MAINTENANCE MANAGEMENT PLAN FOR THE BOT RIVER ESTUARY MOUTH UNDER SPECIFIC CONDITIONS

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Bot Estuary

STATEMENT OF THE PROBLEM

The mean annual runoff (MAR) into the Bot/Kleinmond Estuarine Lake system is recorded as 89 million m^3, but this has been reduced to 72 million m^3 through water abstraction and alien infestation in the catchment area (CSIR 2011). The reduced flows to the system means that natural breaching levels (and related breaching opportunities) are reduced. At present catchment flows are insufficient to facilitate natural breaching of the Bot mouth except during flood events, while the Kleinmond mouth breaches more frequently as a result of its small size and the input from the Lamloch river. In the recent past the reduced river inflow was further exacerbated by premature breaching of the partially connected Kleinmond mouth which further reduces average water levels in the Bot. However, artificial breaching of Kleinmond mouth has been discontinued in the last decade thus resulting in more breaching opportunities at the Bot Estuary. However, it should be noted that that the impact of this historical management practice on sedimentary processes will take some time to reset.

If the Bot mouth is not breached artificially it will turn into a freshwater lake within five to ten years. As a result the invertebrate communities that serve as a food source for wading birds will change significantly, with crustaceans and molluscs being replaced by freshwater insects. Most of the 41 fish species that occur in the estuary are estuarine dependent or marine species and not adapted to fresh water condition. Mass mortalities of fish have occurred in the past when the estuary's salinity fell below 6 practical salinity units (psu - seawater is 35 psu). The Bot Estuary is regarded as a highly important nursery area for marine fish, providing an ecosystem service valued at some R50 million, so this system's function must be preserved.

Regular mouth breaching of the Bot mouth, e.g. every 2 to 4 years, will result in more frequent connection to the sea, thus greater recruitment of estuary-dependent fish, stabilisation of invertebrate communities, and prevention of extreme fluctuations in salinity. A brackish estuarine environment will in general increase the species diversity (Van Niekerk et al. 2005).

However, the intent is not to turn the Kleinmond Estuary into a blind arm of the Bot Estuary. Where possible, natural breaching should be allowed to occur to flush out sediments and allow for the ingress of seawater into the lower reaches of the smaller system.

OVERALL OBJECTIVE OF THE LOCAL MOUTH MANAGEMENT PROGRAMME

To manage the estuary mouth as an integral part of the Bot/Kleinmond Estuary Management Plan that will maintain the healthy ecological conditions of the estuary.

For the Bot/Kleinmond Estuary this means that its health assessment rating should be consistent with a B Ecological Category defined as "*Largely natural with few modifications*" as defined in terms of Department of Water and Sanitation's (DWS) A to F rating system (Turpie & Clark 2007; Van Niekerk & Turpie 2012).

DESCRIPTION OF THE BOT ESTUARY

Table 1. Description of the estuary and its importance.

Threat	Discussion
Location	The Bot/Kleinmond Estuary forms a relatively shallow triangular coastal lake, roughly 10 km long with a maximum width of about 2 km. It is located on the south-western coast of South Africa some 110 kilometres south east of Cape Town (Koop 1982). The mean depth is -1.5m MSL (mean sea level) (Willis 1985). The Bot Estuary mouth is mostly closed and at present is breached artificially approximately one to two times every three years. **Downstream boundary:** Bot mouth (34°22'6.96"S, 19° 5'55.86"E) Kleinmond mouth (34°20'33.54"S, 19° 2'13.11"E) **Upstream boundary:** 11.4 km from the mouth to the extent of tidal influence **Lateral boundaries:** Estuary Functional Zone 5 m contour above Mean Sea Level (MSL) along each bank 
Estuary Importance	The Bot/Kleinmond Estuary is a large (~1 500 ha) estuarine lake system compared with other South Africa systems. The estuary is ranked 8th most important in South Africa in terms of its botanical, fish and bird biodiversity (Turpie & Clark 2007, Turpie et al 2002). The estuary is rated as "*Highly important*" based on its Estuary Importance Score (EIS) with a score of 94 out of 100. The EIS takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account.
Conservation status	The Bot/Kleinmond Estuary is a declared RAMSAR site at present and is included in the subset of estuaries identified as requiring protection in the National Estuary Biodiversity Plan in order to conserve South Africa estuarine biodiversity estate (Turpie et al. 2012). The system also falls within the Kogelberg Biosphere Reserve boundaries. The estuary also forms part of the core set of estuaries targeted in the Provincial Protected Areas Expansion plan/strategies.

