Department of Water Affairs and Forestry

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KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY

TECHNICAL COMPONENT

MONITORING REPORT: ESTUARIES

Coastal & Environmental Services

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT

MONITORING REPORT: ESTUARIES

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DEPARTMENT OF WATER AFFAIRS and FORESTRY
DIRECTORATE: RESOURCE DIRECTED MEASURES

KROMME/SEEKOEI CATCHMENTS RESERVE DETERMINATION STUDY – TECHNICAL COMPONENT MONITORING REPORT: ESTUARIES

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1 OVERVIEW AND OBJECTIVES

Currently the *Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004a) does not provide any guidance on the determination of ecological specifications for estuaries. Therefore, the approach that was applied and approved by DWAF as part of the Thukela study was followed (DWAF, 2004b).

2 APPROACH

2.1 Ecological specifications

Ecological specifications are clear and measurable specifications of ecological attributes (in the case of estuaries, hydrodynamics, sediment dynamics, water quality, and different biotic components) that define a specific reserve category which was decided upon by the authorities utilizing environmental, social and economic criteria. It must be noted that the Scenarios selected (See below) for monitoring are not the REC's as these were found to be to onerous in terms of their impacts on the social and economic environment.

Kromme Estuary – D (Scenario 4)
Seekoei Estuary – D (Scenario 2)

Thresholds of potential concern (TPC) are defined as measurable end points related to specific abiotic or biotic indicators that if reached prompts management action. In essence, thresholds of potential concern should be defined such that they provide early warning signals of potential non compliance to ecological specifications. In essence this concept implies that the indicators (or monitoring activities) selected as part of a long term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow into the system.

The ecological specifications for the Kromme and Seekoei Estuaries are outlined in Table 3-1 and 4-1 respectively.

2.2 Baseline information

The baseline studies that are carried out for an Ecological Reserve determination study at Comprehensive level may be considered as the baseline data against which the long-term monitoring is carried out on estuaries. The status of baseline data currently available for different abiotic and biotic components in the Kromme and Seekoei Estuaries, after completion of the current ecological reserve determination studies, was established by comparing the currently available information against the data requirements as specified for an Ecological Reserve determination on a comprehensive level (DWAF, 2004). The baseline data analysis for the Kromme can be found in Table 3-2 while for the Seekoei it is available in Table 4-2. The additional information that will need to be collected for the systems is outlined in Table 3-3 & 4-3. All additional work items were given a priority rating using the following scale.

HIGH	High priority, considered as a minimum list of indicators sufficient to monitor the effectiveness of the reserve.
MEDIUM	Medium priority, will improve the confidence of the auditing process and should be added to the process if funding is available.
LOW	Low priority, will add to the overall confidence of the auditing process, but not considered to be a critical indicator in the case of the Kromme Estuary.

If less than the recommended baseline studies for a comprehensive assessment was carried out, due to the Ecological Reserve study being carried out at a rapid or intermediate level as was the case for the Seekoei Estuary, then additional 'baseline' work will definitely be required to produce sufficient baseline data against which future long-term monitoring can take place.

2.3 Long term monitoring requirements

The purpose of long-term monitoring programmes, in this context, is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation of the Reserve. In addition, these programmes can also

be used to improve and refine the Ecological Reserve measures (including the Resource Quality Objectives), in the longer-term through an iterative process (Taljaard *et al*., 2003).

Although baseline studies and long-term monitoring programmes have different purposes, it is extremely important that long-term monitoring programmes follow on from similarly structured baseline studies. In essence, the monitoring activities selected for the long-term monitoring programme should be derived from the monitoring activities conducted as part of the baseline studies, but implemented on less intensive spatial and/or temporal scales (Taljaard *et al*., 2003).

Abiotic and biotic indicators considered relevant for a long-term monitoring programme on the Kromme Estuary are listed in Table 3-4 and for the Seekoei in Table 4-4.

3 RESULTS KROMME

Table 3-1 Kromme: Ecological Specifications

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Water Quality	Salinity distribution not to cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae	Salinities in upper layers (~2 m) greater than 20 ppt upstream of confluence with Geelhoutboom during Nov (i.e. salinity gradient not present in Kromme Estuary during Nov release) Salinities in estuary is greater than 35 ppt (i.e. hypersaline), except during drought periods when salinities in late summer (Jan/Feb) exceed 40 ppt	Illegal abstractions from the river upstream of the estuary Operational procedures not implemented properly (e.g. releases from dam not made during Nov)
	System variables (temperature, pH, turbidity, dissolved oxygen, suspended solids and turbidity) not to cause exceedence of TPCs for biota	River inflow: Summer temp less than 20^{o}C; pH less than 6.5; Turbidity (to be determined); Dissolved oxygen less than 4 mg/l Turbidity in estuarine water column (to be determined) pH in estuarine water column greater than 8.5 or less than 6.5 DO in estuarine water column less than 4 mg/l	Bottom water releases from Impofu Dam where DO concentrations or temperature (particularly during summer) can be below TPC.
	Inorganic nutrient concentrations not to cause in exceedance of TPCs for macrophytes and microalgae	River inflow to estuary considered most important nutrient supplier. Assuming that TPCs for primary producers are dependent on 'nutrient' pulse during November release, TPCs for average nutrient concentrations in river inflow during Nov: DIN less than 100 - 200 µg/l DRP less than 30 µg/l DRS less than 1000 - 2000 µg/l NOTE: In theory, excessive nutrient inputs can potentially also affect TPCs set for primary producers. With no large agricultural or urban developments in the Kromme Estuary's catchments, this is not considered an issue at present. Should the situation change in future, upper limit TPCs should be developed. Also suitable data to set upper limit TPCs are currently not available.	Operational procedures not implemented properly (e.g. releases from dam not made during Nov) Increase in agricultural or urban developments in Kromme Estuary's catchments (exceedance of upper limit TPCs)
	Presence of toxic substances not to cause exceedence of TPCs for biota.	Not considered a major concern in Kromme Estuary as there are no major agricultural or urban developments in its catchments. TPCs can only be confirmed once recent baseline data have been acquired. In interim, where necessary, refer to recommended water and sediment quality guidelines for coastal marine waters for southern Africa	Increase in agricultural or urban developments in Kromme Estuary's catchments

