APPENDIX D7: Sediment Impact Opinion

NM Environmental

THE LOWER UMKHOMAZI BULK WATER SUPPLY SCHEME: SEDIMENT IMPACT OPINION

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Report for:
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1. Introduction

The Lower uMkhomazi Bulk Water Supply System is the recommended augmentation to increase the assurance of water supply to the South Coast of KwaZulu-Natal. The general system consists of the Ngwadini weir and abstraction works to fill the Ngwadini off-channel storage dam during summer, as well as a second abstraction at the Goodenough weir with hydrocyclones to deliver raw water to a Water Treatment Plant (WTP) in Craigieburn. The proposed abstraction works will remove sediment from the river and could have a negative effect on the river system and coastal erosion at the uMkhomazi River mouth.

The purpose of this study was to evaluate the reduction in the sediment yield of the uMkhomazi River, caused by the proposed abstraction works at Ngwadini, as well as at Goodenough. The subsequent impact on the river system and coastal erosion at the river mouth was evaluated to determine whether the release of sediment from the WTP, abstraction works and operational reservoir back to the uMkhomazi River is supported.

Both the Ngwadini and the Goodenough abstraction works are located in section U10M of the uMkhomazi catchment, 30 km and 14 km upstream of the river mouth, respectively. Figure 1.1 shows the proposed sites of the Ngwadini and the Goodenough abstraction works within the uMkhomazi catchment.

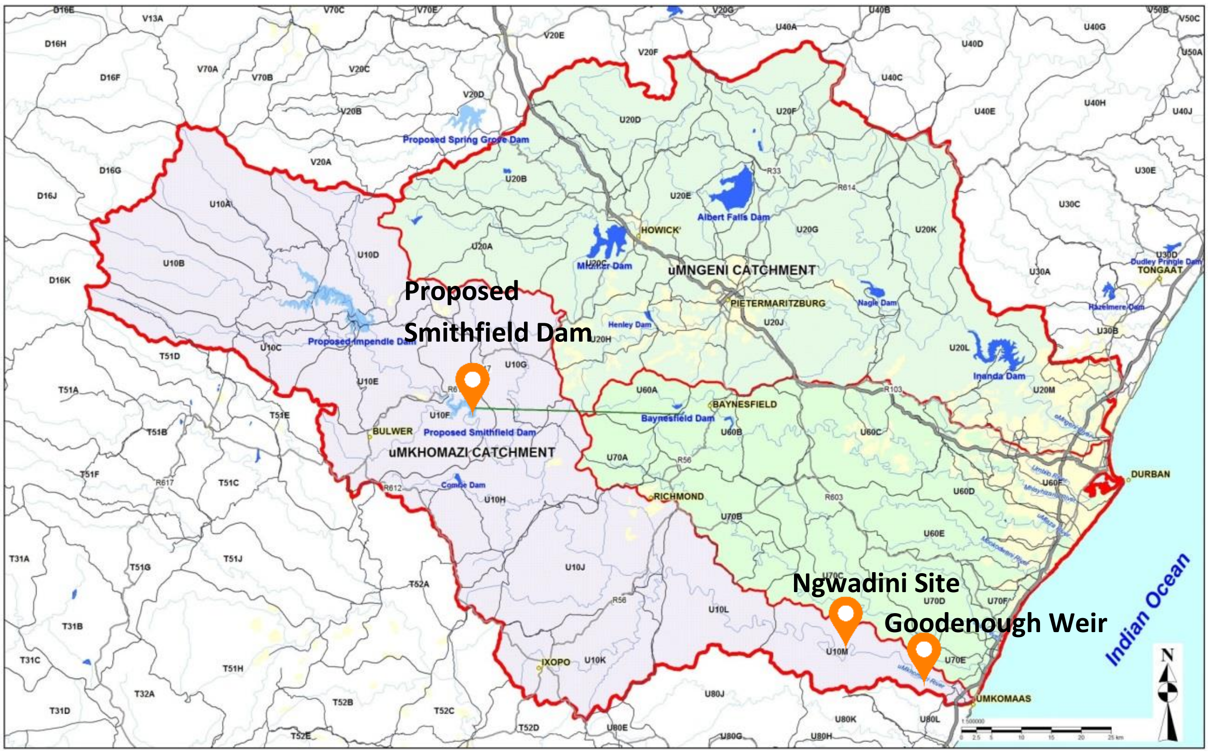


Figure 1.1: Location of the proposed abstraction works at Ngwadini and Goodenough

2. Hydrodynamic Modelling of the Non-Cohesive Sediment Loads

The sediment transport, deposition and erosion processes in the uMkhomazi River was simulated by a 1D Mike 11 hydrodynamic model (DHI Group) which uses the Engelund-Fredsoe sediment transport equation for non-cohesive sediment. The river was modelled downstream of the proposed Smithfield Dam site to the river mouth (although a pre-dam scenario was considered). The upstream boundary of the model was based on the hourly Department of Water and Sanitation (DWS) flow record shown in Figure 2.1 while a discharge-water level relationship was specified at the downstream boundary, at the river mouth, which was based on normal flow depths for the river. Two tributaries were also included in the hydrodynamic model between the dam and the river mouth. The inflow time series of these tributaries were such that a MAR of 1 078 million m^3/a was obtained at the river mouth.

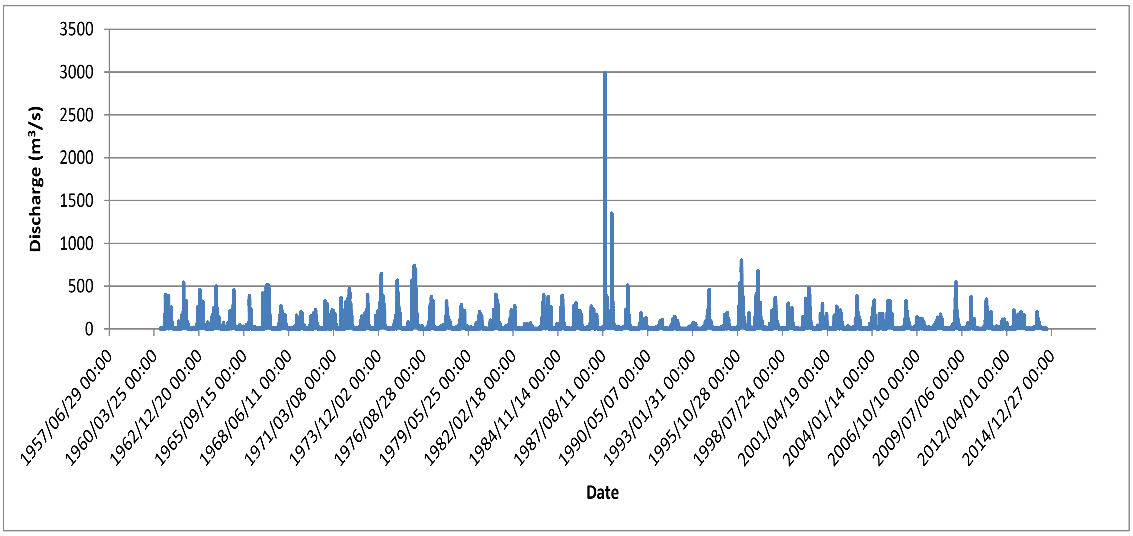


Figure 2.1: Flow record at the proposed Smithfield Dam site for the pre-dam scenario

The bed sediment grading specified in the hydrodynamic model was obtained from sediment samples collected in the field. The non-cohesive sediment fractions used in the model river bed are shown in Table 2.1. Figure 3 shows the resulting non-cohesive annual sediment loads for the river mouth for the 50 year period simulation from 1960/10 to 2010/10. Only non-cohesive sediments were routed through the river system to assess the impact on the coastal sediment budget. The cohesive sediment loads (washload) on the river were however also considered in the sediment balance of the river (section 3).

Table 2.1: Non-cohesive sediment fractions in the hydrodynamic model river bed

Fraction No.	Sediment Size	Percentage in range
	mm	%
1	7.28	6
2	1.17	22
3	0.14	72

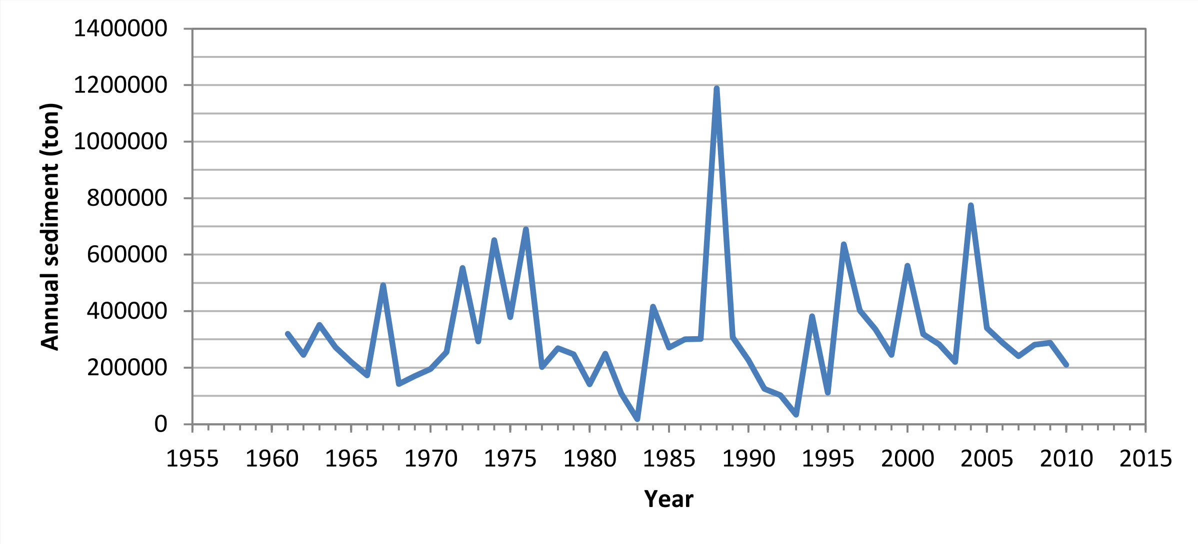


Figure 2.2: Simulated annual non-cohesive sediment loads at the uMkhomazi River mouth

3. Total Sediment Loads in the uMkhomazi River

The total sediment loads in the uMkhomazi River were calculated according to the WRC (2012) methodology at the Ngwadini site, the Goodenough weir and the uMkhomazi River mouth. This method gives the total sediment load which includes coarse non-cohesive sediment, as well as cohesive materials such as silt and clay. Table 3.1 shows the parameters used to calculate the total sediment yield with a value of 1.6 million t/a at the river mouth for a 95% confidence band. The 10 year flood for the uMkhomazi catchment was based on probabilistic hydrological calculations at DWS station U1H003 which were scaled up by 30%. Note the decrease in sediment load with the chainage along the river as the river slope becomes slightly less steep.