Threat	Discussion
Important vegetation	Four of the nine possible macrophyte habitats occur in the Bot Estuary; only mangroves and swamp forest are absent. Water salinity determines species composition in the Bot Estuary; *Ruppia maritima* occurs at salinity between 0-45 psu, Charophytes at 0-20 psu and *Potamogeton pectinatus* at <15 psu. Submerged macrophytes contribute 72 % to the total annual primary production in the estuary. Light is the main abiotic driver of submerged macrophytes in the Bot Estuary. Stable water level for 2 months is required for submerged macrophytes to develop from seed reserves. Peak submerged macrophyte biomass will develop after 9 months if the water level is stable. Salt marsh occurs predominantly in the Lamloch area near the head of the estuary and in isolated areas around the main water body, with a total area of 693 494 m^2. Salt marsh includes intertidal and supratidal habitat as they could not be mapped separately using existing aerial photography. The main species are *Sporobolus virginicus*, *Juncus kraussii, Juncus acutus, Sarcocornia natalensis* and *Sarcocornia decumbens.* When water level exceeds 1.7 m MSL these areas are inundated and can become submerged for prolonged periods. Under these conditions they become heavily epiphytized. Salt marsh dies back when inundated for more than 3 months but recovers rapidly (1 to 2 months) once water level drops and habitat is exposed. Reeds and sedge habitats are characterised by *Chondropetalum tectorum* in the Lamloch area and in isolated patches in the littoral zone around the Bot Estuary being replaced by *Scirpus nodosus* (now called *Ficinia Nodosa*) in sandier areas and *Juncus acutus* near the head of the estuary. At the head of the estuary dense stands of *Phragmites australis* and *Scirpus littoralis* (now called *Schoenoplectus Scirpoides*) reed swamps occur in marginal waterlogged areas. Small patches of reeds and sedges also occur along the edges of the estuary, for example near the Afdaks River and in Lamloch Swamp. The reeds are important as they absorb nutrient input from the land (e.g. fertilizers) and also act as sediment traps. Macroalgae in the Bot Estuary are common opportunistic species that occur in estuaries worldwide mainly in response to eutrophication. They proliferate initially when salt marsh becomes inundated and begins to decompose. When the water level drops, these mats are deposited on the shoreline vegetation. The epiphytic macroalga *Cladophora* sp. forms on submerged aquatic vegetation. It can break free and forms dense mats along the shoreline. It has no definite growth cycle, appears unpredictably and can occur for several months at a time. Because of this drifting nature, biomass is highly erratic.
Important fish nursery	A total of 41 fish species from 24 families have been recorded from the Bot Estuary (CSIR 2011). Nineteen (46 %) of these are entirely dependent on estuaries to complete their lifecycle. Eight of these breed in estuaries and include the estuarine round-herring, Bot River klipvis, Cape halfbeak, Cape silverside, Knysna sand-goby, three species and pipefish. Seven, (dusky kob, white steenbras, leervis, Cape moony, flathead mullet, freshwater mullet and Cape stumpnose, are dependent on estuaries as nursery areas for at least their first year of life. A further three, namely the catadromous African mottled eel, Madagascan mottled eel and longfin eel require estuaries as transit routes between the marine and freshwater environment. In all, 71 % of the fish species recorded from the Bot Estuary can be regarded as either partially or completely dependent on estuaries for their survival. Based on their distributional ranges 20 (40 %) of the fish recorded in the Bot Estuary are southern African endemics including the Botriver klipvis *Clinus spatulatus* which has an extremely limited range being confined to the Bot and nearby Klein Estuary. The Bot Estuary accounts for about 12% of the total estuarine fish nursery area from False Bay to Port Alfred. Its importance lies in its size and its situation in a region of high endemicity within the warm temperate, cool temperate transition zone. The Bot/Kleinmond, together with the Klein (at Hermanus), account for 25-30% of the available estuarine fish nursery-area from Cape Point to Port Alfred. It is crucial that at least one of these two estuaries is open to the sea during the spring/early summer recruitment window each year. With the exception of some drought years, the Klein usually opened annually under natural conditions. In the past decade, however, drought, wastewater spills and eutrophication have seen that system and its fish under severe stress from hypoxia and high water temperatures, with mass mortalities occurring. The Bot, which has opened during this time period, would have provided some level of mitigation by allowing recruitment of juvenile fish and larvae and the export of adult fish to recruit into the marine fisheries. The latter function was probably negated by the high illicit gillnet catches in both the Klein and Bot estuaries. Connectivity between the Klein and Bot is highlighted by the fact that Clinus spatulatus only occurs in these two systems and nowhere else. On the other hand, the *G. aestuaria* population in the Bot is probably the most genetically isolated of this

Threat	Discussion
	species along the entire South African coastline (Norton 2005). This can be at least partly explained by its life-history characteristics but also by the fact that fish recruitment into Walker Bay and its estuaries is limited compared to other bays in South Africa, mostly due to its relative isolation and currents bypassing the bay, deflecting further out to sea. This may also be a factor in the recruitment of estuary-dependent marine species, as it may limit the estuary recruitment window more than elsewhere along this country's coastline. Connectivity between these two estuaries occurs during regional flood events usually coinciding with cutoff-lows when both systems are open and connected via their fluvial plumes (Von der Heyden et al. 2015, CSIR 2011).
Important Bird site	The Bot/Kleinmond Estuary is recognised as one of South Africa's Important Bird Areas with a total of 86 water bird species recorded. The majority of these birds are invertebrate-feeding waders (33 species), followed by piscivores (18 species) and waterfowl (14 species). Twelve (12) species are wading birds (herons, egrets etc.) and nine are pursuit-swimming piscivores. Thirteen species are listed in the South African Red Data Book (Barnes 2000): three as Vulnerable (Bank Cormorant, African Marsh Harrier and Blue Crane), and nine as Near-threatened (Great White Pelican, Cape Cormorant, Crowned Cormorant, Greater Flamingo, Black Harrier, African Black Oystercatcher, Chestnut-banded Plover, Caspian Tern and Half-collared Kingfisher). Eight species are endemic to southern Africa: Bank Cormorant, Cape Cormorant, Crowned Cormorant, Black Harrier, Hartlaub's Gull, African Black Oystercatcher, Blue Crane, South African Shelduck and Cape Shoveler. Of all the threatened and endemic species, only the Cape Shoveler has been reported breeding at the estuary (CSIR 2011). During the closed mouth condition herbivorous waterfowl dominate the system in terms of overall abundance in summer (Mean = 2 470 ± 1 360) and winter (Mean = 3920 ± 1910). During the open mouth conditions the system is dominated by gulls & terns, cormorants and invertebrate-feeding waders with only very low numbers of waterfowl. In general, the different states of the system brought about by breaching tend to favour different communities of aquatic birds. Thus the bird community changes markedly from year to year. After breaching, the system becomes tidal with a salinity gradient. These conditions favour waders and birds that use intertidal areas for roosting (e.g. gulls and terns). Thus, species attracted to the system during the open state include Common Greenshank, Kittlitz's Plover, and Southern Pochard responded positively to inter-tidal conditions. When the estuary closes, it goes into a 'lagoon' state, intertidal areas become permanently inundated which are unfavourable for most invertebrate-feeding waders (especially migratory species). These shallow water areas, however, become attractive to flamingos. Other species attracted to these conditions include Southern Pochard, Red-knobbed Coot, African Darter, Hartlaub's Gull, Cape Shoveler and Red-billed Teal. Swift Tern, Little Stint, Black-necked Grebe, Cape Cormorant, Caspian Tern, Curlew Sandpiper and Reed Cormorant. Piscivores and invertebrate feeders showed greater preference for these conditions, whereas herbivores are mainly intolerant of these intermediate conditions. After about 1.5 - 2 years, during which time water weeds have recovered in the system, the estuary enters a freshwater lake-like state, favouring waterfowl, notably Red-knobbed Coot. This does not only apply to the herbivorous species, but also to the invertebrate feeders, such as Cape Shoveler, whose food supply is also closely linked to the presence of aquatic macrophytes. Other species attracted to the lake-like state include Little Grebe, African Darter, Yellow-billed Duck, Cattle Egret and Reed Cormorant. There is no clear trend for piscivorous birds (Heyl & Currie 1985), which technically should not be affected, but counts suggest that they also favour the deeper water conditions. Thus the system changes from a wader-dominated one to a waterfowl-dominated one over time following breaching. One red data species, the African Black Oystercatcher, is probably little affected by breaching activities, being mainly a resident of the adjacent dune and coastal habitats.
Estuary Condition w.r.t breaching	The Bot/Kleinmond Estuary rated as ***Moderately modified*** (Category C in DWS rating system). The estuary is negatively impacted by the following: • A reduction in river inflow (especially the lack of base flow during summer); • Increased mouth closure causing inundation of supratidal areas and decrease recruitment from the marine environment; • Increased nutrient load from the surrounding catchment land-use; • Over-exploitation of fish (including illegal gillnetting) which reduced the system's nursery function;