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
		(DWAF, 1995; Taljaard, 2006)	
Hydrodynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow distribution patterns differ by more than 5% from that of Scenario 4 (i.e. approved flow scenario for the Kromme) River inflow below 0 m^3/s persists for longer than 7 months	Illegal abstractions from the river upstream of the estuary Operational procedures not implemented properly (e.g. releases from dam in Nov)
	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow decreases to below 0,1 m^3/s at any time	Modification to inflow at head of estuary and Geelhoutboom tributary
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota.	River inflow distribution patterns (flood components) differ by more than 20% (in terms of magnitude, timing and variability) from that of the Present State (2004) Suspended sediment concentration from river inflow deviates by more than 20% of the sediment load-discharge relationship to be determine as part of baseline studies (Present State 2005)	Modification to inflow at head of estuary
	Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates (see above).	The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (Present State). Sand/mud distribution in middle and upper reaches change by more than 20% from Present State (2005) If the rate of upstream movement of marine sediment increases drastically (more than 10 m/year). This should be based on detailed survey data carried out annually. Changes in tidal amplitude at the upper tidal gauge of more than 20% from Present State (2005)	Modification to inflow at head of estuary; Catchment activities; Estuary mouth changes

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (RSA DWAF) (1995) South African water quality guidelines for coastal marine waters. Volume 1: Natural Environment; Volume 2: Recreation; Volume 3: Industrial use; Volume 4: Mariculture. Pretoria.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Microalgae			
Phytoplankton	Increase phytoplankton group richness. Diatoms dominate the phytoplankton (>50 %) after the freshwater release in November. Flagellates (>90 %) return after two months.	No increase in phytoplankton group richness after the freshwater release and flagellates remain dominant (>80 %).	Lack of freshwater inflow, low nutrient input, high salinity and no river-estuary interface zone.
	Increase water column chlorophyll-a (phytoplankton biomass) ~ 25 % higher than before the release and greater than 5 µg l^{-1} that will persist for ~ 2 months.	No increase in water column chlorophyll-a (< 5 µg l^{-1}) after the freshwater release in November.	Lack of freshwater inflow, low nutrient input, high salinity and no river-estuary interface zone.
Benthic microalgae	Increase benthic chlorophyll-a (benthic microalgal biomass), middle reaches ~ 50 mg m^{-2}, lower reaches ~ 100 mg m^{-2}, that will persist for ~ 2 months after the freshwater release.	No increase in benthic chlorophyll-a after the freshwater release in November (< 50 mg m^{-2}, lower reaches, < 100 mg m^{-2} in the middle reaches).	Lack of freshwater inflow, low nutrient input, low organic matter, fine sediment and nutrient content.
Macrophytes			
	Maintain the present (2004) area covered by salt marsh along the permanent transects in the Geelhoutboom tributary and Kromme Estuary.	Greater than 20 % loss of salt marsh area and consequent increase in bare ground.	Increase in sediment and groundwater salinity (conductivity) as a result of high water column salinity.
	Prevent an increase in sediment and groundwater salinity (conductivity).	Sediment and groundwater conductivity in salt marsh areas is greater than 100 mS.cm^{-1}	High water column salinity.
	Reduce the area covered by marine macroalgae.	Macroalgae cover greater than 50 % in 1 m^2 quadrats. Macroalgal cover greater than that of eelgrass *Zostera capensis*.	Lack of flushing and reduced flooding. High water column salinity.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Invertebrates	The current status of the invertebrate community in the Kromme estuary reflects marine dominance. Inter-annual variability in biomass is low. Holozooplankton species richness and biomass of the typical estuarine community is also low. Community composition among the non-burrowing benthic invertebrates has shifted significantly, linked primarily to the expansion of *Zostera capensis* beds. The biomass of species that burrow in non-*Zostera* areas has declined. Resource quality objectives aim to: • Increase inter-annual variability in zooplankton and benthic biomass. • Increase species richness of the holozooplankton typically found in south coast estuaries. • Reduce biomass of *Zostera* associated species and • Increase biomass of burrowing species associated with non-vegetated muddy substrata.	No change in the zooplankton species assemblage and biomass compared to the current state in the main estuary. In the Geelhout tributary, a typical estuarine community should persist for at least two months during summer. Biomass should on average, at least double compared to the current state at these times. No change in the benthic species assemblage compared to the present state.	No or very little change in the current salinity distribution along the main estuary. Any potential benefits of a temporary salinity gradient along the estuary will also be nullified by no vertical mixing of the water column.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Fish	Retain the following fish assemblages in the estuary (based on abundance): estuarine species (30-40%), estuarine associated marine species (60-70%). All numerically dominant species are represented by 0+ juveniles.	Level of estuary associated marine species drops below 60% of total abundance. Level of estuarine planktivorous species decreases below 30% of total abundance. Significant decline in the abundance of 0+ juveniles of any of the dominant fish species.	Recruitment failure due to reduced olfactory cues entering the sea and/or overfishing. Reduced planktonic food resources due to reduced riverine nutrient supply. Breeding failure, habitat change or impaired recruitment.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Birds	Retain the species richness, abundance and diversity of the bird community, including resident and migrant waders, gulls, terns, wading birds and water fowl, within 15% of that of the Present State.	Community composition or bird numbers deviates by more than 50% of average seasonal baseline counts for two consecutive summer or winter seasons, focusing on waders, wading birds & water fowl (summer and winter). Numbers at the tern roost deviate by more than 50% of average for 5 consecutive years.	Changes in: • Salinity • Invertebrate biomass/abundance • Fish biomass/abundance in smaller size classes • Vegetation habitats (e.g. reed beds, submerged macrophytes, salt marsh) • Mud flats • Increased human disturbance