Table 3.1: Total sediment load calculations as per WRC (2012)

Parameter	Unit	Mkomazi River Mouth	Goodenough Weir	Ngwadini Site
Q10	m^3/s	1 720	1 713	1 696
River length	m	803 489	789 425	773 738
River density	m/km^2	183.13	181.32	181.42
Average river slope	(%)	1.063	1.095	1.163
Weighted Erosion Hazard Class	-	3.881	3.911	3.993
Effective catchment area	km^2	4 387	4 354	4 265
Catchment sediment load (50% confidence)	t/a	536 715	553 031	569 958
Catchment sediment load (95% confidence)	t/a	1 610 204	1 645 727	1 663 341

4. Comparison of Sediment Loads for Current and Future Scenarios

The sediment loads for the different non-cohesive sediment fractions from the Mike11 simulation, as well as the cohesive materials, are summarized in Table 4.1 for the current scenario without the proposed abstraction works. These sediment loads are based on a 95% confidence band as this gives a more realistic non-cohesive to total load ratio. The total coarse non-cohesive material accounts for approximately 20% of the total sediment.

Table 4.2 gives the different sediment loads for the future scenario with the proposed abstraction works removing sediment from the river. The sediment balance involves sediment load which is abstracted from the river (at a design pump rate of 2.6 m^3/s), some of which is then returned to the river by flushing or trapped in the off-channel dam or Water Treatment Plant (WTP).

At the Ngwadini site, the boulder trap and gravel traps are capable of flushing sediment and returning abstracted sediment to the river with a size > 0.3 mm. However, sediment with a size < 0.3 mm would be trapped in the off-channel dam, which includes the finest non-cohesive Fraction 3 (0.14 mm) with a load of 24 033 t/a as well as the cohesive sediment load of 112 936 t/a. Subsequently, the sediment load upstream of the Goodenough weir is reduced to 1.5 million t/a. The hydrocyclones at the Goodenough abstraction works would ensure that only a cohesive sediment load of 101 614 t/a would be trapped in the reservoir or transported to the WTP as these are characterized by sediment size fractions < 0.03 mm. All the non-cohesive material would then be returned after flushing. This gives a net sediment load of 1.4 million t/a at the river mouth after subtracting the sediment loads that would be trapped or permanently removed upstream of the mouth.

A direct comparison of the non-cohesive and total sediment loads at the different sites is presented in Table 4.3. The total load would be reduced by 15% (or 238 583 t/a) at the river mouth and by 8% (or 136 969 t/a) at the Goodenough weir. However, cohesive sediment transport (washload) has no effect on coastal erosion and a reduction in washload will actually be good since this counters the land degradation and associated higher sediment yield of the current scenario. Only non-cohesive sediment > 0.063 mm which has been lost from the uMkhomazi River will have a negative impact on the river and the coast. This is because the beaches mainly contain sand, and very little silt and clay, due to the relatively high energy coastline. The non-cohesive sediment load of 24 033 t/a removed from the river at Ngwadini to the off-channel dam alone would have a negative impact on the relevant downstream beaches. The total non-cohesive sediment load is therefore of primary concern and would be reduced by 8% at the river mouth and by 10% at the Goodenough weir.

Note that these calculations are based on the assumption that the abstraction works would operate for 12 months per year as opposed to only in the summer flood season. While the actual total abstracted sediment could be less, it would still be more than 50% of the abstracted loads if the pumps only operated for 6 months due to the higher sediment concentrations that occur in the river during summer. It was also assumed that the weirs will have no long term effect on the river sediment balance as a new equilibrium will probably be reached after the first flood season due to the relatively small storage capacity created by the weirs.

Table 4.1: Sediment load for the current scenario (ton/annum)

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
	Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
Sediment load in river upstream of the Ngwadini Site	15 853	44 506	158 441	218 800	1 444 541	1 663 341
Sediment load in river upstream of the Goodenough Weir	15 612	50 625	165 457	231 693	1 414 034	1 645 727
Sediment load at the River Mouth	18 993	69 639	227 910	316 542	1 293 661	1 610 204

Table 4.2: Sediment load for the future scenario with abstraction works (ton/annum)

		Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
		Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
Ngwadini Site	Sediment load in river upstream of the site	15 853	44 506	158 441	218 800	1 444 541	1 663 341
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 867	3 947	24 033	29 847	112 936	142 783
	Downstream of site after flushing (>0.3mm)	15 853	44 506	134 407	194 766	1 331 605	1 526 371
	Trapped in off-channel dam (<0.3mm)	0	0	24 033	24 033	112 936	136 969
Goodenough Weir	Sediment load in river upstream of the site	15 612	50 625	141 423	207 660	1 301 098	1 508 758
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 798	3 329	24 547	29 673	101 614	131 287
	Downstream of site after flushing (>0.03mm)	15 612	50 625	141 423	207 660	1 199 485	1 407 144
	Trapped in reservoir or taken to WTP (<0.03mm)	0	0	0	0	101 614	101 614
RM	Sediment load at the River Mouth	18 993	69 639	203 877	292 509	1 079 112	1 371 621

Table 4.3: Comparison by percentage reduction in sediment load from the current scenario

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
	Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
% reduction in sediment load at the Ngwadini Site	0%	0%	0%	0%	0%	0%
% reduction in sediment load at the Goodenough Weir	0%	0%	14.5%	10.4%	8.0%	8.3%
% reduction in sediment load at the River Mouth	0%	0%	10.5%	7.6%	16.6%	14.8%

The impact of the weir construction at Ngwadini and Goodenough on the downstream sediment supply and movement is considered negligible. Initially, the increase in water levels would cause the upstream reach of the river to silt up. However, within the first one or two flood seasons, the river would achieve a new morphological equilibrium. Therefore, the weirs would have no long-term effect on the uMkhomazi's sediment loads or ecology. It is not recommended to construct the abstraction works without the weir as they are required to create sufficient head for sediment control at the abstraction works.

~~6.~~5. The Release of Sediment Back into the uMkhomazi River

The proposed abstraction works will remove sediment from the river, some of which is to be released back into the river. Returning sediment to the river is supported because it facilitates the loss of sediment from the river system, thereby reducing any negative impact the abstraction works could have on the river and estuary. Abstraction works interrupt the continuity of sediment transport through river systems by starving downstream reaches of sediment which are essential for channel form and riparian ecosystems.

The boulder and gravel traps at the Ngwadini site and Goodeough site, and the hydrocyclones at the Goodenough abstraction works are necessary to ensure the greatest quantity of non-cohesive materials is removed from the river. Based on the sediment balance in Section 4, if none of the abstracted sediment load is returned to the river by flushing, the total load would be reduced by 17% at the river mouth and by 9% at the Goodenough weir (as opposed to the 15% and 8% with flushing respectively). The total non-cohesive sediment load would be reduced by 19% at the river mouth and by 13% at the Goodenough weir (as opposed to the 8% and 10% with flushing respectively). Therefore, the placement of 5 814 ton/a additional sediment in the river by flushing at the Ngwadini site and 29 673 ton/a sediment at the Goodenough weir is justified, ensuring 35 487 ton/a is returned to the estuary. Tables 5.1 and 5.2 give the different sediment loads and percent reduction in sediment load for the proposed abstraction works without returning the abstracted sediment to the river.

Flushing of sediments should only be carried out during small floods and not under normal or low river flow conditions. The boulder and gravel traps at the river abstraction works have relatively small capacities and only non-cohesive sediments will be trapped and flushed. Flushing durations per trap is less than 0.5 h and therefore the locally increased sediment concentrations in the river downstream should have minimal ecological impact. The settler at the Goodenough site could trap some silt (depending on its design), and it is therefore important that the settler is only flushed when the river is in flood.

Table 5.1: Sediment load for the abstraction works without flushing (ton/annum)

		Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
		Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
Ngwadini Site	Sediment load in river upstream of the site	15 853	44 506	158 441	218 800	1 444 541	1 663 341
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 867	3 947	24 033	29 847	112 936	142 783
	Downstream of site w/o flushing	13 986	40 559	134 407	188 953	1 331 605	1 520 558
Goodenough Weir	Sediment load in river upstream of the site	13 745	46 678	141 423	201 846	1 301 098	1 502 944
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 798	3 329	24 547	29 673	101 614	131 287
	Downstream of site w/o flushing	11 947	43 349	116 876	172 173	1 199 485	1 371 658
RM	Sediment load at the River Mouth	15 328	62 364	179 330	257 022	1 079 112	1 336 134

Table 5.2: Comparison by percentage reduction in sediment load from the current scenario

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
	Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
% reduction in sediment load at the Ngwadini Site	0%	0%	0%	0%	0%	0%
% reduction in sediment load at the Goodenough Weir	12.0%	7.8%	14.5%	12.9%	8.0%	8.7%
% reduction in sediment load at the River Mouth	19.3%	10.4%	21.3%	18.8%	16.6%	17.0%

~~7.~~6. Alternative for Minimal Impact on Sediment Balance

Cohesive sediment or washload that is removed by the abstraction works at the Ngwadini and Goodenough sites will not have a negative impact on the relevant downstream beaches. Cohesive sediment has no effect on coastal erosion and a reduction in washload will actually be good since this counter the land degradation and associated higher sediment yield of the current scenario.