Threat	Discussion
	• Artificial breaching of the Kleinmond inlet which drain waters from the Bot Estuary at high water levels; and • Inappropriate breaching of the Bot mouth changing the seasonality of natural breaching and breaching levels. Of special concern is the increase in closed mouth conditions that causes an increase in the abundance of reed beds, submerged macrophtyes and macroalgal blooms. There are significant changes in the community composition of invertebrates and fish as a result of the increase in closed mouth conditions, changes in salinity. Fishing pressure is also a major concern. Artificial breaching is a management intervention that can mitigate for the loss of river inflow.
Recommended Ecological Condition	The impacts on the Bot/Kleinmond Estuary can be mitigated with very little effort. The recommended health status is a ***Category B (Largely Natural***) because the system is a conservation priority, an important fish nursery, important bird area, as well as the ease with which restoration can be achieved.

MOTIVATION FOR ARTIFICIAL BREACHING

Stakeholder engagement

A workshop known as the 'Bot Indaba 2009' was held at Middelvlei Estate on the south-eastern shore of the Bot River Estuary on 16 April 2009 to discuss a number of issues relating to the estuary system. The development of guidelines for the management of the Bot River Estuary mouth was one of the key items on the agenda. The workshop was held under the auspices of the then Bot River Estuary Advisory Committee (BREAC), that was overseeing the management of the estuary since 1993.

Following the development of an Estuary Management Plan (EMP) for the Bot River Estuary as part of the Cape Estuaries Programme, BREAC was dissolved and replaced by the more broadly representative Bot River Estuary Forum (BREF), responsible for coordinating the implementation of the EMP. BREF comprises representatives of:

- All the government agencies that have the necessary jurisdiction to take actions that are necessary
- All civil society organisations with a direct interest in the proper management of the estuarine ecosystems.

A Bot Estuary mouth MMP was successfully applied for by the OSM in 2011 and implemented for a five year period. This MMP expired and now new MMP was developed due to the fact that no clear Responsible Management Authority in terms of the National Estuarine Management Protocol could be identified. In 2018 proposed amendments to the NEMP included that Provincial Government become the RMA. This then resulted in CapeNature being identified as the RMA for all those priority estuaries in the WCPAES including the Bot Estuary late in 2019. Hence the development and submission of this MMP by CapeNature.

In addition to this, a public meeting was also held at Fernkloof Hall on 25 October 2017, under the auspices of the Western Cape Estuary Management Framework and Implementation Strategy project. A range of concerns were raised at the meeting, including the perception that the Kleinmond system is being neglected in management decision-making that focusses on the Bot system, concerns about progressive siltation, reed infestation and water quality issues.

Interaction between Bot and Kleinmond systems

The Bot and Kleinmond estuaries are linked when the water level is at least 1.7 metres above mean sea level via a shallow channel at Rooisand. Water then flows from the Bot through the Rooisand channel and adjacent Lamloch Swamps into the Kleinmond estuary, and out to sea if the mouth is open (Figure 1, Van Niekerk et al. 2005). The total amount of water required to breach the Bot is thus strongly influenced by the amount ultimately lost to the Kleinmond mouth prior to breaching (Willis 1985, Van Niekerk et al. 2005).

In the past, consideration has been given to construct a berm across 'Die Keel' – the connection between the Bot Estuary and the Rooisand channel – but this required a large engineering structure with other potential environmental impacts. It would also have negative implications for the Kleinmond Estuary, lengthening the period that the Kleinmond mouth remained closed.

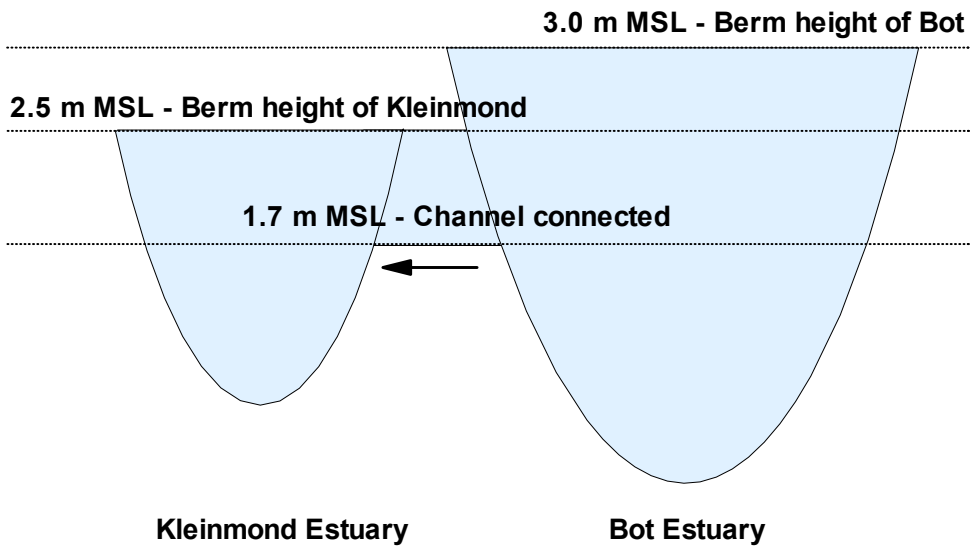


Figure 1 Illustration of the water level change in the Bot/Kleinmond system

The need for artificial breaching

Because the mean annual runoff (MAR) into the Bot Estuary has been reduced from 89 million m^3, to 72 million m^3 through water abstraction and alien infestation in the catchment area (CSIR 2011) artificial breaching is now required to maintain acceptable ecosystem functioning. The dampening of flood peaks and reduction in summer base flow mean that freshwater inflow is insufficient to scour the estuary and prevent marine sediments from blocking the mouth, resulting in sustained periods of mouth closure. The present volume of river inflow is insufficient to breach the sand berm at the Bot mouth, except during flood events. In the 60 years prior to the early 1980s, the Bot mouth opened naturally only three times (although this was partly because the Kleinmond mouth had been prematurely breached artificially, resulting in too low water levels for effective scouring during subsequent opening of the Bot mouth.

