MSL for 3 beach compartments. Rates for erosion, accretion and mining were adopted from Tables 1, 3 & 5 and Section 3.2 of the Report. Inputs into the Awatoto compartment were quantified from HBRC reports. Longshore drift and abrasion rates were inferred from observations, from previous work and from balancing the beach sediment budgets below for each compartment. Because of limitations to the data all values are rounded to the nearest 500m^3.

BEACH SEDIMENT BUDGET
SOUTH NAPIER BARRIER BEACH

	m^3/year	m^3/m/year	Percent	Offshore Loss m^3/year
1 **AWATOTO (1,450m)**				
INPUTS				
Inferred Net Drift from South bypassing Tukituki River	80,000	55.2	74	
Tukituki River	28,000	19.3	26	
Ngaruroro River	0	0	0	
Tutaekuri River	0	0	0	
Barrier Erosion	0	0	0	
	108,000	74.5	100	
OUTPUTS				
Barrier Accretion	-6,000	-4.2	6	
Mining	-50,500	-34.8	47	
Inferred gravel loss by abrasion	-3,500	-2.4	3	→ 3,500
Inferred Net Drift North	-48,000	-33.1	44	
NET BALANCE:	-108,000	-74.5	100	
2 **MID BEACH DOMAIN (6270m)**				
INPUTS				
Inferred Net Drift from South	48,000	7.7	100	
Barrier Erosion	0	0	0	
	48,000	7.7	100	
OUTPUTS				
Barrier Accretion	5,000	0.8	10	
Mining	-1,500	-0.2	3	
Inferred gravel loss by abrasion	-21,000	-3.4	44	→ 21,000
Inferred Net Drift North	-20,500	-3.3	43	
NET BALANCE:	**-48,000**	-7.7	100	
3 **PACIFIC BEACH (970m)**				
INPUTS				
Inferred Net Drift from South	20,500	21.1	100	
Barrier Erosion	0	0	0	
	20,500	21.1	100	
OUTPUTS				
Barrier Accretion	-1,500	-1.5	7	
Mining	-13,000	-13.4	64	
Inferred gravel loss by abrasion	-6,000	-6.2	29	→ 6,000
Inferred Net Drift North bypassing Weather breakwater	0	0	0	
NET BALANCE:	**-20,500**	-21.1	100	

- **Table 9**:Beach sediment budget estimated for the North Napier barrier beach system above MSL for 4 beach compartments. Rates for erosion, accretion and nourishment were adopted from Tables 1 & 4 and Section 3.2 of the Report. Longshore drift and abrasion rates were inferred from observations, from previous work and from balancing the beach sediment budgets below for each compartment. Because of limitations to the data all values are rounded to the nearest 500m^3.

BEACH SEDIMENT BUDGET
WESTSHORE TO NORTH SHORE ROAD

	m^3/year	m^3/m/year	Percent	Offshore Loss m^3/year
1 **WESTSHORE SOUTH (1,192m)**				
INPUTS				
Net Drift from South bypassing Ahuriri Entrance	0	0	0	
Ahuriri Harbour	0	0	0	
Barrier Erosion	3,500	2.9	30	
Beach Nourishment	8,000	6.7	70	
	11,500	9.6	100	
OUTPUTS				
Barrier Accretion	-5,500	-4.6	48	
Inferred gravel loss by abrasion	-500	-0.4	4	→ 500
Inferred Net Drift North past Fenwick Street	-5,500	-4.6	48	
NET BALANCE:	**-11,500**	-9.6	100	
2 **THE ESPLANADE (1,760m)**				
INPUTS				
Inferred Net Drift from South	5,500	3.1	39	
Barrier Erosion	0	0	0	
Beach Nourishment	8,500	4.9	61	
	14,000	8.0	100	
OUTPUTS				
Barrier Accretion	-3,500	-2.0	25	
Inferred gravel loss by abrasion	-1,000	-0.6	7	→ 1,000
Inferred Net Drift North past The Esplanade	-9,500	-5.4	68	
NET BALANCE:	**-14,000**	-8.0	100	
3 **NORTH TO BAY VIEW (2,358m)**				
INPUTS				
Inferred Net Drift from South	9,500	4.0	100	
Barrier Erosion	0	0	0	
Beach Nourishment	0	0	0	
	9,500	4.0	100	
OUTPUTS				
Barrier Accretion	-3,000	-1.3	32	
Inferred gravel loss by abrasion	-4,000	-1.7	42	→ 4,000
Inferred Net Drift North past Fannin Street	-2,500	-1.0	26	
NET BALANCE:	**-9,500**	-4.0	100	
4 **BAY VIEW TO LE QUESNE RD (3,152m)**				
INPUTS				
Inferred Net Drift from South	2,500	0.8	25	
Barrier Erosion	7,500	2.4	75	
Beach Nourishment	0	0	0	
	10,000	3.2	100	

OUTPUTS					
Barrier Accretion	0	0	0		
Inferred gravel loss by abrasion	-8,000	-2.6	80	→	8,000
Inferred Net Drift North past HB-18	-2,000	-0.6	20		
NET BALANCE:	**-10,000**	-3.2	100		
5 **LE QUESNE RD TO TANGOIO (8,577m)**					
INPUTS					
Inferred Net Drift from South	2,000	0.2	15	←	
Barrier Erosion	9,000	1.1	70		
Beach Nourishment	0	0	0		
Esk River	2,000	0.2	15		
	13,000	1.5	100		
OUTPUTS					
Barrier Accretion	0	0	0		
Inferred gravel loss by abrasion	-13,000	-1.5	100	→	13,000
Inferred Net Drift North past Tangoio	0	0	0		
NET BALANCE:	**-13,000**	-1.5	100		

For the 1,760m-long Esplanade compartment, most of the input of about 14,000m^3/year is accounted for by the net Northerly drift out of the compartment (68%) and by barrier accretion (25%) as an artificial embankment (see Figure 2). Only a minor amount is lost by swash-backwash abrasion (7%). The Westshore Nourishment Scheme makes a significant contribution (61%) to the inputs along The Esplanade (Table 9).

For the 2,358m-long Bay View compartment, most of the input of 9,500m^3/year from the net Northerly longshore drift is accounted for by abrasion losses (42%) within the compartment. Significant amounts of the coarse sediment input into this compartment are also accounted for by storage within the compartment as accretion (32%) and the net Northerly longshore drift (26%) out of the compartment (Table 9).

For the 3,152m-long Le Quesne Road compartment, the input of 10,000m^3/year is accounted for mostly by abrasion losses (80%) within the compartment and by the net Northerly drift (20%) out of the compartment. There is no evidence of storage by barrier accretion (Table 9). There is also no evidence of the net benefit of the Westshore Nourishment Scheme extending beyond the Bay View compartment to the South into this compartment.

For the 8,577m-long Tangoio compartment the input of about 13,000m^3/year is entirely accounted for by abrasion losses (100%) (Table 9). There is no evidence of the coarse greywacke-derived sediment bypassing the Tangoio headland to the North. The beaches North of Tangoio are formed of yellow limestone-derived sand.

The 17km-long North Napier System is generally in deficit in terms of coarse sediment as a result of no coarse material entering the system naturally at Southern Westshore from the net Northerly longshore drift South of the Port of Napier. Of the 14,600m^3/year that has been added to the system by the Westshore Nourishment Scheme (Table 1), the deficit is compounded by the loss offshore of some 26,500m^3/year by swash-backwash abrasion and some 12,000m^3/year from storage by barrier accretion (Table 9). The nourishment

volume has been reduced to about 12,000m^3/year since 1999 (Table 1) further reducing the potential net benefits in total to the North Napier System.