Therefore, only the non-cohesive sediment load will have a negative impact on the river and the coast. None of the non-cohesive sediment fractions are trapped at the Goodenough Weir thus its abstraction works would not interrupt the natural flow of sediment to the coast. To ensure that no impact is made on the sediment yield at the coast, the 24 033 ton/annum of the 0.14 mm coarse non-cohesive sediment (Fraction 3) that is trapped in the off-channel dam at the Ngwadini site would have to be returned to the uMkhomazi River. Two alternatives could be considered for the Ngwadini site as mitigation measure for sediment trapping:

1. Hydrocyclones such as those at the Goodenough Weir could be used to capture sediment >0.03mm that can be returned to the river.
2. Long settlers could be used to settle out the finer fractions of sediment (fine sand and silt) which could then be flushed back to the river during floods.

The tables below summarizes the sediment load for the future scenario with the abstraction works if one of the two alternatives were to be implemented at the Ngwadini site.

Table 6.1: Sediment load for the future scenario with abstraction works only removing cohesive sediment (ton/annum)

		Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
		Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
Ngwadini Site	Sediment load in river upstream of the site	15 853	44 506	158 441	218 800	1 444 541	1 663 341
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 867	3 947	24 033	29 847	112 936	142 783
	Downstream of site after flushing (>0.3mm)	15 853	44 506	158 441	218 800	1 331 605	1 550 405
	Trapped in off-channel dam (<0.3mm)	0	0	0	0	112 936	112 936
Goodenough Weir	Sediment load in river upstream of the site	15 612	50 625	165 457	231 693	1 301 098	1 532 792
	Sediment load abstracted (pump rate = 2.6 m^3/s)	1 798	3 329	24 547	29 673	101 614	131 287
	Downstream of site after flushing (>0.03mm)	15 612	50 625	165 457	231 693	1 199 485	1 431 178
	Trapped in reservoir or taken to WTP (<0.03mm)	0	0	0	0	101 614	101 614
RM	Sediment load at the River Mouth	18 993	69 639	227 910	316 542	1 079 112	1 395 654

Table 6.2: Comparison by percentage reduction in sediment load from the current scenario at different sites for abstraction works only removing cohesive sediment

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	Total Sediment Load
	Fraction 1 7.28 mm	Fraction 2 1.17 mm	Fraction 3 0.14 mm			
% reduction in sediment load at the Ngwadini Site	0%	0%	0%	0%	0%	0%
% reduction in sediment load at the Goodenough Weir	0%	0%	0%	0%	8.0%	6.9%
% reduction in sediment load at the River Mouth	0%	0%	0%	0%	16.6%	13.3%

If consideration were to be given to apply hydrocyclones or long settlers at the Ngwadini site, the total reduction in non-cohesive sediment load at the river mouth will be improved from 7.6% to 0% while the reduction in total sediment load will only decrease from 14.8% to 13.3%. However, this 13.3% is entirely composed of washload or cohesive sediment.

Flushing of sediments at the boulder and gravel traps, as well as the settlers, would ensure that the trapped sediment is returned to uMkhomazi River. To minimize the impact of the abstraction works on the river downstream and to assist restoration of the sediment balance, flushing should be of a short duration (less than 0.5 h) and only during small floods (not under normal or low river flow conditions). The locally increased sediment concentrations in the river during the small floods would have minimal ecological impact.

However, should continuous flushing be given preference over continuous flushing, hydrocyclones or sand traps should be constructed in the place of settlers. Continuous flushing is not recommended because it would have a severe impact on the base flow by elevating the sediment concentrations.

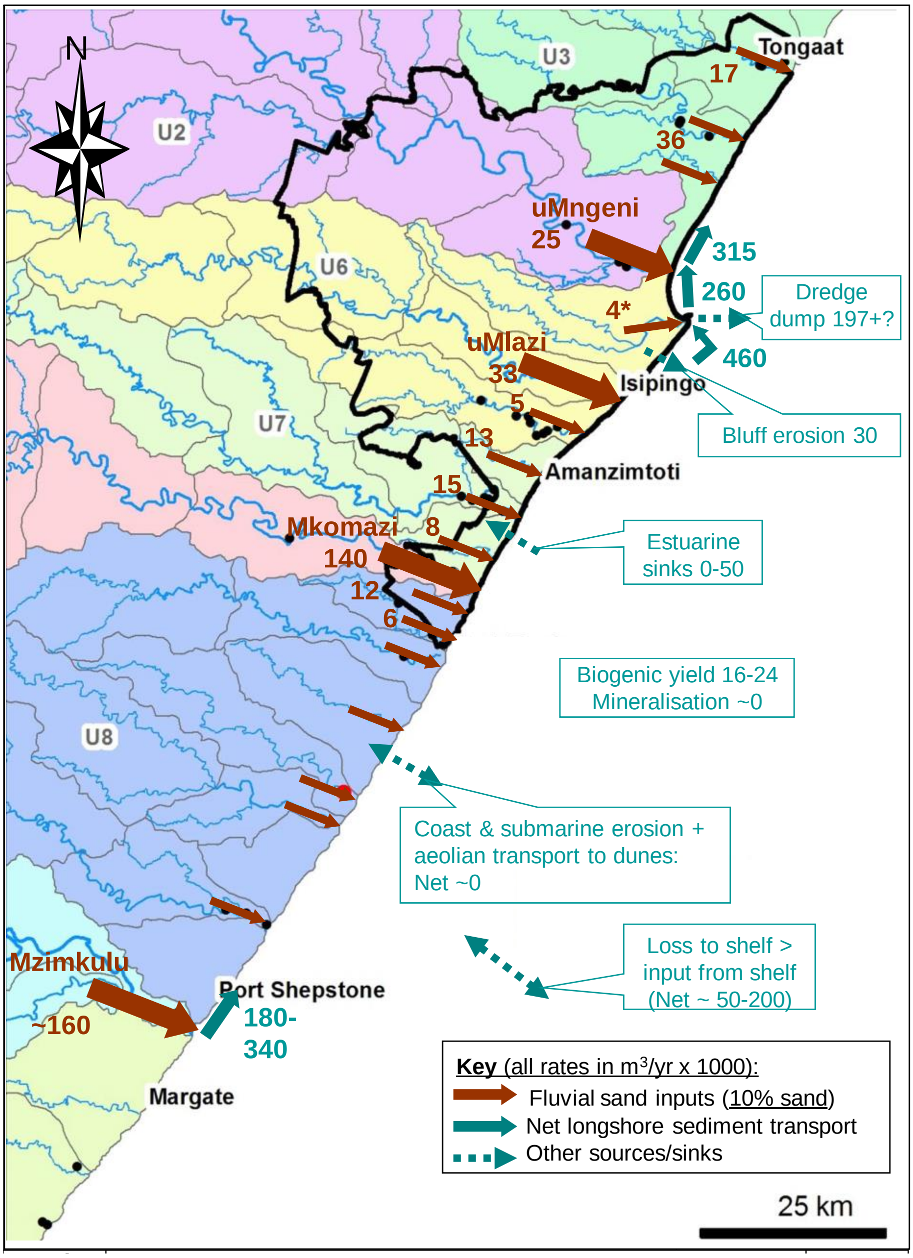
~~8.~~7. Consideration of the South KwaZulu-Natal Coastal Erosion

7.1 Interpretation of Previous Studies on the KZN Coastal Sediment Erosion

In 2007/2008, Theron *et al* (2008) conducted an investigation on behalf of the eThekwini Municipality regarding the long-term sustainability of the coastal sand resource and potential implications for coastal “stability”, which specifically entailed quantifying the possible reduction in sand supply to the coast. This study included deriving estimates of sediment yield for all rivers within the eThekwini Municipal jurisdiction, and an assessment of the impacts of dams and sand mining on fluvial sand yields. It was found that there are 12 large dams on the 18 rivers within the eThekwini jurisdiction (Tongati River to Mahlongwa River) and that these dams reduce the sand yield to the eThekwini coast by about one third. Based on a survey of sand mining operations on the 18 eThekwini related rivers, the total mined volumes were estimated to be at least 400 000 m^3/a in 2008.

Potential sediment sources along the KZN coast are fluvial discharge, coastal and submarine erosion, aeolian transport, biogenic products and in situ authigenic mineralisations. These were all assessed and quantified, clearly indicating that the sediments contributed by river discharge dominate total production. From these studies, it follows that in the long-term, the amount and character of central KZN coastal sediments is ultimately determined by the larger rivers (and the nature of their catchments) within the region. It is also important to understand that the net littoral drift (i.e. the longshore sediment transport) along the southern and central KZN coast is strongly towards the north-east (i.e. “upcoast”). The only really large potential sources of sediments to the central KZN coast from further south are the Kei, uMzimvubu and uMzimkulu Rivers. The firm conclusion is that relatively little sand reaches the southern KZN shoreline from downcoast river sources or longshore drift. The amounts and locations of the sand sources and sinks, as well as longshore transport rates are graphically indicated in a synthesis of the southern-central KZN coastal sediment budget as depicted in Figure 7.1 (Theron *et al*, 2008).

It was concluded in the 2008 study that the combined impacts of the dams and mining could result in mean coastal erosion of > 1 m/a. A strong recommendation was made to ban river sand mining from the eThekwini rivers as soon as practicable, while urgently seeking and evaluating other sources of sand. The fact that large in-stream impoundments have significant detrimental impacts, including on sediment yield to coastal areas and thus on coastal stability, was also emphasised.