If the mouth of the Bot estuary is not breached artificially it will turn into a freshwater lake within five to ten years. The invertebrate communities that serve as a food source for wading birds will change significantly, with crustaceans and molluscs replaced by freshwater insects. In addition, most of the 41 fish species that occur in the estuary are estuarine or marine species that are unable to survive in fresh water. Mass mortalities of fish have occurred in the past when the estuary's salinity fell below 6 practical salinity units (psu - seawater is 35 psu). The Bot estuary is known to be a highly important nursery area for marine fish, providing an ecosystem service

valued at some R50 million annually (through a range of fisheries related income generation in the local area), so this function must be preserved.

Advantages associated with regular mouth breaching every 2 to 3 years are therefore a more frequent connection to the sea, greater recruitment of estuary-dependent fish, stabilisation of invertebrate communities, and prevention of extreme fluctuations in salinity. A more typical estuarine environment would in general increase the species diversity (Van Niekerk et al. 2005).

However, the intent is not to turn the Kleinmond Estuary into a blind arm of the Bot Estuary. Where possible breaching should be allowed to occur naturally to flush out sediments and allow for the ingress of seawater into the lower reaches of the smaller system. It should also be noted that the berm at the Kleinmond mouth will build-up significantly if the period between breachings were to extend 12 to 18 months. This, in turn, will lead to the inundation of low lying infrastructure.

ASSESSMENT OF RISKS, THREATS, OPPORTUNITIES ASSOCIATED WITH MOUTH MANAGEMENT DECISIONS

A summary of the motivations for potential artificial breaching is provided below in Table 1.

Table 1: Summary of artificial breaching motivation

	Potential Threat	Relevance	
Human wellbeing and safety	Threat to human life (as a result of high water levels)	No threats to human life	
	Threat to immoveable property and infrastructure (as a result of high water levels)	Yes, there are a number of low lying properties around the edges of the Bot/Kleinmond Estuary, e.g. Yacht club, Meerensee at the Bot and the municipal stormwater drain at the Kleinmond as the lowest.	
	Human health impact (e.g. flooding of sewage pump station, septic tanks, chemical storage yards, etc.)	Swimming is not a major consideration at the Bot Estuary, but the Kleinmond mouth is a recreational area. Water Quality in the Kleinmond Estuary can deteriorate to where it poses a risk to human health. Signage is then erected to warn local residents not to swim.	
	Potential loss of agricultural resources (as a result of high water levels)	Not applicable.	
	Potential impact on nearshore environment if breached (e.g. aquaculture facilities)	Not applicable.	
	Loss/impaired access (e.g. roads, footpaths, cattle crossings)	The foot bridge at Meerensee can become inundated.	
	Harmful / Noxious algal blooms	Noxious algal blooms can occur at the Kleinmond Estuary as a result of poor water quality.	
	Impact(s) on recreational use (e.g. increase depth / surface area when mouth is closed, reduce fishing).	Recreational activities such as yachting and wind surfing in the Bot Estuary can be impacted on by mouth state as the estuary is shallow. Recreational activities at the Kleinmond estuary mouth is largely confined to swimming and canoeing.	
		Impact of artificial breaching of the Bot Estuary	*Bot Recreational fishing*: Enhanced by open mouth conditions. *Bot Yachting and wind surfing*: Can be limited to the lake area in the lower reaches of the Bot Estuary during open state when the upper reaches are very shallow. *Bot/Kleinmond Birdwatching*: More estuarine associated species such as waders present in the intertidal areas during the open mouth state, but large number of water fowl are disturbed by breaching

Potential Threat		Relevance	
			Kleinmond swimming: If not recently breached,water quality problems may impact on swimming activities. This needs to be addressed at source.
		Impact of NOT breaching of the Bot Estuary	*Bot Recreational fishing*: Recreational fish catches are lower (number and size of fish) if the mouth has been closed for an extended period. *Bot Yachting and wind surfing:* Can be limited to the lake area in the lower reaches as dense macrophyte beds prevent activities in the middle and upper reaches. *Bot/Kleinmond Birdwatching*: Waterfowl increase significantly during closed mouth state. Kleinmond swimming: Kleinmond Estuary mouth more likely to breach and scour out algal blooms and sediment from the mouth area.
Ecosystem requirements	Impact on avifuana abundance, species richness/ community composition	Important bird habitat	The Bot/Kleinmond estuary has been recognised as one of South Africa's Important Bird Areas (CSIR 2011).
		Impact of artificial breaching of the Bot Estuary	The open state, following mouth breaching provides exposed Intertidally areas which favours Waders, gulls and terns (e.g. Curlew Sandpiper, Kittlitz's Plover, Common Tern and Hartlaub's Gull) Post breaching, open state conditions also favour Flamingos, wading birds (e.g. Greater Flamingo, Black-winged Stilt, Sacred Ibis, Grey Heron and Egrets. Breaching has a negative effect on water fowl.
		Impact of NOT breaching of the Bot Estuary	The deep water and abundant macrophytes associated with not breaching favours Waterfowl and piscivores (e.g. Red-knobbed Coot, Great Crested Grebe, Southern Pochard, Yellow-billed Duck, Red-billed Teal and Reed Cormorant) Mouth closures and related high water levels have negative effect on Waders, gulls and terns as they prefer exposed sandbanks in lower estuary. The higher water levels and reduction in fish abundance during closed mouth state also indirectly impact on the Cormorants, wading piscivores, kingfishers and fish-eagles.
		Occurrence of avian botulism	Not a major concern in this system.
	Impact on estuarine fish abundance, species richness/ community composition	Important fish nursery	Artificial breaching of the Bot mouth may be necessary to maintain the ecological functioning of the estuary and its value as a nursery area for fish; this being achieved by ensuring that the mouth is open to allow recruitment and emigration during the peak recruitment period during spring – early summer (August – November)
		Impact of artificial breaching of the Bot Estuary	Positive impacts are recruitment of larval and juvenile fish and return of adolescents and reproductively active fish to the sea to spawn. Negative aspects are a temporary reduction in water volume and littoral habitat and limited