5. REVIEW OF WESTSHORE NOURISHMENT SCHEME

The following review is based on the findings and sediment budgets set out in Sections 3 & 4 of this report. The first part (Sect. 5.1) addresses the nearshore seabed nourishment programme; the second part (Sect. 5.2) potential source areas for the beach nourishment programme; and the third part (Sect. 5.3) suggestions to improve the Westshore Nourishment Scheme. Recommendations are made at the end of each Section.

5.1. NEARSHORE SEABED NOURISHMENT

Since 1982, Fine Sand has been dredged from both the Port Fairway and Ahuriri Inner harbour and dumped at an average rate of about 16,900m^3/year on the nearshore seabed off Westshore out to a depth of –7m below Chart Datum. This review has found that the programme has provided significant positive net benefits to both Westshore beach and the Westshore Bay seabed by contributing to mitigating coastal erosion. On this basis, the programme should continue but be refined to enhance the net benefits. The present Dump Ground "R" Extended is quite adequate to achieve this outcome along Westshore Beach.

To maximise the net benefits to the beach-nearshore zone all dredgings of Fine Sand should be dumped as close to the shore as possible, subject to the safe navigation of the dredgers. Fine Sand should be dumped along a shore-parallel contour to form an artificial, temporary "*offshore bar*". The artificial bar will then migrate shoreward by wave action to eventually weld on to the beach. The effect of this process will be to progressively create a flatter nearshore profile gradient which will enhance onshore transport of Sand and further contribute to erosion mitigation by reducing incident wave energy on the shore.

The existing Coastal Permit (No CPA 0101) granted to Port of Napier Ltd by the Minister of Conservation on 30 November 1998 limits the achievement of the above net benefits by imposing what we consider to be unnecessary restrictions. Condition 7 requires that the Port spread the dredge spoil as evenly as practicable over Dump Ground "R" Extended. Condition 7 should be revised to allow dumping by the trailer suction dredge as close to the shore as possible and in the form of a shore-parallel offshore bar within the area bounded by Dump Ground "R" Extended, at say –4 to –6m water depth below Chart Datum. Such action, in our opinion, will provide a significant benefit at both mitigating coastal erosion and improving the amenity of Westshore Beach.

5.1.1. Recommendations

i. The nearshore dumping programme on Dump Ground "R" Extended should formerly become part of the Westshore Nourishment Scheme and be managed and monitored accordingly.

ii. Condition 7 of Coastal permit No. CPA 0101 should be revised to allow dredgings of Sand to be dumped as close to the shore as possible within Dump Ground "R" Extended to form a shore-parallel offshore bar in 4 to 6m-water depth off Westshore Beach.

5.2. POTENTIAL MIXED SAND AND GRAVEL SOURCES

Potential supply sources for the Westshore Nourishment Scheme may be either renewable or non-renewable in the long-term. By definition, renewable sources of coarse sediment are sustainable, and if managed wisely, will continue to be so this century. In contrast, non-renewable sources are finite and therefore, unsustainable in the long-term.

The appropriate grain size envelope for Westshore Beach is Very Coarse Sand to Pebble size (1 to 40mm mean diameter). Repeat beach profile surveys have shown that coarse sediment within this envelope will form a beach profile gradient of 1:10 to 1:16, averaging 1:14, depending on the proportions of either Coarse Sand or Pebbles. At this gradient, the beach profile will attract and hold Fine to Medium Sand that migrates onshore from the nearshore seabed, particularly from Dump Ground "R" Extended. The present sediment extracted from Pacific Beach falls within the required grain size envelope.

5.2.1. Rivers

The Esk, Ngaruroro and Tukituki Rivers are all potential renewable sources of suitable coarse sediment for the Westshore Nourishment Scheme. The most suitable source areas are the existing extraction sites where the river bed gravels are screened by the quarry operators. At these sites we observed stockpiles of screened greywacke pea gravel grade sediment. The stockpiles are suitable for the Westshore Nourishment Scheme as the sediment falls within the required grading envelope.

Of the 3 rivers, the Ngaruroro is probably the most suitable potential source. At the Holcim Quarries site we observed a stockpile of approximately 100,000m^3 of coarse sediment (mostly pea gravel) which is presently available. Preliminary discussions with the Company indicated that they could easily supply 10,000 to 20,000m^3 of suitable sediment per annum over and above the stockpile volume to meet the requirements of the Westshore Nourishment Scheme. The Ngaruroro is unlikely to supply any coarse sediment to the coast until about A.D.2400. Extraction for the Westshore Nourishment Scheme therefore, will have no adverse effects on the South Napier barrier beach system.

The Esk River also is a source of suitable coarse sediment from the Esk River Shingle extraction site. At this site we observed a stockpile of screened greywacke pea gravel that would be suitable for the Westshore Nourishment Scheme as it easily falls within the required grading envelope. The volumes however, are comparatively small, amounting to only a few thousand cubic metres per annum. Further, the Esk River is a potential supply source to the depleted North Napier barrier system which has a negative sediment budget around the river mouth. A more sustainable option may be to create a management regime that allows the river to once again supply the coast naturally, as it probably did prior to extraction operations intercepting a significant portion of its mobile bedload transport to the coast.

The Tukituki River bed is a source of suitable coarse sediment from the extraction sites. The river however, is the only river source supplying significant bedload to the South Napier barrier system. It is absolutely vital that this function be allowed to continue and enhanced by existing management regimes to increase if possible, the existing 28,000m^3/year being transported to the coast. Any extraction of coarse sediment for the Westshore Nourishment Scheme therefore, should be sourced from the riverbed well above the lower reaches. The costs of transporting sediment to Westshore from such mid to upper reach source areas however, are likely to be prohibitive.

5.2.2. South Napier System

This review has found that extraction at both ends of the South Napier barrier beach system has not prevented the historic trend of accretion established since the 1931 Hawke's Bay earthquake, continuing. Further, suitable coarse sediment can be extracted directly from the beach without the requirement for screening. Such sediment includes a natural mix of Coarse Sand and Well Rounded Pebbles.

Care must be exercised in permitting such extraction to continue, however, as the South Napier barrier beach ridge is the natural first line of defence between the forces of the sea and Napier City. Should extraction rates exceed the natural rate of supply, the sediment budget will be in net deficit placing the assets and infrastructure of Napier City at increasing risk from coastal hazards such as erosion and flooding from the sea.