~~Figure 6~~Figure 7.1: Present understanding and quantification of the Durban regional sediment budget

***including dams and dredging, but excluding sand mining (Theron et al, 2008)**

7.2 uMkhomazi River Sand Yield Reductions in Context of the Coastal Sediment Erosion

Regarding the present study on the uMkhomazi River, it must be emphasised that this river is by far the most dominant source of fluvial sand supply to the whole coastline between the uMzimkulu River mouth and Durban. The 2008 study (Theron *et al*, 2008) estimated the sand (i.e. coarse sediment fraction only) yield of the uMkhomazi River to the coast at between about 140 000 m^3/a to 215 000 m^3/a, while the present (2017) study on the impacts of the abstraction works estimates the sand yield at about 200 000 m^3/a. (This is based on conversion of the coarse sediment loads from tons to volumetric loads assuming an appropriate in situ sediment density of 1 600 kg/m^3. Thus, for example, the sand yield of 316 542 ton/a equates to a volume rate of 197 839 m^3/a.) The present (2017) study further estimates that the sand yield will reduce by about 15 000 m^3/a as a result of sand removed by the proposed abstraction works, which would be an 8% reduction in sand supply to the coast from this river. As indicated, the focus here is on the coarse non-cohesive sediment fraction, i.e. the sand fraction of the total sediment load, as this is the material that replenishes the beach sand found along the seashore. The sand fraction is typically only about 10% of the total fluvial sediment load i.e. including fines.

In terms of the regional coastal sediment budget, the sand yield of the uMkhomazi River (and reductions thereof) should also be considered in the wider context (as for example depicted in Figure 3.1). In this regard, the most important other factors are the coastal sediment input (i.e. the longshore transport rate) from further south, and the net longshore transport rate towards the Port of Durban along the Durban Bluff. An actual net north-eastward longshore sediment transport rate of about 500 000 m^3/a (on average) is estimated along the Durban Bluff coastline (Theron and Rautenbach, 2014). The actual net longshore transport rate at Port Shepstone (north-east of the uMzimkulu Mouth) is estimated to be about 240 000 m^3/a, north-east bound (Schoonees and Theron, 2001), which is about half of the net north-eastward longshore sediment transport rate along the Durban Bluff. Thus, it is estimated that the uMkhomazi River naturally contributed between about 50% to 85% of the additional sand inputs required for the coast from Port Shepstone to Durban. Besides the longshore transport input from further south of Port Shepstone, the uMkhomazi River is thus by far the most dominant source of fluvial sand supply to the whole coastline between the uMzimkulu River mouth and Durban. Based on the present (2017) study estimates of a mean fluvial sand yield at about 200 000 m^3/a for the uMkhomazi River and trapping and reduced sediment transport capacity of some 15 000 m^3/a due to the proposed abstraction works, represents a reduction of 6% of the additional sand inputs required for the coast between Port Shepstone and Durban. This is not such a significant reduction but may lead to various impacts as discussed in the next chapter.

Unfortunately, in addition to the above potential impact to the sand yield of the uMkhomazi River, this important source of sand has also already been impacted on by sand mining (as is the case with many of the other central KZN rivers). Much of the sand mining operations extract sand directly from the main river channel and active/dynamic sand banks along the main channel, as can clearly been seen in the example shown in Figure 7.2. In the 2008 study (Theron *et al*, 2008), it was estimated that the sand mining rate from the uMkhomazi River is at least 42 000 m^3/a. It seems likely that present (2017) sand mining volumes would be higher than the 2008 value. Based on the 2017 estimate of fluvial sand yield of the uMkhomazi River, the sand mining (2008 volume) constitutes a loss of about 21% of the "natural" sand yield. Thus, the reduced sand load by the proposed abstraction works would have a far lesser impact than the sand mining on the sand yield, and in total would reduce the sand yield of the uMkhomazi River by as much as about 29%.

Figure 7.2: Example of sand mining operations directly in uMkhomazi main river channel 2008

7.3 SHORELINE VARIABILITY AND LONG-TERM STABILITY

A brief interpretation of selected data and information from the study area is provided regarding specific parameters relevant to coastal sediment supply and long-term shoreline stability issues along this portion of the central KZN coast, focussing mainly on the approximately 10 km of shoreline from Umkomaas northward to Umgababa.

7.3.1 INTERPRETATION OF AERIAL PHOTOGRAPHY

The beach and shoreline morphology in the direct vicinity of the mouth of the uMkhomazi River is highly dynamic and variable. Episodic events, especially river floods and sea storms move large volumes of sand in the short-term (days), interspersed by longer periods (weeks to months) of more moderate change as milder conditions allow a gradual return towards the longer-term equilibrium configuration. These dynamics result in large natural shoreline variations (e.g. Figure 7.3.1 (from CSIR, 1973)) which would tend to obscure possible slight long-term trends in shoreline location.

A previous investigation of the coastline south of Durban (Theron *et al*, 2003) included aerial photograph analyses and determination of coastline changes and long-term beach stability derived there from. The long-term shoreline variability was quantified by considering the variation in shoreline location over an extended period based on vertical aerial photography. Historical shorelines were referenced relative to ortho-corrected aerial photography. The limitations of assessing shoreline variation and stability using aerial photographs analysis are the level of accuracy when establishing the position of the high-water mark (accurate to within 10 m) and especially the availability of aerial photographs (for example the number of photographs available for the last 50 years). By using the high-water run-up mark and not the water line, uncertainties relating to the tidal level at the time of the photography are eliminated.

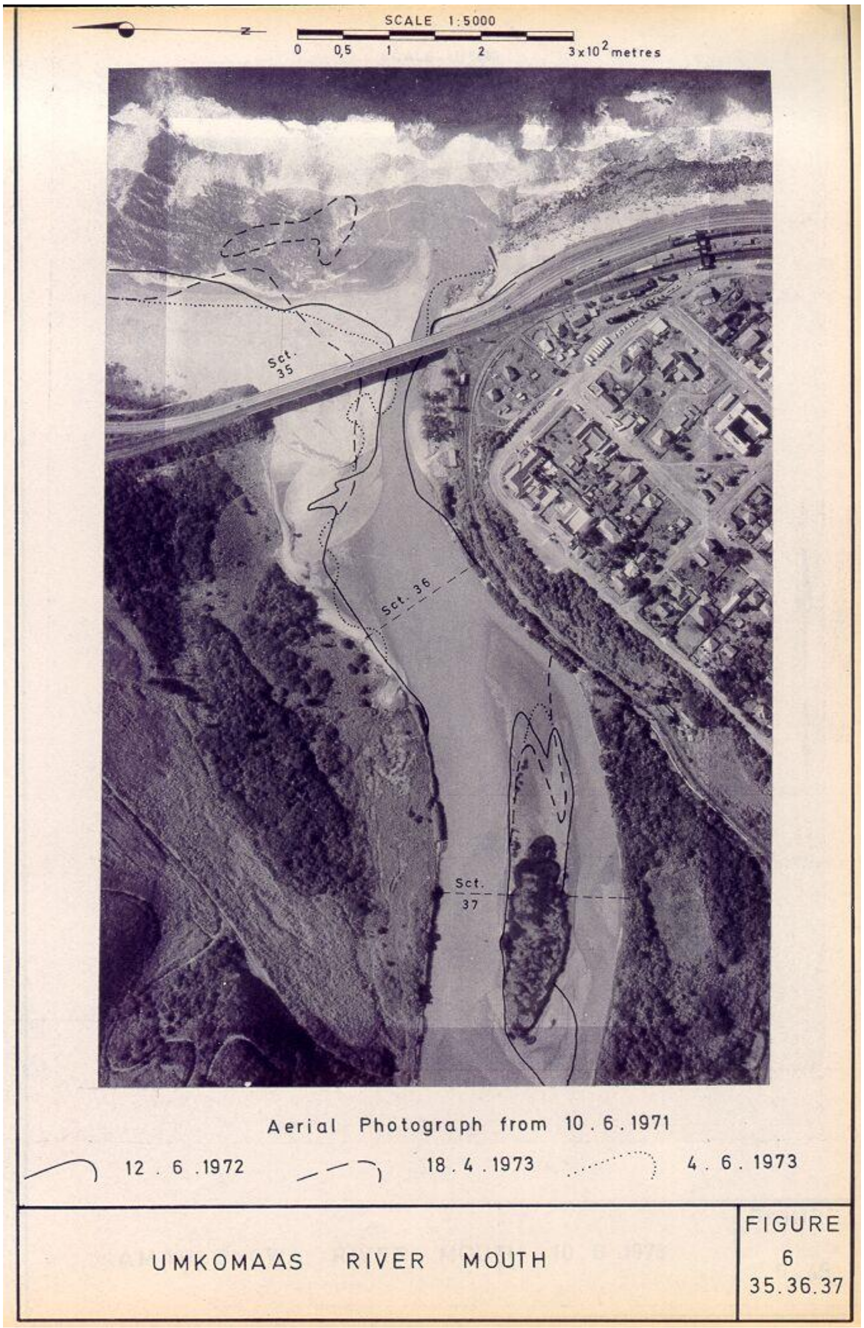


Figure 7.3.1: Shoreline changes at the mouth of the uMkomazi River (Theron et al, 2003)

Thus, time series aerial photograph mosaics, which show historical shoreline configurations and locations, were produced. Aerial photographs used in the analysis covered 63 years. Photographs were available for the years 1937, 1959, 1967, 1973, 1976, 1978, 1987, 1990 and 2000. The historic high-water lines were transposed onto the "master" ortho-corrected aerial photograph mosaics. The results for the area in the vicinity of Umkomaas to Umgababa are show in Figures 6.3.2 to 6.3.4.