	Potential Threat	Relevance	
			mortality of resident benthic species through stranding in algal and macrophyte beds. Aggregations of fish at the mouth just prior to and during breaching are particularly vulnerable to exploitation especially by illegal methods such as gaffing and snagging with treble-hooks. (Draft legislation related to the Marine Living Resource Act has existed for the past decade that prohibits fishing of any kind in an estuary the two days before, during and one day after a breaching event whether artificial or natural.)
		Impact of NOT breaching of the Bot Estuary	Significant nursery area (>10%) not available to juvenile fish on the Cape south coast and eventual drop in recruitment or available biomass of exploited species to marine fisheries.
		Occurrence of fish kills	Yes, a major fish kill have been associated with extremely low salinities in the Bot Estuary (< 6 psu). Fish kills arising from hypo / hypersalinity and / or estuarine harmful algal blooms (HABs) (e.g. *Microcystis*, golden algae *Prymnesium parvum*) may be mitigated by open mouth conditions. Fish may also escape hypoxia, ammonia toxicity etc. arising from poor waste water treatment in the estuary and catchment. Seawater 35 psu will also treat pathogens such as the water mould Epizootic Ulcerative Syndrome (EUS) now prevalent in many estuaries and catchments. The above said, ill-timed or inadequate breaching at low water levels and with little water movement may compromise already-stressed fishes' immunity to pathogens and exacerbate fatalities.
	Impact on estuarine invertebrate abundance, species richness/ community composition	Impact of artificial breaching of the Bot Estuary	During open mouth conditions salinity levels increase. When salinities increase above 10 psu it creates opportunity for euryhaline species) to increase in biomass and abundance An open mouth is also important larval recruitment from the marine environment and vice versa.
		Impact of NOT breaching of the Bot Estuary	Prolonged closed mouth conditions lead to decrease in species richness (absence of marine associated species). The associated decrease in salinity has a negative impact on invertebrates within the lower reaches of the Estuary which are adapted to life in a more saline tidal system.
		Occurrence of invertebrate kills	No information available on the Bot/Kleinmond Estuary but invertebrate mortalities have occurred in the Breede (sandprawn *Callichirus kraussi*). Ammonia toxicity and hypoxia impact benthic invertebrates and the osmotic stress arising from abrupt changes in salinity may help control pathogens and parasites.
	Estuarine Macrophytes (plants)	Impact of artificial breaching of the Bot Estuary	Open mouth conditions at the Bot Estuary associated with artificial breaching create intertidal habitat for salt marsh and reeds and sedges. Fluctuating water levels would

Potential Threat		Relevance	
			decrease submerged macrophyte biomass and extent. Strong tidal flows could limit the establishment of submerged macrophytes in lower reaches. Submerged macrophyte area cover will vary with seasonal water level. When the mouth breaches, 60 to 80 % of these beds are lost through exposure (CSIR 2011). Salt marsh expands when water level is low and will continue to grow even when inundated, as long as it is not covered for more than 2 to 3 months. Salt marsh expands rapidly into exposed areas when water level drops and 100% cover can be achieved within 1 to 2 months. Increased sediment salinity due to evaporation may result in a temporal loss of species. Dune stabilisation along the Hawston coastline has led to a build-up of sand at Sonesta (Meerensee area), reducing/preventing natural breaching. Increased sedimentation in the lower reaches may also reduce the tidal elevation range, thereby restricting salt marsh zonation.
		Impact of NOT breaching the Bot Estuary (i.e. die back of saltmarsh)	Submerged macrophytes in the Bot Estuary expand but restricted to shallower areas. The large submerged macrophyte beds that develop during the closed phase are important as they have diverse faunal communities associated with them. 10 % of the *Ruppia* beds are estimated to be eaten by coots and 10 % by fish (associated epiphytic fauna on the leaves of Ruppia). Anthropogenic nutrient inputs presently encourage growth. Die-back occur of salt marsh, reeds and sedges due to inundation and high water level (>1.6 m MSL).
	Water quality Thresholds of concern (that would compromise estuarine ecosystem or ecosystem services	Salinity (high or low) that would compromise ecosystem or ecosystem services	Low salinities (<6 psu) tend to develop within 2 to 3 years after breaching of the Bot Estuary. Low salinities have been associated with fish kills in the Bot as they increase the susceptibility of fish to other environmental stress (e.g. Hypoxia (low oxygen) or low temperatures). The Kleinmond estuary in general have lower salinities that the Bot as it smaller and more perched, however during extended period of mouth closure (12 to 18 months) it becomes very fresh contributing to reed growth.
		Dissolve Oxygen	< 4 mg/l in the Bot Estuary
		Ammonia levels	Not a major concern.
		Toxic substance	Not a major concern.
		A major pollution source in this system relates to the failures of sewage pump stations, low lying septic tanks and inappropriately placed storm water drain in Kleinmond. An action plan is required urgently to address this to prevent unnecessary breaching of the Kleinmond mouth	