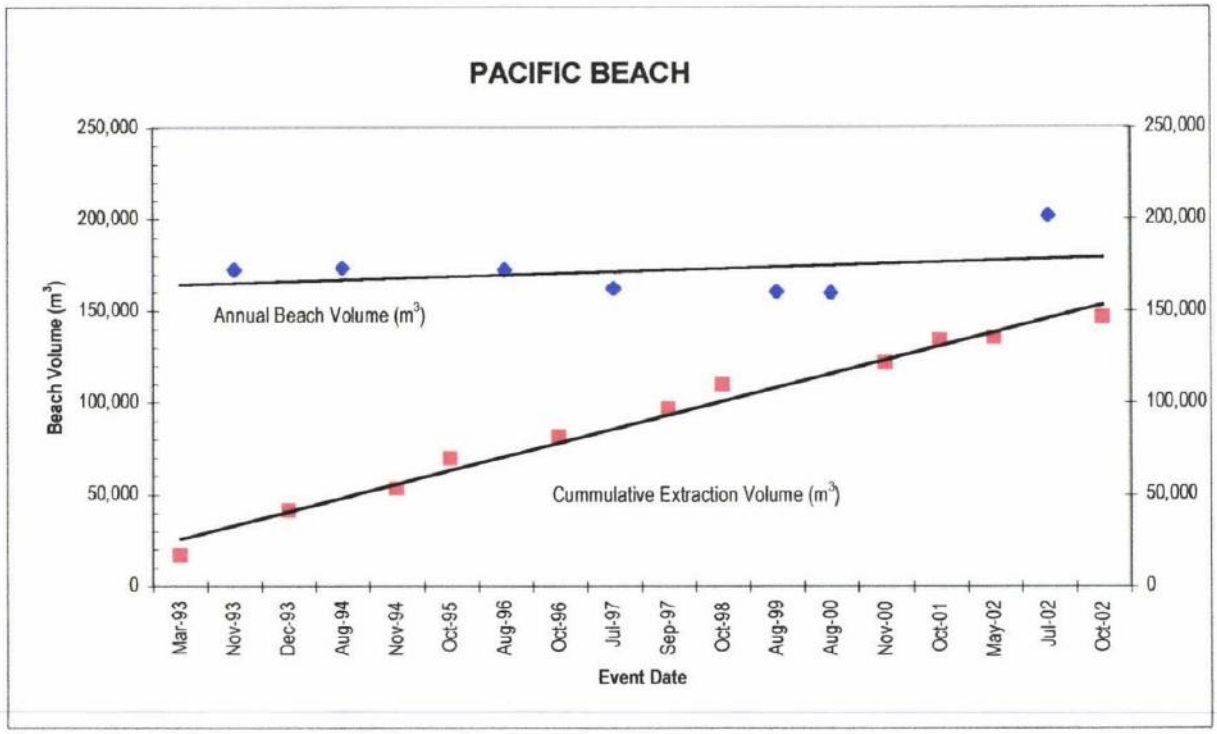
The assets at potentially greatest risk will be those on the seaward side of Marine Parade which are currently within reach of storm wave runup during severe wave storms. It is in the long-term interests of the City and the Region as a whole that the South Napier System have an established management regime that allows the long-term trend of accretion to continue as a first priority, and not be threatened by excessive beach mining.

Because of the net Northerly longshore drift the extraction site of potential least impact on Napier City is Pacific Beach at the distal end of the South Napier System. Since March 1993, coarse sediment has been extracted annually at a net rate of about 13,000m^3/year, ranging from 41,000m^3/year (1993), to 12,000m^3/year (1994, 1996, 2000, 2001, 2002) (Table 1). Monitoring of beach volumes by HBRC at Pacific Beach since November 1993 has revealed that although there was an average net gain of 29,613m^3 from November 1993 to July 2002, the gain occurred between August 2000 and July 2002 of 42,203m^3. From November 1993 to August 2000 Pacific Beach was suffering a net loss at about -1,600m^3/year (Figure 7).

The deposition of 42,203m^3 of coarse sediment between August 2000 and July 2002 mostly occurred during the Southerly wave storms of 6 February and 3 April 2002 (Kamen Ganev, pers. comm., 2002). Sustainable management of this site therefore, should not allow extraction rates to exceed the natural rate of supply which obviously fluctuates from year to year depending on the frequency and magnitude of Southerly wave storms that power the net Northerly longshore drift.

Based on the sediment budget analysis in this study (Table 8) we believe that Pacific Beach has the potential to sustain an average annual extraction of 12,000 to 13,000m^3/year, and possibly up to about 20,000m^3/year from the beach, subject to the results of monitoring. At these rates a sufficient barrier width will be maintained to protect both the base of the Port of Napier weather breakwater and the assets and infrastructure to landward of Pacific Beach, thus ensuring they are not placed at risk from coastal hazards this century. Conversely, if gravel is not utilised at Pacific Beach it will be destroyed by abrasion and lost from the beach.

Linear regression analysis in Figure 7 clearly shows that Pacific Beach has been able to sustain extraction averaging about 13,000m^3/year over the last 10 years. During this period the net volume of the beach has remained reasonably constant to a small net increase in volume largely in response to the Southerly wave storms of 2002. At current and past extraction rates, Pacific Beach is clearly a sustainable source area as it has proved to be renewable.



• **Figure 7:** Graph showing the surveyed annual beach volume along the 970m-long Pacific Beach between HBRC profiles HB-12 and TB-3, compared with the cumulative volume of extraction from the beach from March 1993 to October 2002. Linear regression lines are added to highlight trends. (Data Sources: Table 1 & Jones Zorn Surveying Ltd).

Another potential extraction site along the South Napier System is the beach between the Ngaruroro River mouth and the present Awatoto shingle extraction site. At this location, extraction would get the first cut at the 108,000m^3 of coarse sediment entering the South Napier System from the net Northerly longshore drift. Furthermore, such extraction would contribute to keeping the Ngaruroro River mouth open reducing potential flood risk in the lower reach area.

HBRC profile HB-7 which is at the North end of this proposed site records a net shoreline advance from accretion of 38m from 1939 to 2002 at 0.6m/year. Over the last 10 years, there has been a net accretion between HBRC profiles HB-6 and HB-7 at about 10,000m^3/year. The presence of accretion plus the conveyance of about 108,000m^3/year through this compartment by the net Northerly longshore drift suggests that this site could supply all of the annual requirements of the Westshore Nourishment Scheme at an extraction rate up to 15,000-20,000m^3/year or more.

If extraction of coarse sediment was permitted for the Westshore Nourishment Scheme from the potential Ngaruroro River mouth site it would be prudent to reduce the current average annual extraction rate at Awatoto by a proportionate amount. For example,

assuming an extraction rate of 15,000 to 20,000m^3/year for the Westshore Nourishment Scheme would require that the annual extraction rate permitted at Awatoto to be reduced from about 50,000m^3/year to 30,000 to 35,000m^3/year. Such a reduction would be precautionary to ensure the long-term stability of the South Napier barrier beach ridge as an integral measure to continue protecting Napier City from the sea.

5.2.3. Non-renewable Sources

Both the North and South Napier barrier beach ridges have the potential to supply suitable coarse sediment for the Westshore Nourishment Scheme. The non-renewable source areas are those landward of the effects of contemporary coastal processes where extraction will not adversely affect beach stability. For the North Napier barrier beach ridge such potential areas are the old washover fans of beach gravel to the landward sides of State Highway 2, Rogers Road, Le Quesne Road and North Shore Road. The washover fans were active until tectonic uplift accompanying the 1931 Hawke's Bay earthquake cut off the natural supply process.

For the South Napier System the potential source areas are generally landward of State Highway 2 and Marine Parade. Any likely extraction seaward of State Highway 2 must take account of the fact of the importance of the barrier beach at providing natural protection to Napier City from the sea. As a precautionary measure, such extraction should not be permitted within say 60 to 80m of the active beach. Extraction pits in areas seaward of State Highway 2 would need to be filled with suitable sediment to prevent enhancing sea flood hazard during severe wave storms.

5.2.4. Recommendations

i. The most sustainable source area of suitable sediment for the Westshore Nourishment Scheme is Pacific Beach. Based on monitoring of beach volumes, Pacific Beach has the potential to supply between 12,000-13,000m^3/year, and up to about 20,000m^3/year after Southerly storms.

ii. The second sustainable beach source area is the barrier between Awatoto and the mouth of the Ngaruroro River which has the potential to supply about 15,000 to 20,000m^3/year of suitable sediment for the Westshore Nourishment Scheme. If this site was utilised then extraction from Awatoto must be reduced proportionately to ensure the continued trend of accretion of the South Napier barrier system and long-term protection of Napier City.

iii. No gravel and coarse sand should be extracted from the shoreface along the South Napier barrier system between Pacific Beach and Awatoto.

iv. The preferred sustainable river source is the Ngaruroro riverbed at the Holcim Quarries extraction site where there is currently a stockpile of about 100,000m^3 of suitable fine gravel available.

v. Both the Tukituki and Esk Rivers should be managed in such a way that promotes the maximum potential discharge of bedload to the coast to sustain the Napier City beaches. Current extraction of river bedload for commercial purposes should accommodate this important requirement and not be permitted to adversely affect bedload transport to the coast.