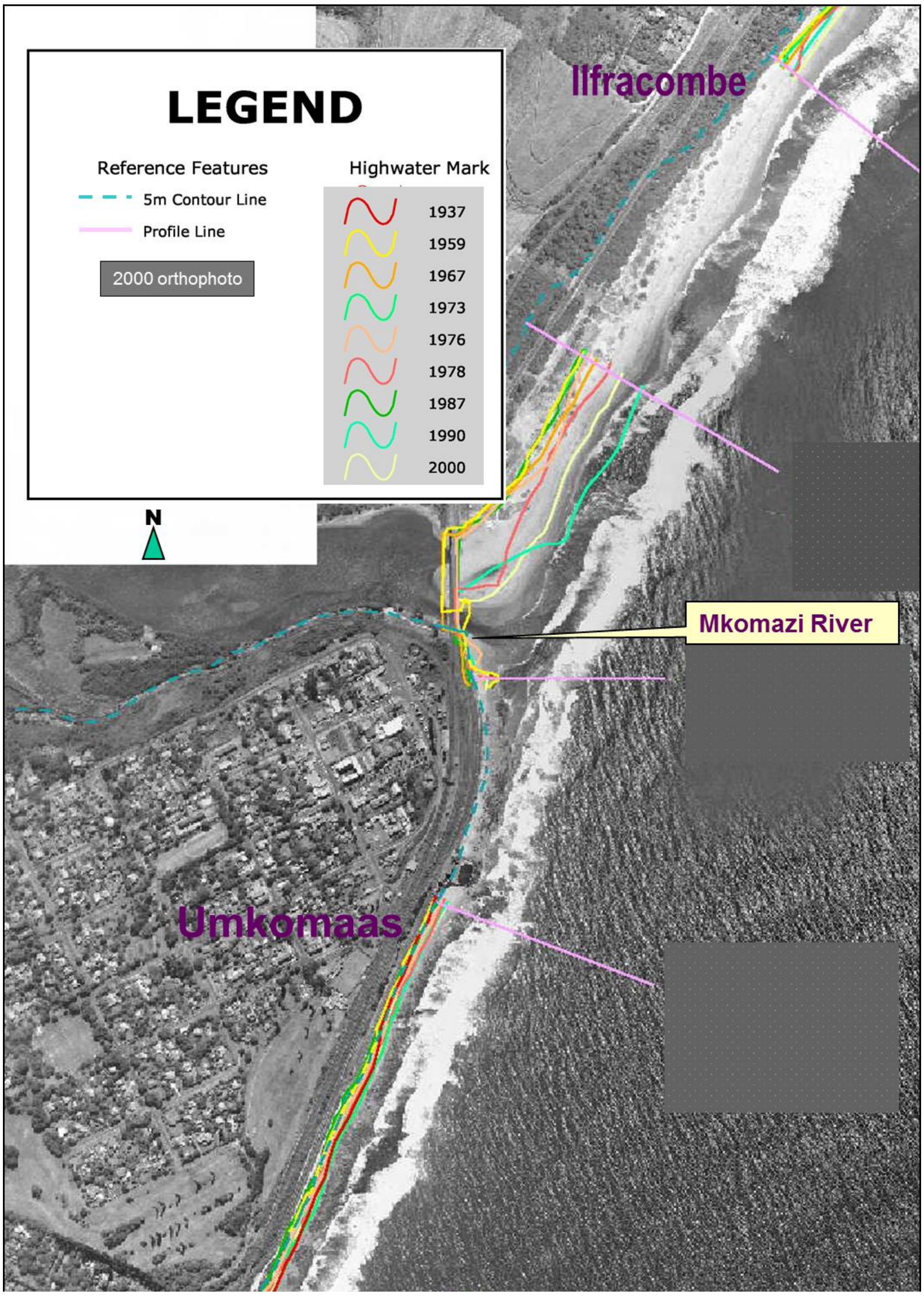


Figure 7.3.2: **Coastal high-water lines at and south of uMkomazi Mouth (Theron et al, 2003)**

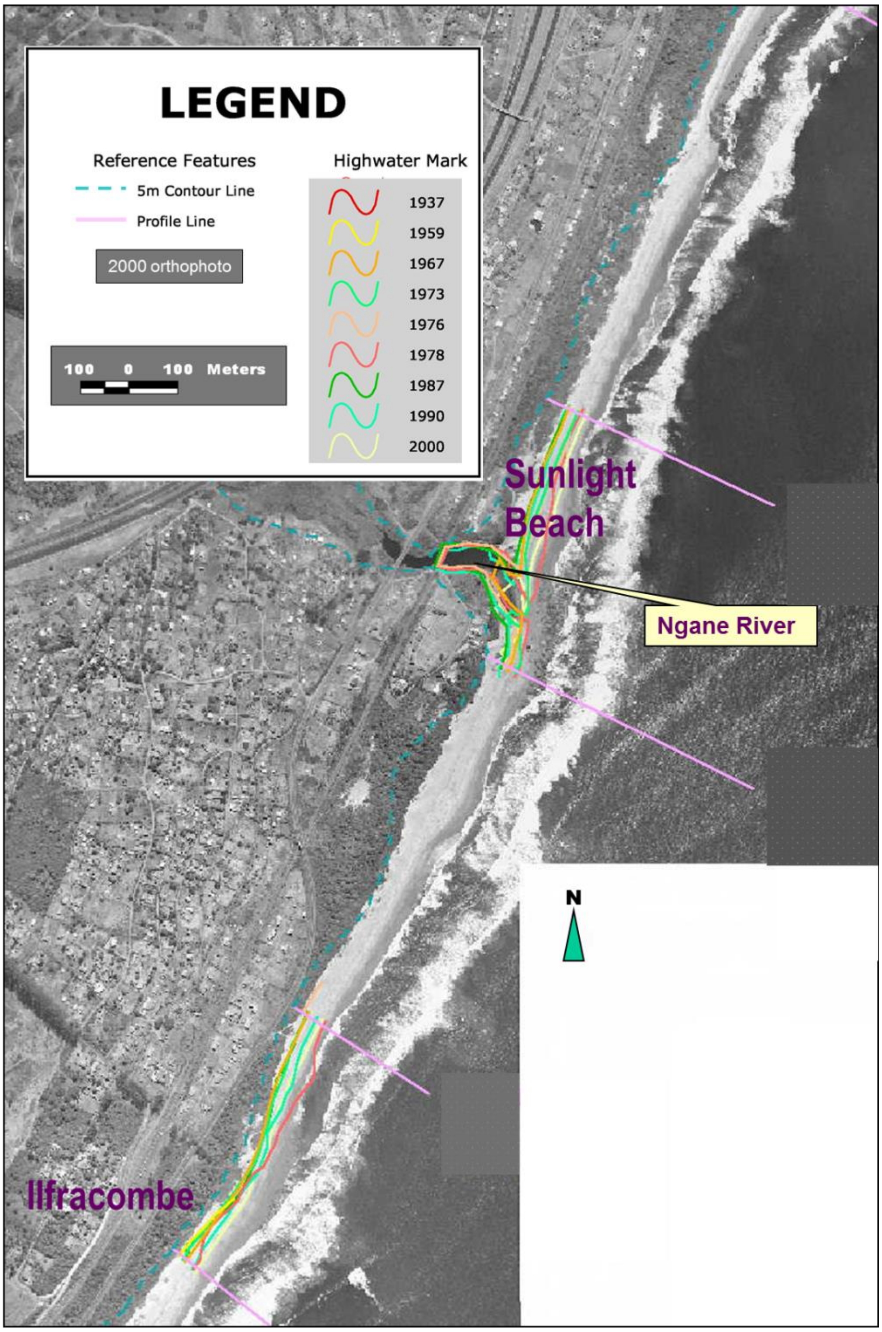


Figure 7.3.3: **Coastal high-water lines north of uMkomazi Mouth - Ifracombe to Sunlight Beach (Theron et al, 2003)**

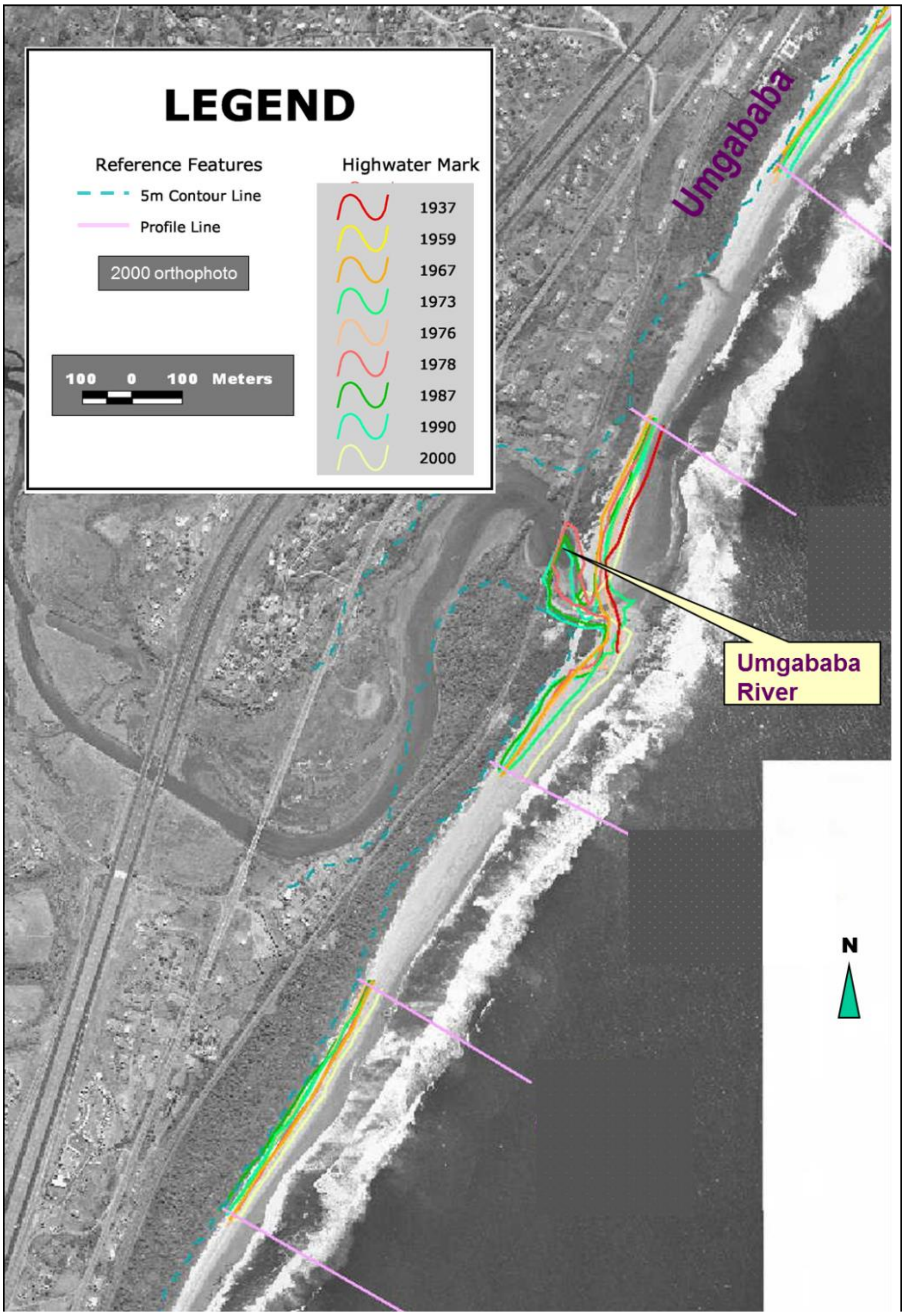


Figure 7.3.4: Coastal high-water lines north of uMkomazi Mouth - Sunlight Beach to Umgababa (Theron et al, 2003)