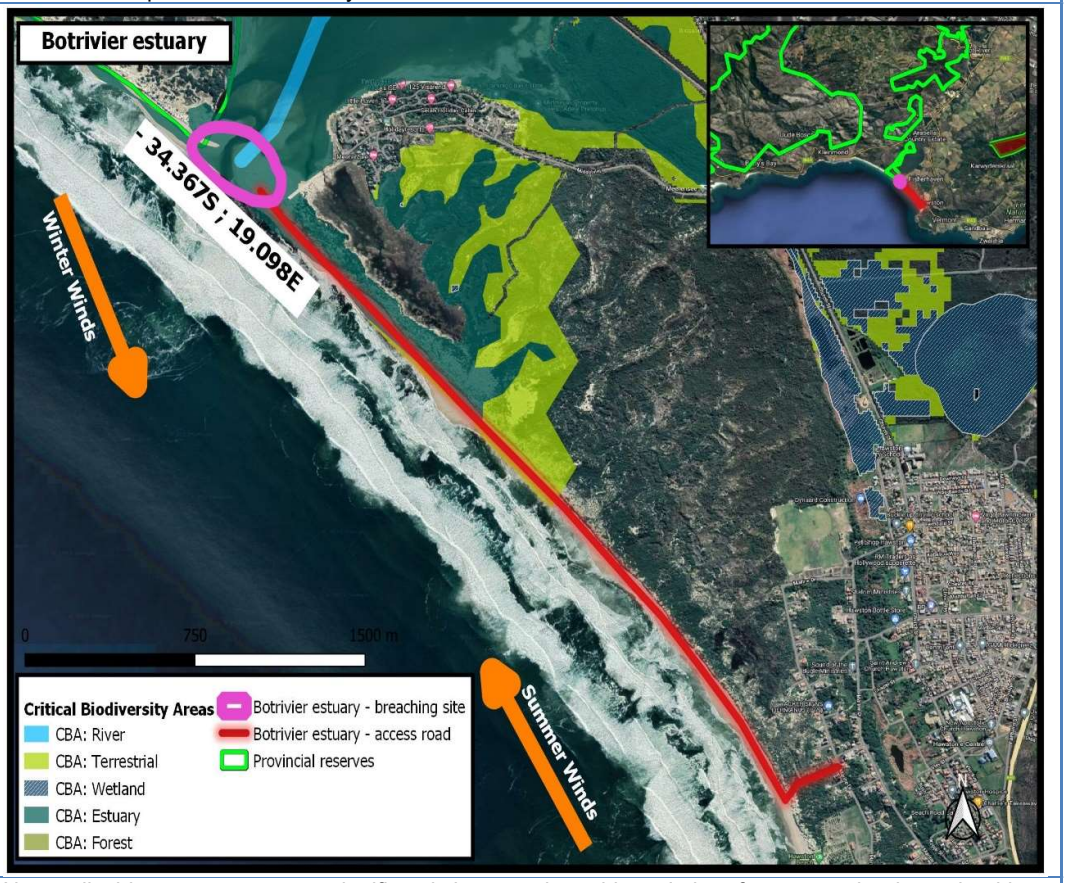
Potential Threat		Relevance	
	Eutrophication	Excessive reed growth	Increased salinity associated with breaching assist with the control excessive reed growth (i.e. cannot survive when exposed to higher salinities)
		Macrophyte blooms	Higher salinities following breaching assist with the control of excessive macrophyte blooms
		Harmful algal blooms	Currently not relevant.
	Sedimentation	On-going sedimentation	Breaching at low water level causes ongoing sedimentation in the Bot Estuary. However, should the Bot Estuary be breached to frequently, e.g. annually over a 5-year period, it will reduce breaching opportunities at the Kleinmond estuary. It is thus advised that at least every 2 to 4 years there be a period in which the accumulated water of the Bot/Kleinmond system be allowed to run out through the Kleinmond mouth (1 to 3 months at a time) to facilitate the scouring of deep channels and reduce sediment build-up at the Kleinmond berm.
	Type	**Yes/No**	**Motivation**
	Major flood events associated with severe flood damage	Yes	This is only an emergency when water levels in the estuary is high at the time of the flood
	Poor and/or unfavourable water quality	Yes	Low oxygen levels throughout the Bot system may be considered an emergency (e.g. levels consistently below 4 mg/l and/or stressed observed in fish populations but the situation must be verified by a qualified estuarine ecologist before the breaching can be approved) Low salinity levels (especially if low temperature is experienced/predicted at the same time) are pre-conditions for major fish kill. Artificial breaching will not be considered to flush polluted water out of the Bot or Kleinmond estuaries (which will pollute the nearshore).
	Fish kills	Yes	DFFE to determine if major fish kill can be remedied by breaching
	Hazadous spill	Yes	Breaching will only be considered if hazardous substances hold no risk to nearshore environment and the event is registered as a disaster. In the event of an oil spill at sea, the mouth(s) of the Bot/Kleinmond Estuary can be closed temporarily to prevent oil from entering the system.

INTEGRATED ASSESSMENT

The following breaching specifications need to be met before artificial breaching of the Bot Estuary can be considered (Table 3):

Table 3: Bot Estuary Breaching Specifications

Breaching considerations	Details		
Minimum breaching level (water level should be as high as possible before breaching)	>2.5 m MSL	Y	Level to MSL
	<u>1st & 2nd year after previous breach:</u> - Water level > 2.5m MSL and salinity =< 10 psu OR - Water level < 2.5m MSL, but breaching feasible and salinity =< 6 psu **<u>3rd year</u>** - Water level = 2.5m MSL - Salinity not considered OR - Consensus decision by breaching sub-committee and specialists should salinities <6 psu and catastrophe is imminent (e.g. mass mortality of fish) even though level has not reached 2.5m MSL **<u>4th year</u>** - If no breach has occurred for 4 years and breaching is feasible, breach. **While it is recognised that it is not always possible to determine the breaching criteria accurately across the system and that a certain degree of latitude may be require by the management authorities, it is especially important to adhere to these criteria in the 1st year after a breaching to ensure that too frequent breaching of the Bot Estuary do not occur at the expense of the Kleinmond system. Consideration should also be given to natural rainfall patterns, i.e. wet and dry cycles, which may cause annual breachings during "wet years" interspersed with extended periods of closed mouth conditions during "dry years". However, it is estimated that on average the Bot Estuary should be open every 2 to 4 years.**		
Optimum breaching period (if applicable)	01 May – 30 November Consideration should also be given the mouth state of the Klein system as evolutionary/genetic processes require that both system be open one to two time a decade. During extreme events, the Bot and Klein mouths needs to be open simultaneously, i.e. once in 10 years to ensure flow of genetic material between systems.		
Neap-spring breaching considerations	Preferably 3-4 days before spring tide, but priority should be given to wave conditions and water levels. Higher water levels generate greater outflow so this recommendation can be overruled to prevent significant seepage and evaporation losses.		
Timing of breaching	Breach 2 hours before high tide, or just after high tide (to prevent high waves from reclosing the opening), to maximize the outflow. Breaching at the Bot Estuary holds a risk for water fowl if the maximum outflow is at night. It is therefore recommended that the system be breached in the early hours of the day or at first light, so that maximum outflow can occur during the day.		
Consider safety of public during breaching	Breaching at the Bot Estuary holds a risk to public safety, e.g. surfers wanting to body surf standing waves, children and dogs falling in outflow channel. Care should therefore be taken with the general public to ensure their safety. Cordoning off the works area with the aid of red and white emergency tape will aid in keeping the public out of the area where breaching will take place. Ideally an official or security person must man the area in question. Temporarily close the designated area in circumstances that could pose a danger to the human life or property. This must be accompanied by appropriate signage.		
Breaching trench to	Excavated a deep and wide trench with backactor before breaching to maximize outflow.		

maximize outflow	
Location of the breaching position.	At the mouth of the Bot between Meerensee Resort and Rooisand Nature Reserve, within 300 m of the 2008 breach position. The location must be adjacent to the deep channel in the estuary and well away from dunes to prevent unnecessary sand entrainment.
Propose area of breaching position	
Estimate amount of sediment to be moved during breaching	Not applicable, as amounts vary significantly between breachings. It therefore cannot be determined in advance.
Disposal of sediment removed during excavation	The sand excavated from the trench should be stored on the banks adjacent to the trench
Mobilizing machinery and equipment on site during breaching	Equipment and machinery to be utilised in a breaching must be in be in a good state. Oil leaks are not to cause pollution. Care should be taken to ensure that earth moving equipment do not disturb indigenous vegetation of conservation worthiness on route to the excavation site. Bird nesting areas are to be avoided. Where possible existing access roads / tracks should be used. Once it has been established that a clear outflow channel has formed and breaching is progressing on its own momentum the earth moving equipment may be removed from the beach. Implement an appropriate control mechanism, such as erecting comprehensive signage with information of the launching areas and the associated dangers. Allow DFFE officials access to the designated area for the purpose of assessing and/or monitoring compliance with the conditions contained in the MMP and Maintenance Management Plan authorisation, at all reasonable times.