5.3. WESTSHORE NOURISHMENT SCHEME IMPROVEMENTS

As noted in the Introduction to this report, the primary objectives of the Westshore Nourishment Scheme in order of importance are to:

1. Mitigate the hazard of long-term coastal erosion along Westshore.
2. Maintain and enhance the amenity of the Westshore coastal environment.
3. Remedy the hazard of occasional flooding from the sea.

5.3.1. Mitigating Sea Erosion Hazard

Since its inception in January 1987, the Westshore Nourishment Scheme has successfully mitigated coastal erosion over about 4.6km of coastline between Fenwick Street (Westshore) and the Snapper Park Motor Camp (Bay View) (Gibb 2002). Despite beach nourishment since March 1991 at about 8,000m^3/year the 1.2km-long coastline of Southern Westshore has continued to retreat from erosion at about –3,500m^3/year (Table 9). The coastline subject to the erosion extends from about 12 Charles Street (near HBRC Profile W-40) to about Fenwick Street (near HBRC Profile W-51C).

In contrast, The Esplanade area North of Fenwick Street, between HBRC Profiles W-51C and W-60, has advanced from accretion as a result of the combination of supply by the net Northerly longshore drift at about 5,500m^3/year and beach nourishment at about 8,500m^3/year (Table 9). Needless to say that the net Northerly longshore drift entering this compartment is supplied entirely from the Southern Westshore compartment. Therefore, it follows that by placing more coarse sediment along Southern Westshore and less along The Esplanade each year, erosion can be mitigated in the former compartment without compromising the latter.

It is therefore recommended, that about 12,000m^3 be placed along Southern Westshore shoreface each year between HBRC Profiles W-40 and W-51C, and 2,000 to 3,000m^3 be placed along The Esplanade shoreface between E-6 and E-18 every 2 years. It is noted here that the beach profiles between W-52 and E-20 in the middle of Westshore Beach have all apparently reached an equilibrium and are advancing seawards. As noted above, we believe the dumping of dredgings on Dump Ground "R" Extended is making an important contribution to this significant reversal from a long-term erosion trend to one of stability and accretion.

5.3.2. Maintaining and Enhancing Amenity Values

The combination of nourishing the beach above MSL with Very Coarse Sand to Pebble grade coarse sediment and the nearshore seabed with Fine Sand has made a significant contribution to maintaining and enhancing the amenity of Westshore Beach. It is reasonable therefore, that this programme continue subject to some onshore physical improvements.

At The Esplanade, there is a 5.5 to 6.3m-high artificial embankment that has truncated the beach profile and lowered beach levels. The embankment is too steep to safely access the beach without the provision of steps and protrudes a few metres seawards of the natural shoreline alignment North and South of The Esplanade.

The situation can be remedied in 2 ways to improve the performance of the Westshore Nourishment Scheme. Firstly, by reducing the slope mechanically and second, by allowing the sea to erode the profile landward over time. Whichever option is adopted we recommend that a new top seaward edge of the "finished" artificial embankment be established about 2m seaward of the 1986 top edge. The 1986 position is marked on the ground along The Esplanade by posts in the ground.

Along Southern Westshore, the beach profile is truncated to a lesser degree by a 3.6 to 4.5m-high artificial beach ridge between HBRC Profiles W-40 and W-51. The seaward face of the beach ridge is difficult to access without the provision of selected artificial accessways. By direct comparison, the beach profile along the Southern part of The Esplanade between W-51 and W-53 is easy to access, as the artificial ridge is easy to cross to the beach.

Tables 10 and 11 provide recommended design parameters that if implemented, will improve public access to and along Westshore Beach without compromising the capacity of the artificial beach ridge to mitigate erosion. The recommended distances and heights given in both Tables can easily be marked on the ground by survey and the modifications achieved under very careful supervision. Figure 8 shows representative examples of existing and recommended profiles to illustrate these recommendations.

Along Southern Westshore, it is recommended that the top seaward edge of the artificial ridge be mechanically shifted landwards by 9 to 13m, averaging 11.25m (Table 10). The landward shift by mechanical contouring of the seaward face of the ridge will improve public access by lowering the gradient of the existing profile and re-align the ridge nearer to its natural alignment. The surplus coarse sediment can either be placed on the beach or pushed landward to establish the recommended new ridge crest position. Pushing it landward to increase both the existing height of the ridge where necessary (Table 10) and storage volume within the ridge would be the preferred option (Figure 8).

Along The Esplanade, it is recommended that the top seaward edge of the artificial embankment be mechanically shifted landwards by 1.0 to 9m, averaging 4.7m (Table 11). The landward shift by either mechanical contouring and softening of the seaward face or allowing the sea to do the work over time, will improve public access to the beach by lowering the gradient of the existing profile (Figure 8). It will also decrease wave reflection of the existing semi-vertical face of the embankment. Mechanically contouring of the face is the preferred option.

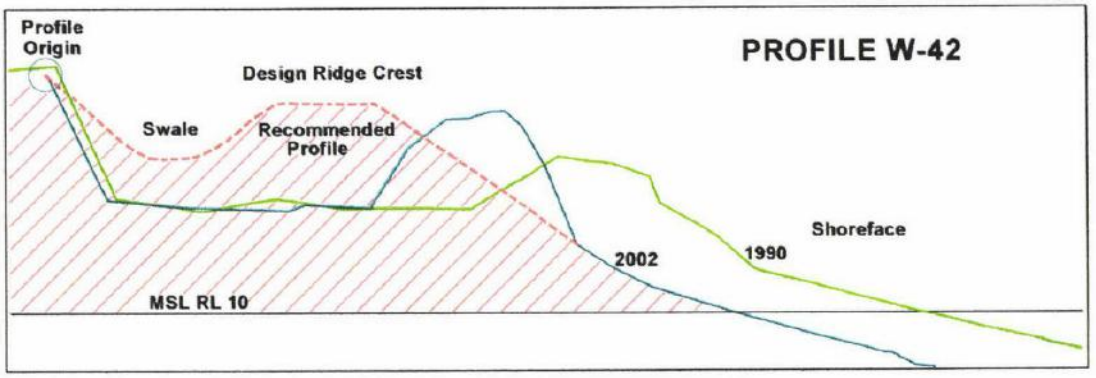
For both Southern Westshore and The Esplanade, the recommended position for the top seaward edge of the artificial beach ridge and embankment can be the design line in plan to hold and manage for the Westshore Nourishment Scheme. For The Esplanade the recommended line is about 2m seawards of the 1986 position of the top seaward edge of the bank, but still of sufficient distance from the road to provide an adequate buffer against erosion and flooding from the sea.

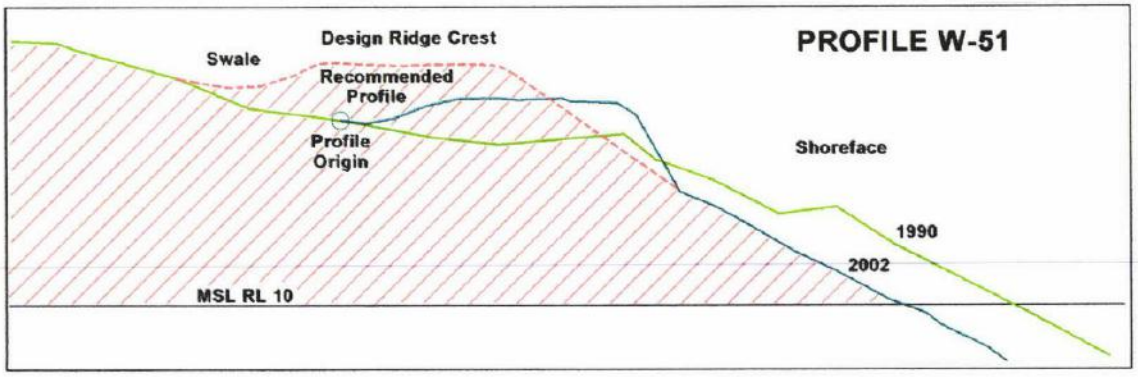
- **Table 10**: Recommended design parameters for the artificial beach ridge along Southern Westshore between HBRC Profiles W-40 and W-60. All horizontal measurements are in relation to the landward point of origin of the 2 December 2002 Profile survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m).