In the uMsimbazi to uMkhomazi River Mouth area, rocky headlands have a significant impact on shoreline morphology. Between Ifracombe and the uMkhomazi River Mouth, relatively large accretion was exceeded by erosion in the ensuing periods. This might be linked to a large influx of sediment during floods, while in the ensuing periods erosion caused retreat of the shoreline. Between Umgababa and Sunlight Beach, envelopes of mobility are relatively low and rates of change between successive photographs are also relatively low. In the Umkomaas area to the south of the uMkhomazi River Mouth the shoreline is mainly rocky, with low to medium temporal patterns of erosion and accretion.

No significant eroding or accretionary long-term trend in the shoreline location is apparent in the Study Area from the aerial photography (Figures 6.3.2 to 6.3.4). In general, it seems that the beaches of the study area have remained dynamically stable since the 1930s.

7.3.2 INTERPRETATION OF COASTAL TOPOGRAPHIC SURVEYS

In the early 1970s the CSIR measured 11 beach profiles at each of three locations, one of which was located just north (ca. 0.5 km) of the mouth of the uMkhomazi River, and another at the Umgababa Holiday Resort to the north of the uMkhomazi Mouth (CSIR, 1973). Profile envelopes based on these surveys are shown in Figure 7.3.5. From the profile envelope of the beach near the uMkhomazi mouth, it can be seen that short-term horizontal variations of the upper beach (within approximately the 0 m to +2 m to mean sea level elevations) ranged up to 50 m within the recording period, while variations near the low-tide mark can be even more.

The eThekwini Municipality’s extensive coastal monitoring programme includes surveyed profiles of the beaches located to the south of Durban (refer to Figure 5.3.6) and in the vicinity of the uMkhomazi Mouth. In Figure 7.3.6 the monitoring sections are given together with their locations. Profile SC38 is located near Umkomaas just south of the uMkhomazi Mouth, while Profiles SC33 and SC34 are located to the north of the mouth, with SC34 being the nearest to the mouth. Over the 7 year monitoring period (approximately 3 months between surveys) Profile SC38 showed small short-term horizontal variations of the +2 m contour (up to in the order of 10 m), due to this being a rocky shoreline with only limited sandy patches. In comparison Profile SC34 located just north of the uMkhomazi River mouth has shown short term horizontal variations of the +2 m contour of up to 50 m within the 7 year period, while Profile SC33 located a bit further north of the uMkhomazi River mouth has shown short term horizontal variations of the +2 m contour of up to 40 m over the same period. Profiles SC 33 and SC34 located just north of the uMkhomazi River mouth show net shoreline erosion over the 7 years, but this “trend” does not extend further northwards to Profiles SC31 or SC32. The erosion nearer to the uMkhomazi River mouth might be linked to a large influx of sediment during floods, while in the ensuing periods erosion caused retreat of the shoreline. In general, the 7 year monitoring period is still insufficient to identify possible underlying long-term trends with any certainty, especially under the larger prevailing natural short-term fluctuations due to sea storms and river floods.