Table 3-2 Kromme Current Status

i. Abiotic components

DATA REQUIRED	CURRENT STATUS
Simulated monthly runoff data (at the head of the estuary) for present state, reference conditions and the selected future runoff scenarios over a 50 to 70 year period	Provided for 73-year period by Ninham Shand Consulting Engineers (Low confidence as runoff data is of low quality)
Simulated flood hydrographs for present state, reference conditions and future runoff scenarios: • 1:1, 1:2, 1:5 floods (influencing aspects such as floodplain inundation) • 1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)	Available
Series of sediment core samples for the analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) taken every 3 years along the length of an estuary (200 m to 2 km intervals).	Only grab samples were collected and grading analyses carried out. Origin of the sediment was not determined using microscopic observations, but rather the sediment grading was used to interpret the origin of the sediment. While not specified under the data required,comprehensive sediment cores would be useful in establishing layering and age of the deposited sediment to confirm the assumptions made during numerical modeling. Isotope analysis of the sediment would also be advantageous in future stages of work to establish the rate of historical sediment deposition and the sources of sediment.
Series of cross-section profiles (collected at about 500 to 1000 m intervals) taken every 3 years to quantify the sediment deposition rate in an estuary.	Survey data and a DTM were obtained from the CSIR. A new survey was not carried out and it is important that new survey data are obtained, which are repeated on the same cross-section as before to make comparisons. The surveys should include the marina, with more details at the mouth and longitudinal sections.
Set of cross-section profiles and a set of sediment grab samples for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) need to be taken immediately after a major flood.	Sediment grab samples were taken along the estuary once only, not after a flood.
Aerial photographs of estuary (earliest available year as well as most recent)	Limited historical photos available
Measured river inflow data (gauging stations) at the head of the estuary over a 5-15 year period	Some data provided by DWAF, but of low confidence
Continuous water level recordings near mouth of the estuary	Data records available from DWAF water level recorder at mouth
Water level recordings at about 5 locations along the length of the estuary over a spring and a neap tidal cycle (i.e. at least a 14 day period).	Smith *et al.* (1991) – data collected in Aug 1988
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion) • peak of high flow season (i.e. period of maximum flushing by river water)	Hecht (1973), Hanekom (1982), Emmerson & Erasmus (1987), Bickerton & Pierce (1988), Wooldrige, UPE (unpublished data) Scharler *et al.* (1998), Scharler and Baird (2003), Slinger (unpublished data,) CSIR (1999), Snow *et al.* (2000), Scharler & Baird (2000) (However, data often aggregated in a manner which made it impossible to relate to river inflow)
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Hecht (1973), Hanekom (1982), Watling (1982), Emmerson & Erasmus (1987), Bickerton & Pierce (1988), Wooldrige, UPE (unpublished data) Scharler *et al.* (1998), Scharler and Baird (2003), Slinger (unpublished data), CSIR (1999), Snow *et al.* (2000), Scharler & Baird (2000). (However, data often aggregated in a manner which made it impossible to relate to river inflow)
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	Trace metal data - Watling and Watling (1982)

DATA REQUIRED	CURRENT STATUS
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	DWAF data available for Mpofu Dam (K9H002) (1985 to 1994) and weir down stream of Dam (K9H003) (1985 to 2004)
Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater	Data extracted from South African Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995)

ii. Biotic Components

MICRO ALGAE – DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Phytoplankton: Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae Measurements must be taken coinciding with typically high and low flow conditions	Completed for the low flow condition, will need to sampled during a high flow (dam freshwater release study).
Benthic microalgae: Intertidal and subtidal benthic chlorophyll-a measurements Epipelic diatoms need to be collected for identification These measurements must to be taken coinciding with a typical high and low flow condition	

MACROPHYTES - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the Present State, as well as the Reference Condition (if available) Available orthophotographs	Available
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit	The area covered by different plant community types were mapped using GIS. The distribution of species was described for the estuary. Detailed distribution patterns of species along four transects in relation to controlling environmental conditions was provided.
Permanent transects: - Measurements of percentage plant cover along an elevation gradient - Measurements of salinity, water level, sediment moisture content and turbidity	Completed for two transects in the Geelhoutboom tributary and two in the Kromme Estuary. Additional parameters measured were sediment type, organic content, depth to groundwater and groundwater salinity.

INVERTEBRATES- DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	Benthic samples were collected to sample the subtidal benthos at ten stations in the main and Geelhout tributaries on four occasions in 2004 (Seasonal). More sampling sites were included due to the size of the estuary and to improve the sensitivity of the analysis. A similar programme was followed for the hyperbenthos and only four sets of samples are available. Intertidal benthic and zooplankton samples have been well-researched over the years and good data sets exist. In the case of the zooplankton, ten sites were sampled for the same reasons as described above. In nearly all research programmes, invertebrate sampling occurred under conditions similar to the present day. Thus, data sets are heavily biased towards persistent drought conditions when little or no salinity variation occurs along the estuary. In order to improve confidence levels concerning biotic response
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	
Collect three zooplankton samples, at night, one each from	

INVERTEBRATES- DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
the upper, middle and lower reaches of the estuary. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	to the freshwater allocation (Scenario 4), a single release of the 5 x 10^6 m^3 of water from the Mpofu Dam should be accompanied by additional baseline sampling of all invertebrate groups prior to and after the release.

FISH - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Sampling should be representative of small fish (seine nets) and large fish (gill nets). Sampling should be done in all four seasons for the full extent of the system (as far as tidal variation) to allow for predictive capabilities. In a larger estuary (>5 km) sampling can either be at fixed intervals (every 2 km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. *Zostera* beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system.	Historical records of fish sampling in the Kromme Estuary tended to use seine or gill nets but not at the same time. Although gill netting records covered all seasons and reaches, the seine netting was focused on *Zostera* vs non-*Zostera* habitats. A once off spring sampling using seine and gillnets was conducted in the lower, middle and upper reaches of the Kromme Estuary by the CSIR as part of their national estuary survey for DEAT.

BIRDS - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. Monthly data sets for at least one year are required. If this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).	Ten years of bi-annual Coordinated Water bird Counts (CWAC) were available from the Avian Demography Unit at UCT. The estuary was counted in four different months for this study. Ten years of bi-annual Coordinated Water bird Counts (CWAC) were available from the Avian Demography Unit at UCT. The estuary was counted in four different months for this study.

Table 3-3 Additional baseline data required to increase confidence of Reserve and to set baseline for long-term monitoring in KROMME Estuary

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Water Quality	Water quality (at least conductivity, temperature, dissolved oxygen, turbidity, pH, DIN, DRP & DRS, organic matter) measurements on river water entering at the head of the estuary and through tributaries	At least monthly, daily during release from dam	One station at position representative of inflows to estuary (both on Kromme and Geelhoutboom rivers)
	Collected longitudinal salinity & temperature profiles	At least once, during high river inflow event	Entire estuary, plus sampling point in river and sea (10-15 stns)
	Water quality measurements taken along length of estuary (at least surface and bottom samples) for pH, dissolved oxygen, suspended solids/turbidity, inorganic and organic nutrients	At least once, during high river inflow event	Entire estuary, plus sampling point in river and sea (10-15 stns)
Hydrodynamic	Accurate flow gauging of river inflow to estuary	Continuous	One station at position representative of inflows to estuary (both on Kromme and Geelhoutboom rivers)
	Aerial photographs of estuary (photographed at spring low tide)	Once-off	Entire estuary
Hydrodynamic in relation to sediments	Water level recordings	Continuous	Near mouth and 5 km upstream of mouth
	Flow gauging	Continuous	Impofu Dam outflow, and estuary inflow or quantification of irrigation abstractions & Geelhoutboom River flow
	Aerial photos at spring low tide at 1:2000 scale, including the marina and dune field area	5 Years	Entire estuary
	Water level recordings along estuary	Once off during a spring and neap tidal cycle	Two existing stations and near tributary and in upper-estuary
	Near-shore wave data records (only if available)		-
Sediment dynamics	Bathymetric survey: Series of cross-sections and a longitudinal profile collected at about 500m intervals, but in some locations a previous survey. More detailed at the mouth. Vertical accuracy should be better than 300 mm.	5 Years	Entire estuary and marina
	Set of sediment grab samples at cross-sections for grading analysis	Once off	Entire estuary
	Set of core samples (2m) save at cross-sections for grading analysis, age and origin (Isotope analysis)	Once off	Entire estuary every 1 km
	Sampling of suspended sediment (and organic matter) required to quantify actual sediment and organic yield and variability.	Weekly, but daily during floods, for at least 5 years	Upstream of estuary and tributary