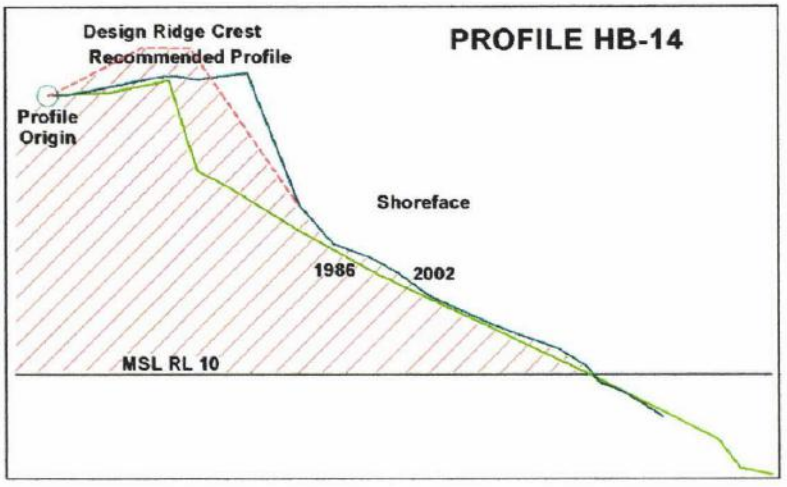
HBRC PROFILE	EXISTING CREST HEIGHT (m)	EXISTING DISTANCE TO TOP SEAWARD EDGE (m)	RECOMMENDED CREST HEIGHT (m)	RECOMMENDED DISTANCE (m)
W-40	13.61	30	13.6	21
W-41	13.82	40	13.8	27
W-42	13.65	42	13.8	30
W-44	13.95	61	14.0	50
W-45	14.15	55	14.0	44
W-46	14.07	49	14.0	39
W-48/HB-13	14.00	70	14.5	58
W-50	14.33	62	14.5	50
W-50C	14.49	26	14.5	16
W-51	13.88	27	14.5	15
W-51B	13.58	39	14.5	30
W-52	13.82	48	14.5	36
W-53	15.33	35	No change Required	
W-60	15.80	0	No change Required	

- **Table 11**: Recommended design parameters for the artificial embankment along The Esplanade between HBRC Profiles EA and E24. All horizontal distances are in relation to the landward point of origin of the 2 December 2002 profile Survey. All vertical measurements are in relation to HBRC Reduced Level Datum of R.L. 10m (equals 0.0m MSL). All values are in metres (m).

HBRC PROFILE	EXISTING CREST HEIGHT (m)	EXISTING DISTANCE TO TOP SEAWARD EDGE (m)	RECOMMENDED CREST HEIGHT (m)	RECOMMENDED DISTANCE (m)
E-A	16.15	19	16.0	10
E-2	16.10	20	16.0	15
E-4	15.99	18	16.0	14
E-6	15.95	16	16.0	15
E-8	15.85	19	16.0	16
E-10	15.56	19	16.0	15
E-12	15.53	17	16.0	11
E-14/HB-14	15.51	18	16.0	13
E-16	15.39	21	16.0	16
E-18	15.53	23	15.5	22
E-20	15.93	26	15.5	17
E-22	15.99	31	15.5	25
E-24	16.29	36	15.5	33







• **Figure 8:** Recommended profiles at 3 representative sites along Westshore to improve the performance of the Westshore Nourishment Scheme.

5.3.3. Remedying Sea Flood Hazard

Tables 10 and 11 provide recommended crest heights for the artificial beach ridge along Southern Westshore (Table 10) and the embankment along The Esplanade (Table 11). The new design heights are to prevent overtopping by wave storms of similar magnitude to the 3 April 2002 event which was observed. Overtopping resulted in temporary flooding of low-lying areas landward of the beach.

Table 10 shows that the Southern Westshore artificial beach ridge crest is of uneven height with parts being particularly susceptible to overtopping and other parts being of adequate height. The recommended heights (Table 11) increase Northwards from 3.6m above MSL at W-40 to 4.5m above MSL between Profiles W-48 and W-52. The increase allows for a progressive exposure of Westshore to increasing wave heights Northwards away from the protection of Westshore Bay.

Table 11 shows that The Esplanade embankment is also of uneven height but overall, is above the level reached by storm wave runup from wave storms of similar magnitude to the 3 April 2002 event. The recommended heights increase Northwards from 5.5m above MSL between Profiles E-24 and E-18, to 6.0m above MSL between profiles E-16 and E-A (Table 11).

In addition, it is recommended that the low-lying flood prone swale behind the artificial beach ridge be partly filled with gravels to raise the elevation of the ground surface. The area to be filled extends from near Profile W-41 to near Profile W-51. As a guideline for filling, the base of the swale should be about 1.0m below the recommended crest height of the artificial beach ridge (Figure 8). This approach will still preserve the coastal landform whilst reducing the likely area subject to temporary inundation by the sea. The use of gravels will allow rapid drainage of seawater following wave overtopping.

The recommended re-siting landward of the artificial beach ridge and raising the elevation of the adjacent swale will impact significantly on infrastructure presently located in the area. Such infrastructure includes toilet blocks and changing rooms, the Surf Club building, and vehicle parking areas. At present these assets are severely constraining the effectiveness of the Westshore Nourishment Scheme by forcing the artificial ridge seawards away from the buildings and carparks. As a result the ridge is truncating the beach profile, thereby suffering erosion and making public access to the beach difficult. Re-siting these assets on the landward side of the improved swale may be the most practical solution, as it will allow for the natural re-alignment of the shoreline to an equilibrium plan position without being constrained by buildings at extreme risk.

5.3.4. Recommendations

i. The artificial beach ridge needs to be reconstructed at both Southern Westshore and The Esplanade according to the recommended parameters given in Tables 10 and 11 and shown in Figure 8.

ii. To fully utilise the net Northerly longshore drift and mitigate erosion the focus of dumping of nourishment sediment should be between HBRC Profiles W-40 and W-51C (Southern Westshore) at a rate of about 12,000m^3/year and 2,000 to 3,000m^3 every 2 years between HBRC Profiles E-6 and E-18 (The Esplanade). All 12,000 to 15,000m^3/year should be placed on the modified shoreface (Figure 8) to be distributed by wave action.

iii. To mitigate coastal flooding, the crest of the re-positioned artificial barrier ridge needs to be raised about 0.05 to 1.0m, increasing in height Northwards, according to the recommended crest heights given in Tables 10 & 11.

iv. To improve both access and amenity of Westshore Beach the gradient of the seaward slope needs to be mechanically reduced and the sediment pushed landward to both increase the height of the artificial ridge and to raise the level of the swale behind as shown in Figure 8.

v. Additional gravels will be required over and above the recommended annual nourishment volumes of 12,000-15,000m^3/year to raise the level of the swale behind the artificial beach ridge. The current stockpile of 100,000m^3 of pea gravel at the Holcim Quarries site may be a useful supply source.

6. MONITORING

HBRC manage the beach profile monitoring network and offshore survey extensions to the HB Series including the storage and production of profile data. Port of Napier Ltd manage the bathymetric surveys of the seabed including the production and storage of data. Both organisations have their own consultants to undertake these important tasks and no doubt, to make recommendations on improvements to the monitoring programmes. Notwithstanding, this review has highlighted the importance of monitoring programmes focussing on the following issues:

7. The long-term stability of both the North Napier and South Napier barrier beach systems.

8. The effects of dumping of sediment dredged from the Port Fairway and Ahuriri Inner Harbour on the bathymetry of Dump Ground "R" Extended (Figure 5) and on the long-term stability of Westshore Beach.