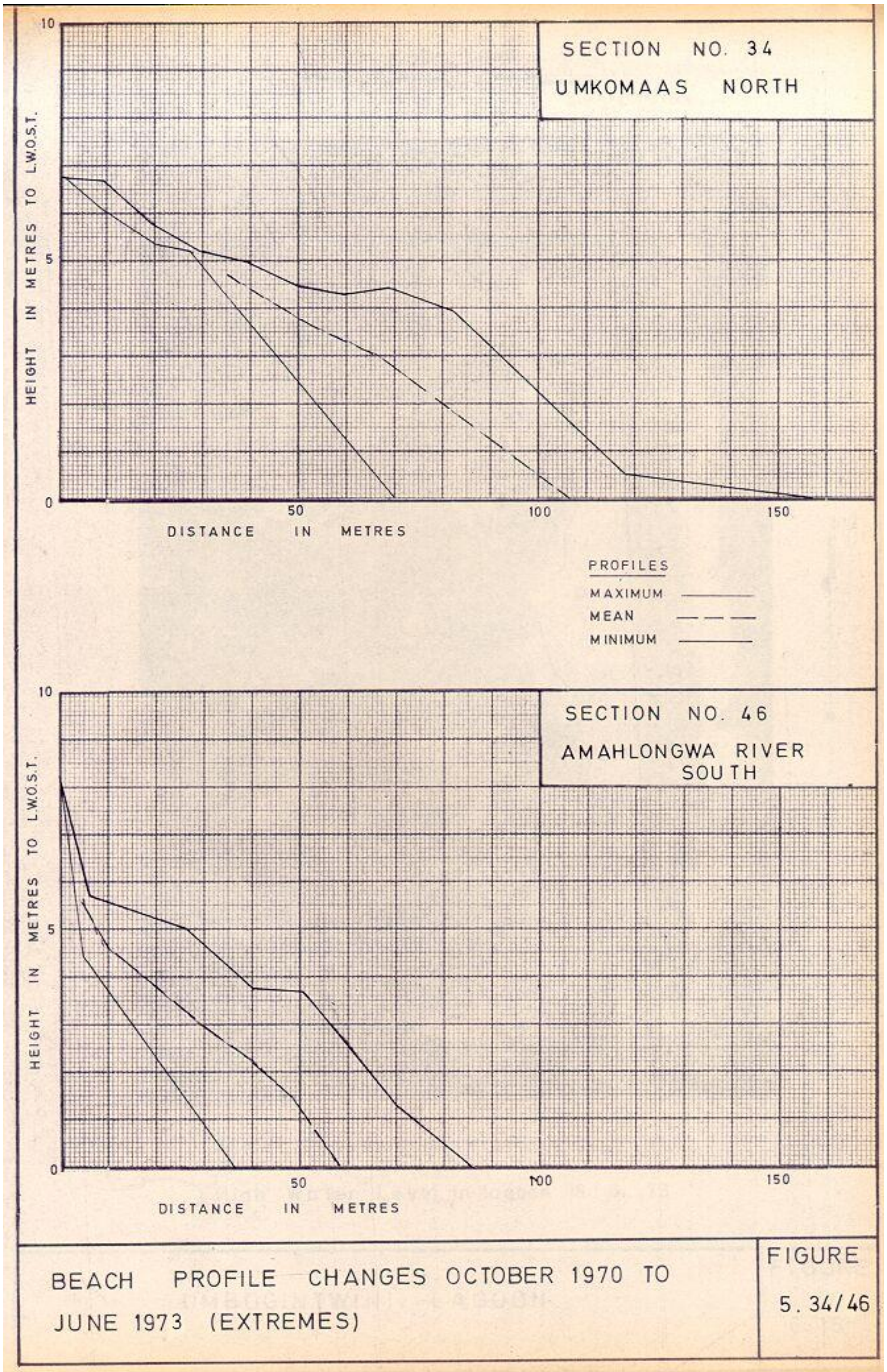


Figure 7.3.5: Beach profile envelope October 1970 to June 1973

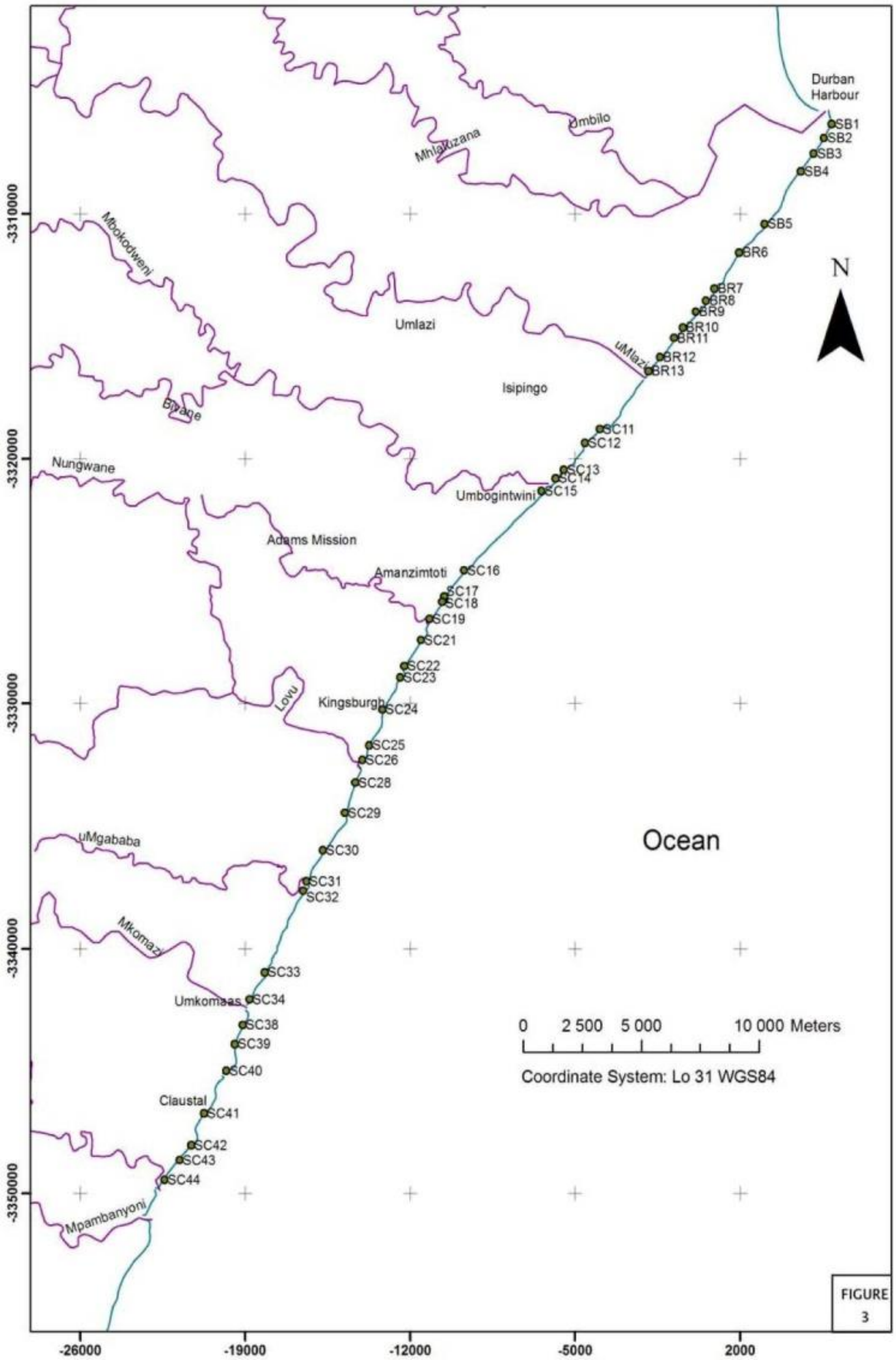


Figure 7.3.6: Location of Durban southern beach profiles survey stations (adapted from Theron and Rautenbach, 2014)

~~9.~~8. Conclusions and Recommendations

Abstraction works interrupt the continuity of sediment transport through river systems by starving downstream reaches of sediment which are essential for channel form and riparian ecosystems. The study established that the proposed abstraction works at Ngwadini and Goodenough would reduce the total sediment yield in the uMkhomazi River by 8% at Goodenough and 15% at the estuary. However, washload has a limited effect on the river and coastal erosion, and thus only the non-cohesive sediment load of 24 033 t/a removed at Ngwadini would have a negative impact on the system. The total non-cohesive sediment load would be reduced by 8% at the river mouth and by 10% at the Goodenough weir. If none of the abstracted sediment is returned to the river by flushing, the total non-cohesive sediment load would be reduced by 19% at the river mouth and by 13% at Goodenough. Therefore, the placement of 5 814 ton/a additional sediment in the river by flushing at Ngwadini and 29 673 ton/a sediment at Goodenough is supported. The release of sediment back to the river facilitates the impacts the project will have on sediment load within the river and estuary.

Flushing of sediments should only be carried out during small floods and not under normal or low river flow conditions. The boulder and gravel traps at the river abstraction works have relatively small capacities and only non-cohesive sediments will be trapped and flushed. Flushing durations per trap is less than 0.5 h and therefore the locally increased sediment concentrations in the river downstream should have minimal ecological impact. The settler at the Goodenough site could trap some silt (depending on its design), and it is therefore important that the settler is only flushed when the river is in flood.

From the aerial photographic analyses and the topographic survey results, it cannot be clearly ascertained whether there is currently a significant long-term trend in the shoreline location in the vicinity of the uMkhomazi River Mouth. Horizontal shoreline variations are naturally relatively large on this exposed high energy coastline and are further subject to the effects of episodic flood derived pulses of sediment input from the larger rivers in the region. However, based on the longer-term aerial photographic analyses it appears that if indeed an eroding trend were present, it would have to be quite small (<=0.3 m/a, i.e. <=15 m over 50 years) to remain undetected at this stage.

Nevertheless, it is clear that the proposed abstraction works on the uMkhomazi River could have a long-term effect on the coastal erosion due to the volume of sand of 15 000 m^3/a (8% reduction in sand supply) to the coast that will be trapped by the abstraction works. The impact in terms of net coastal erosion will be most noticeable in the first 10 km to the north of the mouth of the river, but even in this area it may be a decade or more after completion of the abstraction works before the impact is clearly apparent. However, in the long-term the impact (although reducing in magnitude/intensity towards the north), will gradually spread further north and could possibly eventually even result in a reduction of the longshore sand supply to the Durban Bluff area.

If major developments on the uMkhomazi River are inevitable, then the potential impacts in terms of reduced fluvial sand supply to the coast could be mitigated by stopping the current sand mining in the river. While the abstraction works may cause an 8% reduction in sand supply to the coast from the river, sand mining constitutes a loss of at least 21% of the “natural” sand yield. Furthermore, it is recommended to investigate and implement the exploitation of other sources of sand.

As mitigation measure, consideration should be given to apply hydrocyclones or long settlers at the proposed Ngwadini abstraction works to settle out smaller grain sizes (fine sand and silt), which could be flushed back to the river during floods. To further minimize the impact of the abstraction works on the river and to assist restoration of the sediment balance, flushing of boulder traps and gravel traps should be of a short duration, of non-cohesive sediment and aerated, and only during floods. If the settler at the Goodenough weir is to return the flushed sediment, this should be done during floods even though relatively short settlers typically cannot trap the washload. Provision should be made in the design of the rising main to the WTP to ensure that the velocity in the pipe is higher than the scour velocity for the washload.

References

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312 - Inception report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/1 - Main report ,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/2/1 - Hydrological assessment of the uMkhomazi River catchment report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/2/2 - Water requirements and return flows report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/2/3 - Water resources yield assessment report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/2/4 - Water resources planning model report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/2/5 - Hydropower assessment report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1 - Engineering feasibility design report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1/2 - Supporting document 2: Dam position report ,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1/3 - Supporting document 3: Optimization of scheme configuration,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1/4 - Supporting document 4: Cost model,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1/5 - Supporting document 5: Dam type selection,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/1/6 - Supporting document 6: Economic comparison of the uMkhomazi-uMgeni transfer scheme with desalination and re-use options,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2 - Geotechnical report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2/1 - Supporting document 1: Probabilistic seismic hazard analysis (Smithfield Dam),* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2/2 - Supporting document 2: Seismic refraction investigation at the proposed uMkhomazi Water Project Phase 1,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2/3 - Supporting document 3: Smithfield Dam: Materials and geotechnical investigation,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2/4 - Supporting document 4: Langa Dam: Materials and geotechnical investigation,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/3/2/5 - Supporting document 5: Conveyance system: Materials and geotechnical investigation,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/4 - Record of Implementation Decisions,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/5; Institutional and financial aspects report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/6 - Economic impact assessment report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA 11/U10/00/3312/7 - Environmental screening report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/2/1/1 - Supporting document 1: Groundwater resources of the uMkhomazi catchment and interaction with surface water,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/2/3/1 - Supporting document 1: Sediment yield report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/2/5/1 - Supporting document 1: Interim investigation for hydropower potential at Impendle Dam and Smithfield Dam transfer system,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/3/1/1 - Supporting document 1: Optimisation of conveyance system report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/3/1/1 - Supporting document 1: Optimisation of conveyance system report,* Pretoria, South Africa: Department of Water Affairs (DWA).

AECOM, AGES, MMA & Urban-Econ, 2014. *The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water; P WMA11/U10/00/3312/6/1 - Supporting document 1: Baseline socio-economic assessment,* Pretoria, South Africa: Department of Water Affairs (DWA).

AURECON, 2013. *Investigation into the possibility for deslination plants to augment the water supply on the north and south coasts,* Durban, South Africa: eThekwini Municipality.

Author or Company , Year. *Add title of report,* s.l.: eg DWA.

BKS (Pty) Ltd, 1999. *Mgeni River System Analysis Study; Main Report (PB U000/00/2492),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 1999. *Mgeni River System Analysis Study; Mooi and Mkomazi rivers - Hydrology (PB U000/00/1092),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 1999. *Mgeni River System; Review of the Operating Rules (P671431),* Pretoria, South Africa: Umgeni Water.

BKS (Pty) Ltd, 1999. *Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study; Mkomazi/Mgeni/Mooi River Hydrology Update: Volume 1 (PB1 U200-00-0299),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 1999. *Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study; Mkomazi/Mgeni/Mooi River Hydrology Update: Volume 2 (PB1 U200-00-0299),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 1999. *Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study; System Analysis Update: Volume 1 (PB1 U200-00-0399),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 1999. *Mkomazi/Mgeni/Mooi River Hydrology and Yield Update Study; System Analysis Update: Volume 2 (PB1 U200-00-0399),* Pretoria, South Africa: Department of Water Affairs (DWA).

BKS (Pty) Ltd, 2003. *National Water Resource Strategy; Mvoti to Umzimkulu WMA: Overview of Water Resources Availability and Utilisation (PWMA 11/000/00/0203),* Pretoria, South Africa: Department of Water Affairs (DWA).

Brune, G.M. (1953). Trap Efficiency of Reservoir. *Trans. Am. Geoph. Union*, 34(3).

Campbell, Bernstein & Irving (CBI), 2005. *SAPPI SAICCOR Mill; Ngwadini Dam - Conceptual Design Report (SM.C.05038),* Durban, South Africa: SAPPI.

CSIR (1973). Coastal Research: Natal South Coast Progress Report and Evaluation of Completed Programme 1970 to 1973, Volume 1. CSIR Report ME 1256. NMERI, Pretoria. pp 46.