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Macrophytes	Survey the four permanent transects for macrophyte cover and species composition in relation to controlling environmental conditions (i.e. water column salinity, sediment salinity, moisture content, groundwater salinity and depth to groundwater) after a freshwater release in November. This is necessary to check the ecological specifications and thresholds of potential concern for the RDM study.	The sampling should take place prior to the freshwater release and then repeated 1-2 weeks after the freshwater release.	Permanent transects set up in 2004, two in the Geelhoutboom tributary and two in the middle reaches of the Kromme Estuary.
Microalgae	Phytoplankton and Benthic microalgae : Sample for biomass and species composition after a freshwater release in November. As far as possible use the same sampling strategy as that used in 1998.	Sampling should take place prior to the freshwater release and then 2, 4, 6, 17, 31 and 50 days after the release. Sampling should take place at spring high tide where possible.	Eight sampling stations in the Kromme Estuary and two stations in the Geelhoutboom tributary.

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Invertebrates	Collect quantitative samples for zooplankton after dark prior to and after a single release of 5×10^6 m^3 of water from the Mpofu Dam. Zooplankton samples to be collected at near-surface and at midwater level. Chlorophyll-a data must be collected at all sites and on all sampling occasions.	Zooplankton samples to be collected: 1 month prior to the release, 2 weeks prior to the release, 1 week prior to the release, At the time of the release, 1 week after the release, 2 weeks after the release, 3 weeks after the release, 1 month after the release, 6 weeks after the release	Samples to be collected at all ten stations
	Subtidal benthic samples to be collected prior to and after a single release of 5×10^6 m^3 of water from the Mpofu Dam.	Benthic samples to be collected: 1 month prior to the release, 2 weeks prior to the release, At the time of the release, 2 weeks after the release, 1 month after the release, 6 weeks after the release. 2 months after the release	Samples to be collected at all ten stations

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
	Intertidal benthic samples to be collected prior to and after a single release of 5 x 10^6 m^3 of water from the Mpofu Dam.	Intertidal samples to be collected: 1 month prior to the release, 2 weeks prior to the release, At the time of the release, 2 weeks after the release, 1 month after the release, 6 weeks after the release. 2 months after the release	Samples to be collected at six stations – two in sandy substrata below the bridge, 2 samples in the middle estuary, 1 sample in the Geelhout tributary and 1 sample in the main tributary above the confluence with the Geelhout

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. Stations)
Fish	Conduct fish surveys using both seine and gill nets as primary gear.	Quarterly over one year, covering all four seasons and representative of temperature and average river inflow of that season.	Entire estuary (12-15 stations)
ECOLOGICAL COMPONENT	**MONITORING ACTION**	**TEMPORAL SCALE (frequency and when)**	**SPATIAL SCALE (no. Stations)**
Birds	Monthly count data are required for at least one year.	Monthly, on spring low tide	Whole estuary

Table 3-4 Long-term resource monitoring programme proposed for the Kromme Estuary after implementation of the Reserve

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Water Quality	Collect data on conductivity, temperature, suspended matter/turbidity, dissolved oxygen, pH, inorganic nutrients and organic content in river inflow	At least monthly	One station at position representative of inflows to estuary (both on Kromme and Geelhoutboom rivers)	Recommend that existing station be selected or additional station be added in the DWAF's water quality monitoring programme on the Kromme and Geelhoutboom rivers					
	Collect longitudinal salinity profiles (*in situ*)	Monthly	Entire estuary (5 - 10 stns)	-	1 x12	-	-	1 x 1	-
	Collect longitudinal salinity & temperature profiles (*in situ*)	To be measured when biotic surveys require information for interpretation	Entire estuary, plus sampling point in river and sea (10-15 stns)	-	1 x 2	-	-	1 x 1	-
	Water quality measurements taken along the length of the estuary (surface and bottom samples) for pH, dissolved oxygen, suspended solids/ turbidity and inorganic/organic nutrients	To be measured when biotic surveys require information for interpretation	Entire estuary, plus sampling point in river and sea (10-15 stns)	See related biotic components - samples can be collected as part of biotic survey		*In situ* measurements Accredited analytical laboratory		1 x 1	-
	Baseline data set for pesticides/herbicides/trace metal accumulation in sediments	Every 3 – 6 years, if deemed necessary in future	Focus on depositional areas, e.g. areas with fine sediments (mud)	-	1 x 2	Depend on parameters selected (Accredited analytical laboratory)		1 x 1	-
Hydrodynamics	Water level recordings	Continuous	Near mouth	Included in DWAF national monitoring programme				1 x 1	-
	Flow gauging	Continuous	One station at position representative of inflows to estuary (both on Kromme and Geelhoutboom rivers)	Included in DWAF national monitoring programme				1 x 1	-

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
	Aerial photographs of estuary (spring low tide)	Annually	Entire estuary	Should be recommended for inclusion in DEAT national coastal survey programme				1 x 1	-

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Sediment	Bathymetric survey: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but more detailed in the mouth (vertical accuracy better than 300 mm)	5 Years	Entire estuary	1	5		3	2	2
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations	5 Years	Entire estuary		1		5	1	1
	Suspended sediment and organic matter	Weekly, but daily during floods	Upstream of estuary and Geelhoutboom tributary		10		5	2	
	Monitoring marine sediment delta movement in an upstream direction, by detailed survey in the field	Annually	At the delta		1		1	1	1