	Be responsible for all costs necessary to comply with these conditions unless otherwise specified. The municipality retains the management responsibility of the designated area, even though the applicant may grant permission to manage the designated area, on their behalf, to any competent contractor /service provider. Ensure that all users adhere to the local authority By-Laws relating to the designated areas. The legal requirements associated with the use of the designated area must be brought to the attention of all persons that are granted access to the designated area by the applicant (licensee) in terms of the conditions of this licence and the applicant shall take measures necessary to bind such persons to these requirements.
Water Quality considerations related to breaching	Salinity: < 10 psu in Year 1 and 2, < 6 psu after Year 2 See above in conjunction with water levels.
	Oxygen: < 4 mg/l in Bot Estuary (must be verified by qualified estuarine ecologist prior to approval of breaching (not a consideration for breaching of Kleinmond mouth as the cause of oxygen problems in that estuary can be addressed at source
	Ammonia: Currently not a consideration for breaching in this system
	Toxic substances: Currently not a consideration for breaching of this system
Ecological considerations	Birds: Breaching to be conducted between 1 May and 31 September where possible to not interfere with optimum breading seasons.
	Fish: Annual breaching per natural conditions. Two days before the breaching, responsible authority will issue notices and erect signs placing a moratorium on fishing until after the breaching and the risk to fish aggregations has subsided.
	Invertebrates: Annual breaching per natural conditions
	Plants: Annual breaching per natural conditions.

Table 4: Kleinmond Estuary Breaching Specifications

Breaching considerations	Details		
Minimum breaching level (water level should be as high as possible before breaching)	Natural level	N	Level to Mean Sea Level (MSL)
	It is recommended that the Overstrand Municipality Department of Environmental Management and CapeNature cooperate to police the berm at Kleinmond when high water levels may tempt local residents to artificially breach the Kleinmond.		
Optimum breaching period (if applicable)	Not a consideration at this system.		
Neap-spring breaching considerations	Not a consideration at this system.		
Timing of breaching	Not a consideration at this system.		
Consider safety of public during breaching	Not a consideration at this system.		
Breaching trench to maximize outflow	If the Kleinmond Estuary has not breached for 2 to 3 years and significant sediment build up have occurred (>3.0 MSL) consideration can be given to skimming the Kleinmond berm to 2.5 MSL to facilitate natural breaching.		
Location of the breaching position.	Not a consideration at this system.		
Estimate amount of sediment to be moved during breaching	Not a consideration at this system.		
Disposal of sediment removed during excavation	Not a consideration at this system.		
Water Quality considerations related to breaching	Not a consideration at this system.		
	Not a consideration at this system.		
	Ammonia: Currently not a consideration for breaching in this system		
	Toxic substances: Currently not a consideration for breaching of this system		
Ecological considerations	Birds: Not a consideration at this system.		
	Fish: Not a consideration at this system.		
	Invertebrates: Not a consideration at this system.		
	Plants: Not a consideration at this system.		

According to the new Environmental Impact Assessment (EIA) Regulations promulgated on 18 June 2010 in terms of the National Environmental Management Act 1998, the artificial mouth breaching may not commence without an environmental authorisation from the competent authority:

The infilling or depositing of any material of more than 5 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock from:

I. a watercourse;
II. the sea;
III. the seashore;
IV. the littoral active zone, an estuary or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever distance is the greater

but excluding where such infilling, depositing, dredging, excavation, removal or moving

I. is for maintenance purposes undertaken in accordance with a management plan agreed to by the relevant environmental authority; or
II. occurs behind the development setback line.

[Listing Notice 1, Activity Number 18]

Application for a special dispensation to implement the mouth management plan for a period of five years (at which time it will be subject to specialist review) is therefore required from DFFE in terms of the need for ecosystem maintenance.

RELEVANT AUTHORITIES

Table 5 lists the Key lead authorities involved in artificial breaching at the Bot Estuary.

Table 5: Key lead authority involved in artificial breaching

Management authority	CapeNature	
Advisory Committee	Bot River Estuary Forum (BREF)	
Authorisation (breaching / emergency)	DFFE	
Lead authority	**Breaching sub-committee**	**Minimum consultation In case of Emergency**
Overstrand Municipality (Environment Management and Disaster Management sections)	✓	✓
District Municipality (Environment Management and Disaster Management sections)	✓	✓
DEA&DP	✓	✓
DFFE	✓	✓
Department of Water and Sanitation	✗	✗
CapeNature	✓	✓
SANParks	✗	✗

CSIR	✓	✗
Non-Governmental Organisations	✓	✗

The decision to artificially breach will be made by a Breaching sub-committee comprising the Overstrand Municipality Environmental Manager, BREF Chairperson and the CapeNature Senior Manager: Marine and Coasts Operations, Landscape Manager following consultation with at least two members of a team of ecological specialists from the CSIR, Nelson Mandela University and DFFE: Inshore Fisheries Research and DFFE: Estuaries Management. These lead authorities are important role players with respect to emergency situations and administer their relevant empowering provisions (Disaster Management Act 2002, NEMA 1998, and the Integrated Coastal Management Act 2008).

Data on water level, berm height, salinity, as well as water quality parameters where feasible, will be collated by CapeNature and the specialists team.

Once the Breaching sub-committee has decided that an artificial breach must occur, the Disaster Risk Department of the Overstrand Municipality (in conjunction with CapeNature), shall be responsible for overseeing the breaching activities.

The BREF representative will be responsible for feedback to BREF members.

Disaster Management	Authority/Organisation	Status
Early warning system	South African Weather Services (weather)	No
	DWS warning system (flow/water levels/dam safety)	No
Disaster Management Plan	Municipality	Yes
Approved Maintenance Management Plan	CapeNature	Yes

Planned mouth breaching procedures

Two types of breaching are distinguished for the Bot Estuary, namely (a) Planned artificial breachings undertaken according to the MMP (and authorised Maintenance Management Plan) and (b) Emergency breaching (e.g. to avoid danger of flooding). Each type is briefly discussed below with breaching procedures illustrated in the form of flow charts (Figures 1 and 2).