CSIR Building and Construction Technology, 2000. *Guidelines for Human Settlement Planning and Design,* Pretoria, South Africa: Department of Housing.

Department of Water Affairs (DWA), 1998. *Nkomazi Estuary; Flood Frequency Analysis: Flood Magnitudes for Required Exceedance Probabilities (U100-9805),* Pretoria, South Africa: Department of Water Affairs (DWA).

DWA Spatial and Land Info Management, 2011. *Mkomazi W542 - Baynes_Smithfield_Impendle_Umlaas (Survey data),* Pretoria, South Africa: Department of Water Affairs (DWA).

DWA, 2012. *Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas,* Pretoria: WRP.

Enviromap cc, n.d. *KZN Town and Regional Planning Suite of Reports; An inventory of the wetlands in the Mkomazi Catchment of KwaZulu-Natal (ISBN: 1-874961-10-7),* Pretoria, South Africa: Town & Regional Planning Commission.

GeoterraImage (Pty) Ltd, 2010. *2008 KZN PROVINCE LAND-COVER MAPPING (from SPOT5 Satellite imagery circa 2008),* Pretoria, South Africa: Ezemvelo KZN Wildlife (Biodiversity Research).

Goba Moahloli Keeve Steyn (Pty) Ltd, 2003. *Mooi-Mgeni River Transfer Scheme Phase 2: Feasibility Study; Main Report (PB V200-00-1501),* Pretoria, South Africa: Department of Water Affairs (DWA).

Goba Moahloli Keeve Steyn (Pty) Ltd, 2003. *Mooi-Mgeni River Transfer Scheme Phase 2: Feasibility Study; Supporting Report No. 1: Water Resource Analysis (PB V200-00-1601),* Pretoria, South Africa: Department of Water Affairs (DWA).

Goba Moahloli Keeve Steyn (Pty) Ltd, 2007. *Mooi-Mgeni River Transfer Scheme Phase 2: Feasibility Study; Bridging Study No.5: Hydrology and yield analysis (P WMA 07/V20/00/1807),* Pretoria, South Africa: Department of Water Affairs (DWA).

Graham Muller Associates, 1998. *Socio-Economic Impact of outcomes relating to the Mkomazi-Mgeni Augmentation Scheme,* Pietermaritzburg, South Africa: Umgeni Water.

IWR Environmental, 1998. *Mkomazi IFR Study (Acc No: 502-2010; BRN: 503, Class: U1/U2, Box: 113),* Pietermaritzburg, South Africa: Umgeni Water.

Knight Piésold Consulting, 2003. *Water Resources Situation Assessment; Mvoti to Umzimkulu WMA - Water Resources Situation Assessment: Volume 1 of 2 (P 11000/00/0101),* Pretoria, South Africa: Department of Water Affairs (DWA).

Knight Piésold Consulting, 2010. *Western Aqueduct Project,* Durban, South Africa: eThekwini Municipality.

Knight Piésold Consulting, 2014. *uMkhomazi Water Project Phase 1: Module 3: Technical Feasibility Study: Potable Water,* Pietermaritzburg, Pretoria: Umgeni Water.

N.H.G Jacobsen Ecological Consultant, 1997. *A Prefeasibility study of the potential impact on the Fauna and Flora of the Mpendle and Smithfield Dam Sites on the Mkomazi River (Acc No: 496-2010; BRN: 497, Class: U1/U2, Box: 98),* Pietermaritzburg, South Africa: Umgeni Water.

Nemai Consulting, 2014. *uMkhomazi Water Project Phase 1: Module 2: Technical Feasibility Study: Environmental Impact Assessment,* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand Consulting Engineers, May 1999a. *Mkomazi-Mgeni Transfer Scheme: Main report,* s.l.: Department of Water Affairs and Forestry in association with Umgeni Water Corporate Services Division.

Ninham Shand Consulting Engineers, May 1999b. *Mkomazi-Mgeni Transfer Scheme Pre-feasiblity Study: Mgeni Augmentation Overview Report,* s.l.: Department of Water Affairs and Forestry in association with Umgeni Water Corporate Services Division.

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.4 - Hydrology & Water Resources (PB U100-00-0899),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.6 - Engineering Design & Costing Supplementary Documents - Volume 2 (PB U100-00-1499),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.6 - Engineering Design & Costing - Volume 1 (PB U100-00-1399),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.7 - Economics - Volume 1 (PB U100-00-1599),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.7 - Economics Supplementary Documents - Volume 1 (PB U100-00-1699),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Main Report (PB U100-00-0499),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.1 - Reconnaissance Investigations (PB U100-00-0599),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.2 - Mgeni System Water Demands (PB U100-00-0699),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mkomazi-Mgeni Transfer Scheme: Supporting Report No.3 - Reconnaissance Basin Study (PB U100-00-0799),* Pretoria, South Africa: Department of Water Affairs (DWA).

Ninham Shand, 1999. *Mkomazi/Mooi-Mgeni Transfer Scheme Pre-feasibility Study; Mooi-Mgeni Transfer Scheme: Supporting Report No.2: Hydrology and Water Resources Study (PB1 V200-01-1499),* Pretoria, South Africa: Department of Water Affairs (DWA).

Schoonees, J S and Theron, A K (2001). Port Shepstone Marina: Sedimentation and Floods. CSIR Report ENV-S-C 2001-018. Environmentek , Stellenbosch, South Africa.

Sigma Beta Consulting Civil Engineers, 1998. *Mkomazi sedimentation study for Umgeni Water (Acc No: 016-2009; BRN: 17, Class: U1, Box: 103),* Pietermaritzburg, South Africa: Umgeni Water.

SRK Consulting Engineers, 1999. *Comparative operational reability assessment of two transfer options for the proposed The Mkomazi-Mgeni Augmentation Scheme,* Pietermaritzburg, South Africa: Umgeni Water.

Statistics South Africa, 2012. *Census 2011,* Pretoria, South Africa: Statistics South Africa.

Theron A K, Schoonees J S, von St Ange U, Silinga A and Davids G (2003). Setback line for the coastal zone: Msimbazi- to Mahlongwana River Mouth, and Mgeni- to Ohlanga River Mouth. CSIR Report EMAS-C 2003-088. Environmentek, Stellenbosch. pp 47

Theron, A.K., De Lange, W.J., Nahman, A. & Hardwick, D. (2008). Sand supply from rivers within the Ethekweni jurisdiction, implications for coastal sand budgets and resource economics. CSIR, Report number: CSIR/NRE/ECO/ER/2008/0096/C, Stellenbosch.

Theron A K and Rautenbach C. (2014). Proposed Durban Dig Out Port, FEL - 2 study: Assessment of sediment transport issues. Contract Report for Transnet/AECOM, CSIR Report CSIR/NRE/COAST/2014/ECCS106, Stellenbosch, South Africa. pp 77.

Umgeni Water, 1996. *Detailed feasibility study of supply of water to Impendle, located in the Hlanganani area of KwaZulu-Natal; Annexure 1: Impendle Dam (Acc No: 015-2009; BRN: 16, Class: U1, Box: 103),* Pietermaritzburg, South Africa: Umgeni Water.

Umgeni Water, 2011. *Umgeni Water Infrastructure Master plan 2011: 2011/2012 - 2041/2042, Vol 1,* Pietermaritzburg, South Africa: Umgeni Water.

Umgeni Water, 2011. *Umgeni Water Infrastructure Master plan 2011: 2011/2012 - 2041/2042, Vol 2,* Pietermaritzburg, South Africa: Umgeni Water.

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Bulwer Donnybrook Water Supply Scheme Area - Ingwe Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Embuthweni and Ogagwini Water Supply Scheme Area - Mkhambathini Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Greater Stoffleton Water Supply Scheme Area - Impendle Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Impendle Town and Enguga Water Supply Scheme Area - Impendle Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Ixopo Water Supply Scheme Area - Ubuhlebezwe Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Kwalembe Water Supply Scheme Area - Vulamehlo Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

Water for Africa, Aurecon, Water Geosciences & Charles Sellick and Associates, 2011. *Development of a Reconciliation Strategy for All Towns in the Eastern Region; First Stage Reconciliation Strategy for Richmond Water Supply Scheme Area - Richmond Local Municipality (Contract WP 9712),* Pretoria, South Africa: Department of Water Affairs (DWA).

WJ & JH O'Keeffe Institute for Water Research, 1998. *A Desktop study of the relevant environmental prognosis of the impact of the transfer of water from the Mkomazi River to the Mgeni Catchment and Mlazi*

Catchment (Acc No: 504-2010; BRN: 505, Class: U1/U2, Box: 113), Pietermaritzburg, South Africa: Umgeni Water.

WRP Consulting Engineers (Pty) Ltd, in association with DMM Development Consultants cc, Golder Associates Africa, Kwezi V3 Engineers and Zitholele Consulting, November 2009. *Water Reconciliation Strategy for the KwaZulu Natal Coastal Metropolitan Areas: Executive Summary,* s.l.: Department of Water Affairs.

WRP, et al., 2009. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; Executive Summary (PWMA 11/000/00/1107),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; First Stage Strategy Infrastructure Report (PWMA 11/000/00/2709),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; First Stage Strategy Report (PWMA 11/000/00/0907),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; First Stage Strategy Water Requirements Report (PWMA 11/000/00/2509),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; First Stage Strategy WCWDM Report (PWMA 11/000/00/2809),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; Second Stage Strategy Report (PWMA 11/000/00/1007),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, et al., 2010. *Water Reconciliation Strategy Study for the Kwazulu Natal Coastal Metropolitan Areas; Water Quality Review Report (PWMA 11/000/00/2609),* Pretoria, South Africa: Department of Water Affairs (DWA).

WRP, DMM & Tlou & Matji, 2004. *Eastern Region ISP: Mvoti to Mzimkhulu WMA,* Pretoria, South Africa: Department of Water Affairs (DWA).