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Microalgae	Phytoplankton: Conduct water column chlorophyll a measurements and counts of dominant phytoplankton group.	One year after implementation after dam release in November thereafter every 3 years.	10 stations	3	8	3	5	2	0
	Benthic microalgae: Conduct benthic chlorophyll a measurements	One year after implementation after dam release in November thereafter every 3 years.	10 stations	3	8	2	2	2	0
Macrophytes	Survey the four permanent transects for macophyte cover and species composition in relation to controlling environmental conditions (i.e. water column salinity, sediment salinity, moisture content, groundwater salinity and depth to groundwater) after a freshwater release in November.	One year after implementation after dam release in November thereafter every 3 years.	4 permanent transects	2	2	2	5	2	2
	Measure the percentage cover of macroalgae in 1 m^2 quadrats in relation to *Zostera capensis* cover along the length of the estuary at random sites.	One year after implementation after dam release in November thereafter every 3 years	Minimum of 10 random sites	1	1	1	1	1	0

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Invertebrates	Collect quantitative samples for zooplankton after dark prior to and following a single release of 5 x 10^6 m^3 of water from the Mpofu Dam. Zooplankton samples to be collected at near-surface and at midwater level. Chlorophyll-a data must be collected at all sites and on all sampling occasions. High priority.	2 weeks prior to the release and 2-3 weeks after the release. Sampling time after the release will be advised by the previous study (Table 3-3).	All ten sampling sites.	2	4	-	20	6	-
	Subtidal benthic samples to be collected prior to and following a single release of 5 x 10^6 m^3 of water from the Mpofu Dam. High priority.	2 weeks prior to the release and ca 6 weeks after the release. Sampling time after the release will be advised by the previous study (Table 3-3).	All ten sampling sites.	2	8	-	60	6	-
	Intertidal benthic samples to be collected prior to and following a single release of 5 x 10^6 m^3 of water from the Mpofu Dam. High priority.	2 weeks prior to the release and ca 6 weeks after the release. Sampling time after the release will be advised by the previous study (Table 3-3).	All six sampling sites.	-	6	-	20	6	-

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Fish	Conduct fish surveys using both seine and gill nets as primary gear.	Two years after implementation conduct a summer and winter survey, followed by summer and winter surveys every 3 years thereafter	Entire estuary (12-15 stations)	6	8	4	4	2	

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Birds	Bi-annual bird counts of the estuary	Mid-summer and mid-winter	Whole estuary	4	8	2	0	1	

4 SEEKOEI RESULTS

Table 4-1 Seekoei: Ecological Specifications

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Water Quality	Salinity distribution not to cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae.	Hyper saline conditions (salinities greater than 35 ppt) maintained throughout estuary for longer than one year Salinities exceed 50 ppt during drought conditions	Illegal abstractions from rivers upstream, operational releases not executed correctly or drought conditions
	System variables (temperature, pH, turbidity, dissolved oxygen, suspended solids and turbidity) not to cause exceedence of TPCs for biota.	River inflow: Turbidity (to be determined); Organic matter (to be determined) Dissolved oxygen less than 4 mg/l; pH less than 6.5 (Seekoei River) (Note: Swart River is black water system pH levels can be naturally be less than 6) Turbidity in estuarine water column (to be determined) pH in estuarine water column greater than 8.5 or less than 6.5, except when fresh conditions are linked to input from Swart River (see above) DO in estuarine water column less than 4 mg/l	Agricultural activities in Seekoei Estuary's catchments (e.g. increased turbidity and organic loading)
	Inorganic nutrient concentrations not to cause in exceedance of TPCs for macrophytes and microalgae.	DIN concentration in river inflow greater than 500 µg/l (low confidence – need to be refined)	Agricultural return flows in Seekoei Estuary's catchments
	Presence of toxic substances not to cause exceedence of TPCs for biota.	Most important concern in case of Seekoei Estuary is pesticides (associated with extensive agricultural activities). No data are currently available for this system. In interim refer to recommended water and sediment quality guidelines for coastal marine waters in southern Africa (Taljaard, 2006).	Inputs associated with agricultural activities in Seekoei Estuary's catchments
Hydrodynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow distribution patterns differ by more than 5% from that of Scenario 2 (i.e. approved flow scenario for the Seekoei) River inflow decreases to below 0.15 m^3/s at any time River inflow below 0.3 m^3/s persists for longer	Illegal abstractions from rivers upstream, operational releases not executed correctly or drought conditions

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
		than 5 months Mouth closure occurs more than twice in 10 years	
Hydrodynamics In relation to sediments	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow distribution patterns differ by more than 10% from that of scenario 2 (adopted flow scenario for the Seekoei)	Modification to inflow at head of estuary
	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow decreases to below 0,1 m^3/s at any time	Modification to inflow at head of estuary
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota.	River inflow distribution patterns (flood components) differ by more than 20% (in terms of magnitude, timing and variability) from that of the Present State (2004) Suspended sediment concentration from river inflow deviates by more than 20% of the sediment load-discharge relationship to be determine as part of baseline studies (Present State 2004)	Modification to inflow at head of estuary
	Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates.	The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (Present State). Sand/mud distribution in middle and upper reaches change by more than 20% from Present State (2004) Changes in tidal amplitude at the tidal gauge of more than 20% from Present State (2004)	Modification to inflow at head of estuary; Catchment activities; Estuary mouth changes

TALJAARD S (2006) Ther development of a common set of water and sediment quality guidelines for the coastal zone of the BCLME (Project BEHP/LBMP/03/04) Report submitted to UNOPS as part of the Benguela Current Large Marine Ecosystem Programme. CSIR Report CSIR/NRE/ECO/ER/2006/0011/C. Stellenbosch, South Africa (www.bclme.org).