9. The effects of mining of beach sediment at Pacific Beach, Awatoto and the Ngaruroro River mouth on the long-term stability of the South Napier System.

10. The effects of the Westshore Nourishment Scheme on both the long-term stability of the North Napier System, and the composition and amenity of the beach.

11. The effects of severe wave storms on short-term barrier erosion and recovery, and flooding from storm wave runup.

12. The volume of bedload discharged at the mouths of the Tukituki and Esk Rivers during floods and the rate of distribution of these subtidal deltaic sediments along the coast.

It is beyond the scope of this report to recommend how both HBRC and the Port should manage their monitoring programmes except to recommend that appropriate staff in Napier City Council liaise closely with both agencies to ensure that the findings of this review are properly taken into account. Council will need to be satisfied that the monitoring programmes provide appropriate information on the 5 issues listed above and that the effects recorded by monitoring are clearly understood by all agencies and the public and used as a basis for sound decision making.

The HBRC profiles selected for this review from those available (Appendix 1), were on the basis of mostly compatible survey dates and adequate coverage of both the South Napier and North Napier Systems. These included selections from the AWA (Awatoto) and TB (Pacific Beach) Series for the South Napier System and Selections from the W (Southern Westshore) and E (Esplanade) Series for the North Napier System. In contrast, all the HB Series Stations were used between the Ngaruroro River mouth (HB-7) and Tangoio (HB-23). It is recommended that the selected profiles used in this review be used to monitor the long-term stability of both the North and South Napier Systems and consideration be given to establishing further stations to fill some of the large gaps in the profile network especially around the Esk River mouth.

A problem we encountered with determining the effects of dumping of dredgings on Dump Ground "R" Extended is that very few of the hydrographic surveys covered the entire Dump Ground area. We understand that this situation arose from the monitoring requirements at the time (Peter Frizzell, pers. comm. Jan 2003). It is recommended that all future bathymetric surveys cover all of Dump Ground "R" Extended and that the surveys be extended Southeast as far as the Ahuriri Entrance and Southwest to include Westshore beach. It would also be helpful if the corrected sounding surveys could be contoured at 1.0m intervals at the precise depths on each sounding line (e.g. 2.0, 3.0, 4.0, 5.0m, etc.) and all soundings normalised to a common datum for quantifying changes.

6.1.1. Recommendations

i. Existing coastal monitoring programmes managed by both HBRC and Port of Napier Ltd., should be revised where appropriate, to provide quantitative information on the 6 issues listed above to the satisfaction of Napier City Council.

7. CONCLUSIONS

1. Napier City has about 20km of coastline which is separated by the Port of Napier into 2 mutually distinct and once connected landforms described here as the South Napier barrier system and the North Napier barrier system.

2. Both the South and North Napier Systems are subject to the natural effects of wave action producing a predominant net Northerly longshore drift and the grinding down of gravels to silt by swash-backwach abrasion.

3. Along the South Napier System the net Northerly longshore drift of bedload reduces Northwards from about 108,000m^3/year at Awatoto, to about 48,000m^3/year along the Mid Beach-Domain area, to about 20,500m^3/year along Pacific Beach, to zero longshore drift passing the Port of Napier weather breakwater.

4. Along the North Napier System zero net Northerly longshore drift enters the system at Southern Westshore principally due to the effective blocking of bedload transport by the weather breakwater. The deficit in supply is compensated for by erosion resulting in a net Northerly longshore drift of about 5,500m^3/year along Southern Westshore, increasing Northwards to about 9,500m^3/year along The Esplanade, reducing to 2,500m^3/year North of Bay View to about 2,000m^3/year North of the Esk River, to zero longshore drift passing Tangoio headland.

5. Swash-backwash abrasion losses account for about 30,500m^3/year along the 8.7km-long South Napier System and about 26,500m^3/year along the 17km-long North Napier System.

6. The Westshore Nourishment Scheme plus the dumping of harbour dredgings close to the shore have proven to be the best practicable options for compensating for the deficit in supply of sand and gravel to the North Napier System, whilst maintaining the amenity of Westshore beach and reducing the effects of erosion and flooding from the sea on property and infrastructure.

7. The Westshore Nourishment Scheme should formerly encompass both the dumping of sediment on the shoreface by HBRC and NCC and the dumping of dredged sand on the nearshore seabed by Port of Napier Ltd as close inshore as practically possible.

8. Pacific Beach is the preferred naturally renewable source area for the Westshore Nourishment Scheme on the basis of compatible sediment, cost-effective mining and transport to Westshore, sustainability, and minimum adverse effects from mining on the South Napier barrier system as Pacific Beach is located at the Northern end of the system (Figure 4).

9. Pacific Beach has the potential to supply 12,000 to 13,000m^3/year and occasionally up to about 20,000m^3/year of compatible beach sediment for the Westshore Nourishment Scheme.

10. Sustainable back-up alternative renewable supply sources for the Westshore Nourishment Scheme include the shoreface between Awatoto and the Ngaruroro River mouth and the Holcim Quarries extraction site on the Ngaruroro River bed, both of which have sufficient supplies of compatible sediment for Westshore Beach.

11. Along Westshore, the artificial barrier ridge constructed for the Scheme is out of alignment in some areas and therefore subject to erosion by the sea and low in others allowing wave overtopping and flooding of low-lying areas of coastal hinterland. Detailed design parameters are given in this report in Tables 10 and 11 and Figure 8 to rectify and improve this situation by modifying the location and shape of the artificial ridge.

12. To maximise the benefits of the Scheme it is recommended that about 12,000m^3 be dumped on the modified shoreface along Southern Westshroe between HBRC Profiles W-40 and W-51C and 2,000-3,000m^3 be dumped on the shoreface every 2 years along The Esplanade between HBRC Profiles E-6 and E-18.

8. SUMMARY OF RECOMMENDATIONS

i. The nearshore dumping programme on Dump Ground "R" Extended should formerly become part of the Westshore Nourishment Scheme and be managed and monitored accordingly.

ii. Condition 7 of Coastal permit No. CPA 0101 should be revised to allow dredgings of Sand to be dumped as close to the shore as possible within Dump Ground "R" Extended to form a shore-parallel offshore bar in 4 to 6m water depth off Westshore Beach.

iii. The most sustainable source area of suitable sediment for the Westshore Nourishment Scheme is Pacific Beach. Based on monitoring of beach volumes, Pacific Beach has the potential to supply between 12,000-13,000m^3/year, and up to about 20,000m^3/year after Southerly storms.

iv. The second sustainable beach source area is the barrier between Awatoto and the mouth of the Ngaruroro River which has the potential to supply about 15,000 to 20,000m^3/year of suitable sediment for the Westshore Nourishment Scheme. If this site was utilised then extraction from Awatoto must be reduced proportionately to ensure the continued trend of accretion of the South Napier barrier system and long-term protection of Napier City.

v. No gravel and coarse sand should be extracted from the shoreface along the South Napier barrier system between Pacific Beach and Awatoto.

vi. The preferred sustainable river source is the Ngaruroro riverbed at the Holcim Quarries extraction site where there is currently a stockpile of about 100,000m^3 of suitable fine gravel available.

vii. Both the Tukituki and Esk Rivers should be managed in such a way that promotes the maximum potential discharge of bedload to the coast to sustain the Napier City beaches. Current extraction of river bedload for commercial purposes should accommodate this important requirement and not be permitted to adversely affect bedload transport to the coast.

viii. The artificial beach ridge needs to be reconstructed at both Southern Westshore and The Esplanade according to the recommended parameters given in Tables 10 and 11 and shown in Figure 8.