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Microalgae			
Phytoplankton	Maintain low phytoplankton biomass. Maintain microalgal group diversity as measured for the baseline survey.	Increase in phytoplankton biomass to 20 % greater than the baseline concentrations. Deviation in phytoplankton group diversity to 20 % of that found for baseline conditions.	Elevated nutrient concentrations in the inflowing freshwater. Reduced freshwater inflow and high salinity.
Benthic microalgae	Maintain high subtidal benthic microalgal biomass during the closed mouth phase and low intertidal benthic microalgal biomass during the open phase. Epipelic diatoms indicative of brackish conditions should be found during the closed phase.	Deviation in benthic microalgal biomass by 20 % compared to baseline concentrations. No brackish epipelic diatoms are found during the closed phase.	Elevated nutrient concentrations in the inflowing freshwater. Change in mouth condition. Increase in salinity.
Macrophytes			
	Maintain the distribution of plant community types i.e. Submerged macrophyte, *Ruppia cirrhosa* beds during closed mouth brackish conditions (~29 ha), salt marsh, *Sarcocornia perennis* marsh during open mouth conditions (~1.2 ha), *Phragmites australis* stands in the middle / upper reaches (~0.18 ha) and salt marsh grasses (~1.6 ha).	Greater than 20 % change in the area covered by different plant community types for baseline open and closed mouth conditions.	Reduced freshwater inflow and high salinity. Change in mouth condition and associated water level fluctuations.
	Prevent excessive filamentous macroalgal growth. Area covered should be half that covered by submerged macrophytes.	Macroalgae cover greater than 50 % in 1 m^2 quadrats compared to that of submerged macrophytes. Vegetation map indicates that macroalgal cover a larger area than that of the submerged macrophytes.	Elevated nutrient concentrations. Prolonged closed mouth conditions and lack of freshwater floods and flushing.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Invertebrates	The current status of our knowledge on the invertebrate community in the Seekoei estuary is extremely low, but species richness and biomass is predicted to be low. Salinity variation in the estuary is highly variable and the mouth remains closed for extended periods - this may also lead to the absence of some invertebrate species that might be expected to occur here.	The absence of a brackish water community and/or species predicted to occur in the estuary. Abundance and biomass levels of euryhaline species consistently remain at low levels compared to other TOCE's in the region.	The absence of strong freshwater pulsing that establishes a salinity gradient along the estuary and a closed mouth state that persists for long periods.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Fish	Retain the following fish assemblages in the estuary (based on abundance): estuarine species (40-60%), estuarine associated marine species (30-50%) and indigenous freshwater species (1-5%). All numerically dominant species are represented by 0+ juveniles.	Level of estuary associated marine species drops below 30% of total abundance. Level of estuarine species increases above 60% of total abundance. Levels of Mozambique tilapia (*Oreochromis mossambicus*) increases above 5% of total abundance. Absence of 0+ juveniles of any of the dominant fish species.	Recruitment failure due to prolonged mouth closure and/ or poor timing of the open mouth phase. Reduced predation by marine piscivorous fishes and decline in marine species abundance. Prolonged closed phase promotes estuarine breeding of Mozambique tilapia (*O. mossambicus*). Breeding failure or impaired recruitment.

Component	Ecological Specification	Threshold of Potential Concern	Potential Causes
Birds	Retain the species richness, abundance and diversity of the bird community, including resident and migrant waders, gulls, terns, wading birds and water fowl, within 20% of that of the Present State	Community composition or bird numbers deviates by more than 50% of average seasonal baseline counts for three consecutive summer or winter seasons, focusing on waders, wading birds & water fowl (summer and winter).	Changes in: • Salinity • Invertebrate biomass/abundance • Fish biomass/abundance in smaller size classes • Vegetation habitats (e.g. reed beds, submerged macrophytes, salt marsh) • Mud flats • Increased human disturbance

Table 4-2 Seekoei Current Status

As the Seekoei Estuary Reserve was undertaken at a Rapid level the lack of data when compared to that required for a comprehensive is to be expected.

i. Abiotic components

DATA REQUIRED	CURRENT STATUS
Simulated monthly runoff data (at the head of the estuary) for present state, reference conditions and the selected future runoff scenarios over a 50 to 70 year period	Provided for 73-year period by Ninham Shand Consulting Engineers (Low confidence as runoff data is of low quality)
Simulated flood hydrographs for present state, reference conditions and future runoff scenarios: • 1:1, 1:2, 1:5 floods (influencing aspects such as floodplain inundation) • 1:20, 1:50, 1:100, 1:200 year floods (influencing sediment dynamics)	No data
Series of sediment core samples for the analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) taken every 3 years along the length of an estuary (200 m to 2 km intervals)	No sediment data
Series of cross-section profiles (collected at about 500 to 1000 m intervals) taken every 3 years to quantify the sediment deposition rate in an estuary	No data
Set of sediment grab samples (at cross-section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) need to be taken immediately after a major flood	No data
Water level recordings at about 5 locations along the length of the estuary over a spring and a neap tidal cycle (i.e. at least a 14 day period).	No data
Aerial photographs of estuary (earliest available year as well as most recent)	1961, 1967, 1968, 1970, 1971, 1972, 1977, 1979, 1980, 1981, 1986, 1992 (available at CSIR)
Continuous water level recordings near mouth of the estuary	Water level data available for the last 2 year measured at the causeway by DWAF
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion) • peak of high flow season (i.e. period of maximum flushing by river water)	Limited once off data sets for Nov 1984 (Bickerton and Pierce, 1988) and Feb 2004 (collected as part of this study)
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Limited once off data sets (only system variables) for Nov 1984 (Bickerton and Pierce, 1988) and Feb 2004 (collected as part of this study)
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	No data
Water quality (e.g. system variables, nutrients and toxic substances)measurements on river water entering at the head of the estuary	No data available from DWAF
Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater	Data extracted from South African Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995)

ii. Biotic Components

MICRO ALGAE - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Phytoplankton: Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae Measurements must be taken coinciding with typically high and low flow conditions	Some unpublished data (Department of Botany, Nelson Mandela Metropolitan Univeristy), would need to be repeated for closed and open mouth conditions.
Benthic microalgae: Intertidal and subtidal benthic chlorophyll-a measurements Epipelic diatoms need to be collected for identification These measurements must to be taken coinciding with a typical high and low flow condition	

MACROPHYTES - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the Present State, as well as the Reference Condition (if available) Available orthophotographs	Aerial photographs are available and GIS vegetation maps have been produced for 1942 and 2000 photographs. A more recent vegetation map would need to be produced for baseline closed and open mouth conditions.
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit	Available from past studies in the 1990s) and also from ongoing PhD study (C Bezuidenhout, Dept Botany, NMMU).
Permanent transects: - Measurements of percentage plant cover along an elevation gradient - Measurements of salinity, water level, sediment moisture content and turbidity	Transect data completed in 1990 as well as in 2004 (C Bezuidenhout PhD study, Dept Botany, NMMU).

INVERTEBRATES- DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	Bickerton & Pierce (1988) collected macrobenthic non-quantitative samples at four sites and noted the presence of some larger species only. In addition, a single survey sampled the estuary in the early 1990's (Wooldridge, unpublished). No data exists for the zooplankton or hyperbenthos.
Collect two sets of beam trawl samples (i.e. mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	
Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	

FISH - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Sampling should be representative of small fish (seine nets) and large fish (gill nets). Sampling should be done in all four seasons for the full extent of the system (as far as tidal variation) to allow for predictive capabilities. In a larger estuary (>5 km) sampling can either be at fixed intervals (every 2 km) or have the upper, middle and lower reaches subdivided into at least a further three sections each. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets should be in the 0 to 1 ppt reach of the system.	Ad hoc historical records of fishes in the Seekoei Estuary are available, with the most complete set of information being provided by CSIR. This latter dataset included a once off spring sampling using seine and gillnets in the lower, middle and upper reaches of the estuary.

BIRDS - DATA REQUIRED FOR COMPREHENSIVE LEVEL	CURRENT STATUS
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. Monthly data sets for at least one year are required. It this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).	Ten years of bi-annual Coordinated Water bird Counts (CWAC) were available from the Avian Demography Unit at UCT. The estuary was counted in four different months for this study.

Table 4-3 Additional baseline data required to increase confidence of Reserve and to set baseline for long-term monitoring in SEEKOEI Estuary

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Water Quality	Water quality (at least conductivity, temperature, dissolved oxygen, turbidity, pH, DIN, DRP & DRS, organic matter) measurements on river water entering at the head of the estuary and through tributaries	At least monthly	One station at position representative of inflows to estuary (both on Swart and Seekoei rivers)
	Collected longitudinal salinity & temperature profiles	Two surveys, during a normal seasonal and a high river inflow event when the mouth is open	Entire estuary, plus sampling point in river and sea (5 -7 stns)
	Water quality measurements taken along length of estuary (at least surface and bottom samples) for pH, dissolved oxygen, suspended solids/turbidity, inorganic and organic nutrients	Two surveys, during a normal seasonal and a high river inflow event when the mouth is open	Entire estuary, plus sampling point in river and sea (5 - 7 stns)
Hydrodynamic	Continuous water level recordings (need 10-15 year record)	Continuous	At causeway near mouth
	Accurate flow gauging of river inflow to estuary	Continuous	One station at position representative of inflows to estuary (both on Swart and Seekoei rivers)
	Aerial photographs of estuary (photographed at spring low tide)	Once-off	Entire estuary

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Hydrodynamics in relation to sediment	Water level recordings	Continuous	Near mouth and upstream of mouth
	Flow gauging	Continuous	Estuary inflow
	Aerial photos at spring low tide at 1:2000 scale	5 Years	Entire estuary
	Water level recordings along estuary	Once off during a spring and neap tidal cycle	Existing station(s) and temporary ones
	Near-shore wave data records (only if available)		-
Sediment dynamics	Bathymetric survey: Series of cross-sections and a longitudinal profile collected at about 500m intervals, but in some locations a previous survey. More detailed at the mouth. Vertical accuracy should be better than 300 mm.	5 Years	Entire estuary
	Set of sediment grab samples at cross-sections for grading analysis	Once off	Entire estuary
	Set of core samples (2m) save at cross-sections for grading analysis, age and origin (Isotope analysis)	Once off	Entire estuary say every 1 km
	Sampling of suspended sediment (and organic matter) required to quantify actual sediment and organic yield and variability.	Weekly, but daily during floods, for at least 5 years	Upstream of estuary

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Macrophytes	Two field visits to update the GIS vegetation map by identifying the distribution of the different plant community types and species. However this would not capture the dynamics of the submerged macrophyte communities which would need to be monitored on at least a monthly basis.	At least once during an open and closed mouth condition.	Entire estuary.
Microalgae	Phytoplankton and Benthic microalgae : Sample for biomass and species composition during an open and closed mouth condition to establish baseline conditions. For phytoplankton chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae completed for the different sties. For benthic microalgae measure intertidal and subtidal benthic chlorophyll-a and epipelic diatoms need to be collected for identification	At least once during an open and closed mouth condition.	Six stations along the length of the estuary, one on the seaward side of the causeway, one on the landward side of the causeway and at least two sites in the Seekoei and Swart arms.

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Invertebrates	Collect quantitative samples for zooplankton after dark from five or six sites. Zooplankton samples to be collected at near-surface and at midwater level where possible. Chlorophyll-a data must be collected at all sites and on all sampling occasions.	Samples to be collected four times per year at approximately quarterly intervals over two years. Times should be selected to maximize low and high flow conditions.	Collections at five or six sites.
	Subtidal benthic samples to be collected using a grab sampler and sieved through 500 micron aperture mesh.	Samples to be collected four times per year at approximately quarterly intervals over two years. Times should be selected to maximize low and high flow conditions.	Collections at five or six sites that correspond to the zooplankton stations. It may not be possible to sample all sites because of water depth.
	Hyperbenthic samples to be collected using a sled with 500 micron aperture mesh.	Samples to be collected four times per year at approximately quarterly intervals over two years. Times should be selected to maximize low and high flow conditions.	Collections at five or six sites that correspond to the zooplankton stations. It may not be possible to sample all sites because of water depth.

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Fish	Conduct fish surveys using both seine and gill nets as primary gear.	Quarterly over one year, covering all four seasons and representative of temperature and average river inflow of that season. Both open and closed mouth phases need to be monitored in a particular year, with particular emphasis on juvenile marine fish recruitment.	Entire estuary (9-12 stations)

ECOLOGICAL COMPONENT	MONITORING ACTION	TEMPORAL SCALE (frequency and when)	SPATIAL SCALE (no. stations)
Birds	Monthly count data are required for at least one year.	Monthly, on spring low tide	Whole estuary

Table 4-4 Long-term resource monitoring programme proposed for the Seekoei Estuary after implementation of the Reserve

				Estimated Human Resources (as days/year)					
Ecological component	**Monitoring action**	**Temporal scale (frequency and when)**	**Spatial scale (no. stations)**	**Sampling**		**Analysis**		**Reporting**	
				Scientist	**Tech**	**Scientist**	**Tech**	**Scientist**	**Tech**
Water Quality	Collect data on conductivity, temperature, suspended matter/turbidity, dissolved oxygen, pH, inorganic nutrients and organic content in river inflow	At least monthly	One station at position representative of inflows to estuary (both on Swart and Seekoei rivers)	Recommend that existing stations be selected or additional station be added in the DWAF's water quality monitoring programme on the Swart and Seekoei rivers					
	Collected longitudinal salinity profiles (*in situ*)	Monthly	Entire estuary (3 - 5 stns)	-	1 x 12	-	-	1 x 1	-
	Collected longitudinal salinity & temperature profiles (*in situ*)	To be measured when biotic surveys require information for interpretation	Entire estuary, plus sampling point in river and sea (5 - 7 stns)	-	1 x 2	-	-	1 x 1	-
	Water quality measurements taken along the length of the estuary (surface and bottom samples) for pH, dissolved oxygen, suspended solids/ turbidity and inorganic/organic nutrients	To be measured when biotic surveys require information for interpretation	Entire estuary, plus sampling point in river and sea (5 -7 stns)	See related biotic components - samples can be collected as part of biotic survey		*In situ* measurements Accredited analytical laboratory		1 x 1	-
	Baseline data set for pesticides accumulation in sediments	Every 3 – 6 years, if deemed necessary in future	Focus on depositional areas, e.g. areas with fine sediments (mud)	-	1 x 2	Depend on parameters selected (to be provided by accredited analytical lab)		1 x 1	-
Hydrodynamics	Water level recordings	Continuous	At causeway near mouth	Included in DWAF national monitoring programme				1 x 1	-
	Flow gauging	Continuous	One station at position representative of inflows to estuary (both on Swart and Seekoei rivers)	Include in DWAF national monitoring programme				1 x 1	-
	Aerial photographs of estuary (spring low tide)	Annually	Entire estuary	Should be recommended for inclusion in DEAT national coastal survey programme				1 x 1	-