ix. To fully utilise the net Northerly longshore drift and mitigate erosion the focus of dumping of nourishment sediment should be between HBRC Profiles W-40 and W-51C (Southern Westshore) at the rate of about 12,000m^3/year and 2,000 to 3,000m^3 every 2 years between HBRC Profiles E-6 and E-18 (The Esplanade). All 12,000 to 15,000m^3/year should be placed on the modified shoreface (Figure 8) to be distributed by wave action.

x. To mitigate coastal flooding, the crest of the re-positioned artificial barrier ridge needs to be raised about 0.05 to 1.0m, increasing in height Northwards, according to the recommended crest heights given in Tables 10 & 11.

xi. To improve both access and amenity of Westshore Beach the gradient of the seaward slope needs to be mechanically reduced and the sediment pushed landward to both increase the height of the artificial ridge and to raise the level of the swale behind as shown in Figure 8.

xii. Additional gravels will be required over and above the recommended annual nourishment volumes of 12,000-15,000m^3/year to raise the level of the swale behind the artificial beach ridge. The current stockpile of 100,000m^3 of pea gravel at the Holcim Quarries site may be a useful supply source.

xiii. Existing coastal monitoring programmes managed by both HBRC and Port of Napier Ltd., should be revised where appropriate, to provide quantitative information on the 6 issues listed above to the satisfaction of Napier City Council.

9. ACKNOWLEDGEMENTS

This review by CMCL of the Westshore Nourishment Scheme could not have been properly executed without having access to existing data held by HBRC, the Port of Napier Ltd and NCC. To this end, the following persons are gratefully acknowledged for their contributions.

Port of Napier Ltd:	Keith Rodel, Engineering Services Manager
Hawke's Bay Regional Council:	Gary Clode, Engineering Manager Craig Goodier, Design Engineer Graham Edmondson, Senior Engineering Officer
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For Coastal Management Consultancy Ltd, Jeremy Gibb analysed the data supplied by David Zorn, HBRC, NCC and the Port of Napier and wrote the report. Ann Gibb produced the report and managed CMCL's contribution to the project. Keith Rodel, Peter Frizzell, David Zorn, Kamen Ganev, Craig Goodier, Cary Clode, Graham Edmondson, Mike Adye, and John O'Shaughnessy provided constructive comments on the Draft report.

10. REFERENCES

Adams, J. and Gibb, J.G. 1982: A sediment budget for the east coast between Oamaru and Banks Peninsula, South Island, New Zealand. *NZ Journal of Geology and Geophysics Vol.25*: 335-352.

ASR Ltd 2001: *Westshore Coastal Process Investigation*. Unpublished report prepared for Napier City Council: 177pp.

Edmondson, G. 2000: *Esk River Gravel Extraction Review*. Hawke's Bay Regional Council Asset Management Group Technical Report. AM00/11: 4pp + Appendices.

Edmondson, G. 2001: *Tutaekuri River-Gravel Resources. Assessment of gravel supply & sustainable annual extraction volume*. Hawke's Bay Regional Council Asset Management Group Technical Report AM 01/10: 5pp + Appendices.

Edmondson, G. 2001: *Lower Tukituki River. Assessment of gravel supply and sustainable annual extraction volume*. Hawke's Bay Regional Council. Asset Management Group Technical Report ? 5pp.

Gibb, J.G., 1962: Wave Refraction Patterns in Hawke Bay. *New Zealand Journal of Geology and Geophysics, Vol 5, No. 3*: 435-444.

Gibb, J.G. 1980: Late Quaternary shoreline movements in New Zealand. *Unpublished PhD thesis lodged in the library, Victoria University of Wellington, Wellington*. 217p.

Gibb, J.G. 1996: *Coastal Hazard Zone assessment for the Napier City coastline between the Ahuriri Entrance and Esk River mouth*. Consultancy Report (C.R. 96/2) prepared for Napier City Council. April 1996. 80p. + Appendices.

Gibb, J.G. 2002: *Review of the 1996 Coastal Hazard Zone between Ahuriri Entrance and Esk River Mouth*. Consultancy Report (C.R.2002/1) prepared for Napier City Council, January 2002. 54p + Appendices

Lindup, F.W. 1948: *Coast Erosion, Napier*. Unpublished report for the Public Works Department. 10p.

McBryde, D.J. 1989: *Heretaunga Plains gravel resource management plan*. Hawke's Bay Catchment Board. 42pp.

Marshall, P. 1927: The wearing of beach gravels. *Transactions of the Royal Society of NZ 58*: 507-532

Marshall, P, 1929: Beach gravels and sands. *Transactions of the N.Z. Institute 60*: 324-65.

O'Callaghan, R.B., 1986: *Report on the Coastal Protection of Westshore Beach*, Napier. Consultancy Report to Napier City Council. 24p.

Smith, R.K. June 1984: *Beach changes between Napier and Clifton, Southern Hawke Bay*. Report prepared for Hawke's Bay Catchment Board. 61p.

Williams, G. 1997: *Ngaruroro River Gravel Resources. Assessment of gravel supply & extraction availability*. Report prepared for Hawke's Bay Regional Council by Williams Consultants Ltd. 12pp + Appendices.

APPENDIX 1

HBRC PROFILE DATA

TABLE A1: Beach and offshore profile surveys between Ahuriri and North Shore Road held by Hawke's Bay Regional Council. General locations of the 56 profile sites are shown on Figure 1. Note that E-14 same station as HB-14; W-48 same station as HB-13.

PROFILE SERIES	BEACH				OFFSHORE			
	FIRST date		LAST date	TOTAL surveys	FIRST date		LAST date	TOTAL surveys
HB-13	27-Aug-75	to	2-Dec-02	64	26-May-88	to	9-Apr-02	7
HB-14	1-Apr-37	to	2-Dec-02	38	23-Dec-96	to	9-Apr-02	4
HB-15	1-Jan-16	to	2-Dec-02	30	23-Dec-96	to	9-Apr-02	3
HB-16	21-Aug-74	to	2-Dec-02	53	12-Nov-74	to	9-Apr-02	5
HB-17	20-Dec-95	to	2-Dec-02	12	9-Oct-01	to	9-Apr-02	2
HB-18	5-Dec-91	to	2-Dec-02	17	30-Mar-92	to	9-Apr-02	4
HB-19	5-Dec-91	to	9-Apr-02	15	30-Mar-92	to	9-Apr-02	2
HB-20	12-Nov-74	to	9-Apr-02	36	12-Nov-74	to	9-Apr-02	2
HB-21	5-Dec-91	to	9-Apr-02	15	12-Nov-74	to	9-Apr-02	2
HB-22	5-Dec-91	to	9-Apr-02	15	30-Mar-92	to	9-Apr-02	2
HB-23	5-Dec-91	to	9-Apr-02	15	30-Mar-92	to	9-Apr-02	2
E-a	2-Dec-86	to	2-Dec-02	20	nil			-
E-b	2-Dec-86	to	15-Jul-97	18	nil			-
E-c	2-Dec-86	to	15-Jul-97	17	nil			-
E-1	20-Oct-77	to	2-Dec-02	28	nil			-
E-2	20-Oct-77	to	2-Dec-02	26	nil			-
E-3	20-Oct-77	to	15-Jul-97	22	nil			-
E-4	20-Oct-77	to	2-Dec-02	27	nil			-
E-5	20-Oct-77	to	15-Jul-97	24	nil			-
E-6	20-Oct-77	to	2-Dec-02	30	nil			-
E-7	20-Oct-77	to	15-Jul-97	23	nil			-
E-8	20-Oct-77	to	2-Dec-02	22	nil			-
E-9	20-Oct-77	to	9-Aug-99	25	nil			-
E-10	21-Feb-55	to	2-Dec-02	27	nil			-
E-11	20-Oct-77	to	2-Dec-02	28	nil			-
E-12	20-Oct-77	to	2-Dec-02	22	nil			-
E-13	20-Oct-77	to	15-Jul-97	20	nil			-
E-14	1-Apr-37	to	2-Dec-02	50	23-Dec-96	to	9-Apr-02	4
E-15	20-Oct-77	to	15-Jul-97	20	nil			-
E-16	20-Oct-77	to	2-Dec-02	25	nil			-
E-17	20-Oct-77	to	15-Jul-97	24	nil			-
E-18	21-Feb-55	to	2-Dec-02	31	nil			-
E-19	20-Oct-77	to	15-Jul-97	21	nil			-
E-20	20-Oct-77	to	2-Dec-02	29	nil			-
E-21	20-Oct-77	to	15-Jul-97	20	nil			-
E-22	21-Feb-55	to	2-Dec-02	32	nil			-
E-23	3-Mar-87	to	20-Jul-01	16	nil			-
E-24	3-Mar-87	to	2-Dec-02	17	nil			-
E-25	3-Mar-87	to	15-Jul-97	14	nil			-