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Hydrodynamics	Water level readings	Continuous	At recorder		3		3	2	
	Flow gauging	Continuous	Estuary inflow		3		3	2	
	Aerial photographs (spring low tide)	5 Years	Entire estuary					2	
Sediment	Bathymetric survey: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but more detailed in the mouth (vertical accuracy better than 300 mm)	5 Years	Entire estuary	1	4		2	2	2
	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations	5 Years	Entire estuary		1		5	1	1
	Suspended sediment and organic matter	Weekly, but daily during floods	Upstream of estuary		10		5	2	

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Microalgae									
Phytoplankton	Phytoplankton biomass, chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths. Cell counts of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements for the open and closed mouth condition.	One year after reserve implementation thereafter every three years.	6 stations	2	2	3	10	3	0
Benthic microalgae	Benthic microalgae biomass, intertidal and subtidal benthic chlorophyll-a measurements. Epipelic diatoms need to be collected for identification. Measurements for the open and closed mouth condition.	One year after reserve implementation thereafter every three years.	6 stations	2	2	3	6	3	0

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Macrophytes	Use aerial photographs to quantify area covered by different plant community types and produce a vegetation map for the open and closed mouth condition. Conduct field surveys during the closed and open mouth condition to document the species composition and area covered by the different plant community types. Measure macroalgal and submerged macrophyte percentage cover in 1 m^2 quadrats along three permanent transects.	One year after reserve implementation thereafter every three years.	Entire estuary	2	2	1	5	2	1

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Invertebrates	Collect quantitative samples for zooplankton after dark. Zooplankton samples to be collected at near-surface and at midwater level, depending on water depth. Chlorophyll-a data must be collected at all sites and on all sampling occasions. High priority.	Two years after implementation and then every three years. Samples to be collected twice a year. Times should be selected to maximize low and high flow conditions.	All five or six sampling sites.	2	4	-	12	6	-
	Subtidal benthic samples to be collected using a grab sampler and sieved through 500 micron aperture mesh. High priority.	Two years after implementation and then every three years Samples to be collected twice a year. Times should be selected to maximize low and high flow conditions.	All five or six sampling sites.	2	4	-	40	6	-

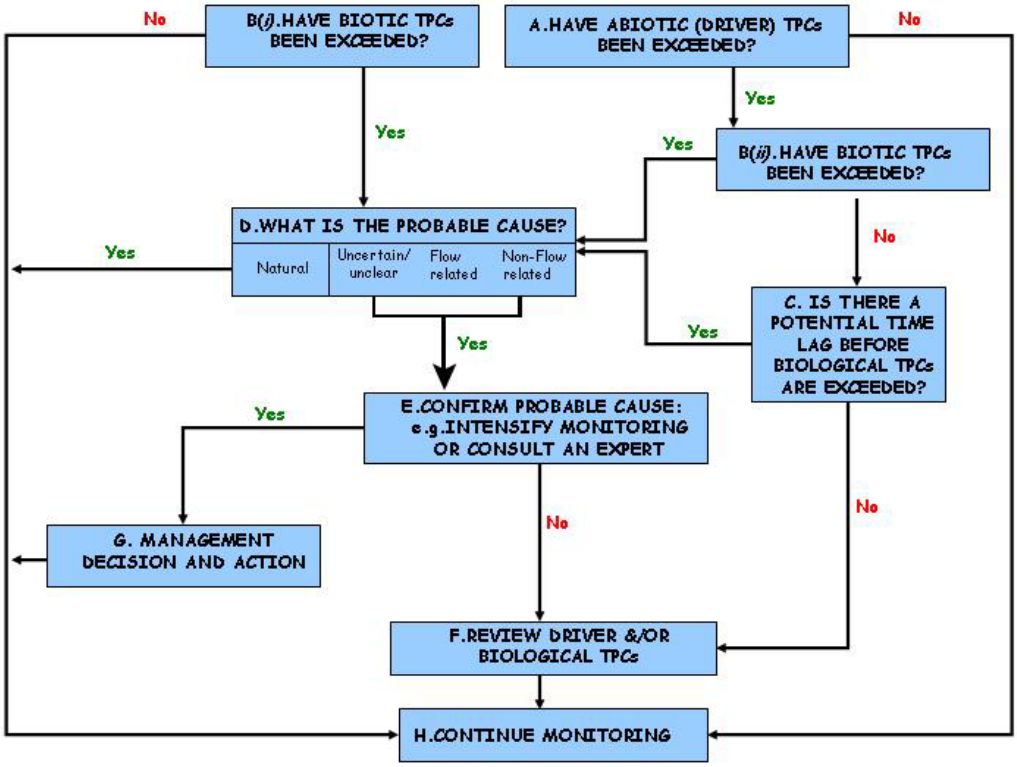
Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
	Collect quantitative hyperbenthic samples.	Two years after implementation and then every three years Samples to be collected twice a year. Times should be selected to maximize low and high flow conditions.	All five or six sampling sites.	2	4	-	12	6	-

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Fish	Conduct fish surveys using both seine and gill nets as primary gear.	Two years after implementation conduct a closed phase survey, followed by a closed phase survey every 3 years thereafter	Entire estuary (9-12 stations)	2	3	1	1	1	

Ecological component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. Stations)	Estimated Human Resources (as days/year)					
				Sampling		Analysis		Reporting	
				Scientist	Tech	Scientist	Tech	Scientist	Tech
Birds	Bi-annual bird counts of the estuary	Mid-summer and mid-winter	Whole estuary	4	8	2	0	1	

5 CONCLUSIONS

The proposed monitoring plans are regarded as appropriate and achievable and must be implemented through the following Monitoring Decision Support System to be applied in the long-term resource monitoring of estuaries, as part of the RDM process (DWAF, 2004b).



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