PROFILE SERIES	BEACH				OFFSHORE			
	FIRST date		LAST date	TOTAL surveys	FIRST date		LAST date	TOTAL surveys
W-39	13-Aug-98	to	9-Apr-02	5	nil			-
W-40	1-Jul-84	to	2-Dec-02	17	nil			-
W-41	1-Jul-84	to	2-Dec-02	18	nil			-
W-42	1-Jul-84	to	2-Dec-02	16	nil			-
W-43	1-Jul-84	to	9-Apr-02	14	nil			-
W-44	1-Jul-84	to	2-Dec-02	16	nil			-
W-45	1-Jul-84	to	2-Dec-02	18	nil			-
W-46	1-Jul-84	to	2-Dec-02	19	nil			-
W-47	1-Jul-84	to	9-Apr-02	16	nil			-
W-48	27-Aug-75	to	2-Dec-02	64	26-May-88	to	9-Apr-02	7
W-49	1-Jul-84	to	9-Apr-02	16	nil			-
W-50	1-Jul-84	to	2-Dec-02	20	nil			-
W-50a	10-Nov-92	to	9-Apr-02	11	nil			-
W-50b	10-Nov-92	to	9-Apr-02	11	nil			-
W-50c	10-Nov-92	to	2-Dec-02	14	nil			-
W-51	1-Jul-84	to	2-Dec-02	19	nil			-
W-51a	10-Nov-92	to	9-Apr-02	9	nil			-
W-51b	10-Nov-92	to	2-Dec-02	11	nil			-
W-51c	10-Nov-92	to	9-Apr-02	9	nil			-
W-52	21-Feb-55	to	2-Dec-02	20	nil			-
W-52a	10-Nov-92	to	9-Apr-02	9	nil			-
W-52b	10-Nov-92	to	9-Apr-02	9	nil			-
W-53	21-Feb-55	to	2-Dec-02	29	nil			-
W-60	21-Feb-55	to	2-Dec-02	27	nil			-

TABLE A2:

Coastal Cross-Section Profiles

Port of Napier to Ngaruroro River

Profile	Data Base Name	Distance	No. of Surveys	First Survey	Last Survey
1	Town Beach		3	8-Dec-92	7-Jul-97
2	Town Beach		2	8-Dec-92	7-Jul-97
3	Town Beach		9	8-Dec-92	26-Jul-02
4	Town Beach		4	8-Dec-92	26-Jul-02
5	Town Beach		9	8-Dec-92	26-Jul-02
6	Town Beach		4	8-Dec-92	26-Jul-02
7	Town Beach		8	8-Dec-92	26-Jul-02
8	Town Beach		6	7-Dec-92	26-Jul-02
9	Town Beach		11	8-Dec-92	26-Jul-02
10	Town Beach		10	8-Dec-92	26-Jul-02
11	Town Beach		8	23-Aug-94	26-Jul-02
12	Town Beach		10	31-Mar-93	26-Jul-02
13	Town Beach		10	30-Nov-93	26-Jul-02
14	Town Beach		9	8-Oct-93	26-Jul-02
15	Town Beach		10	8-Oct-93	26-Jul-02
16	Town Beach		5	7-Jul-97	26-Jul-02
17	Town Beach		5	7-Jul-97	26-Jul-02
18	Town Beach		4	7-Jul-97	26-Jul-02
19	Town Beach		4	7-Jul-97	26-Jul-02
20	Town Beach		2	7-Jul-97	26-Jul-02
21	Town Beach		2	7-Jul-97	26-Jul-02
22	Town Beach		2	7-Jul-97	26-Jul-02
HB12	HB Series		32	13-Nov-74	06-Dec-02
1	Spirit Series		1	17-Sep-99	17-Sep-99
2	Spirit Series		2	17-Sep-99	3-Aug-00
3	Spirit Series		1	17-Sep-99	17-Sep-99
HB 11 & 4	HB Series		25	19-Dec-83	06-Dec-02
5	Spirit Series		2	17-Sep-99	3-Aug-00
6	Spirit Series		1	17-Sep-99	17-Sep-99
7	Spirit Series		1	17-Sep-99	17-Sep-99
8	Spirit Series		2	17-Sep-99	3-Aug-00
9	Spirit Series		1	17-Sep-99	17-Sep-99

TABLE A3:

Coastal Cross-Section Profiles

Port of Napier to Ngaruroro River

Profile	Data Base Name	Distance	No. of Surveys	First Survey	Last Survey
HB12	HB Series		32	13-Nov-74	06-Dec-02
HB 11	HB Series		25	19-Dec-83	06-Dec-02
HB10	HB Series		27	19-Dec-83	06-Dec-02
HB 9	HB Series		26	19-Dec-83	06-Dec-02
AWA 25	Awatoto Series		7	19-Mar-96	09-May-02
AWA 24	Awatoto Series		7	19-Mar-96	09-May-02
AWA 23	Awatoto Series		7	19-Mar-96	09-May-02
AWA 22	Awatoto Series		7	19-Mar-96	09-May-02
AWA 21	Awatoto Series		7	19-Mar-96	09-May-02
AWA 20	Awatoto Series		7	19-Mar-96	09-May-02
AWA 19	Awatoto Series		7	19-Mar-96	09-May-02
AWA 18	Awatoto Series		7	19-Mar-96	09-May-02
AWA 17	Awatoto Series		7	19-Mar-96	09-May-02
AWA 16	Awatoto Series		10	02-Dec-92	09-May-02
HB 8 & AWA 15	HB / Awatoto Series		29	1943	06-Dec-02
AWA 14	Awatoto Series		11	02-Dec-92	09-May-02
AWA 13	Awatoto Series		11	02-Dec-92	09-May-02
AWA 12	Awatoto Series		21	1943	06-Dec-02
AWA 11	Awatoto Series		11	02-Dec-92	09-May-02
AWA 10	Awatoto Series		11	02-Dec-92	09-May-02
AWA 9	Awatoto Series		22	1943	06-Dec-02
AWA 8	Awatoto Series		11	02-Dec-92	09-May-02
K 6	Old Coastal Series		26	13-Nov-74	06-Dec-02
AWA 7	Awatoto Series		11	02-Dec-92	09-May-02
AWA 6	Awatoto Series		22	1943	06-Dec-02
AWA 5	Awatoto Series		11	02-Dec-92	09-May-02
AWA 4	Awatoto Series		11	02-Dec-92	09-May-02
AWA 3	Awatoto Series		11	02-Dec-92	09-May-02
HB 7 & AWA 2	HB / Awatoto Series		35	1939	06-Dec-02
AWA 1	Awatoto Series		11	02-Dec-92	09-May-02