Planned mouth breaching procedures

The Overstrand Municipality is responsible for the operational aspects of the Bot/Kleinmond Estuary MMP. Although they may delegate this function they are ultimately responsible for the correct implementation of the breaching policy. To better formalise institutional arrangements, it is recommended that the already established Breaching Sub-committee be incorporated as a formal institutional structure under the Municipal Coastal Committee. CapeNature (or its delegated structure) is required to co-ordinate the Breaching Sub-committee, which includes:

- Convening Breaching Sub-committee meetings;
- Recording the minutes of the Breaching Sub-committee meetings;
- Distributing relevant information to the Breaching Sub-committee members;
- Making the post-breaching incident report of the Breaching Sub-committee available; and
- Sharing details of the process followed with Estuary Advisory Forum (if time permits).

CapeNature is also responsible for continuous monitoring of the conditions in the catchment when water levels become elevated (>1.5 m MSL). Communication between the different role players, i.e. the local municipality, CapeNature and key authorities (stipulated in Section 4), should take place at a regular basis. This can be done through an advisory committee/forum meeting or as email communications among these parties summarising critical aspects. The day-to-day monitoring should include the following aspects:

- Actual and predicted rainfall in the catchment;
- Water levels in the estuary and its rate of increase;
- Height and width of the sand berm at the mouth;
- Actual and predicted wave conditions;
- Availability of equipment to breach the mouth;
- Water quality conditions (where and if applicable); and
- Biotic responses to elevated water levels (e.g. fish aggregations at mouth, formation of algal blooms, die-back of macrophytes, bird nesting behaviour).

Once the breaching criteria (see Table 3) is met, the decision to artificially breach will be made by the Breaching Sub-committee (See Table 5 for list) comprising presence of, as a minimum, the Overstrand Municipality's Environmental Manager, the BREF Chairperson and the CapeNature Marine and Coasts Operations and Landscape Manager in consultation with at least two qualified estuarine ecologists (e.g. from the CSIR, DFFE: Inshore Fisheries Research and DEA: Estuaries Management). Note, that while the Breaching Sub-committee is tasked with executing the approved Maintenance Management Plan, it should be recognized that an estuary mouth is highly dynamic and unforeseen events may require special management actions. In such an event, additional verbal (followed by written) authorisation may be required from the authorising authority (i.e. DFFE). A flow chart of the procedures for a planned mouth breaching is presented in Figure 2.

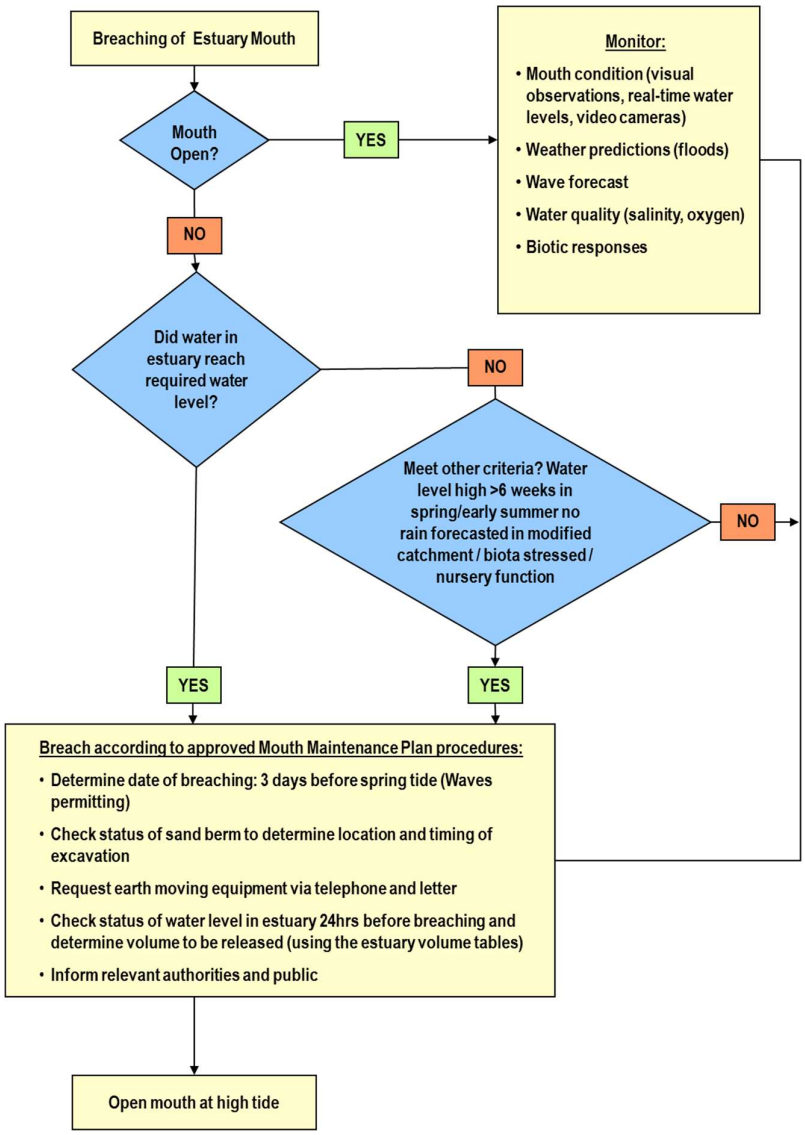


Figure 2: A flow chart of the procedures for a planned mouth breaching

Once the Breaching Sub-committee has established that the relevant criteria have been met and that artificial breach must occur, the Disaster Risk Management Department of the Overstrand Municipality (in conjunction with Cape Nature) shall be responsible for overseeing the breaching activities.

The Disaster Risk Management Department of the Overstrand Municipality, upon request from CapeNature, is responsible for the following:

- Ensuring the availability of earth moving equipment on day of breaching;
- Establishing the exact location of the breaching channel;

- Verifying that the sandberm at the mouth is high enough above the water line so that there is no risk of “fluidization” of berm sediment (i.e. turning to quicksand when breaching starts) and become a hazard to the operator and equipment;
- Deploying flags and signage to warn the public of the safety risks safety; and
- Breaching of the estuary mouth.

Finally, CapeNature as the RMA is responsible for the compilation of a Breaching Incident Report to be submitted to DFFE within 14 days of the breaching activity (see Section 8 for more detail on the report).

Emergency

Emergency conditions could develop when an estuary mouth is closed/constricted and severe rainfall occurs in the catchment causing a large flood. Alternatively, they could also develop at the (largely unlikely) event of a break of the dam wall. Constant monitoring of the conditions in the catchment is required when emergency conditions develop. Communication between the different role players, i.e. the local municipality, CapeNature and key authorities (DFFE and DM) involved, should take place, if time is available, to monitor the situation. Included in the monitoring are:

- The actual and expected rainfall in the catchment.
- The water level in the estuary and its rate of increase.
- The height and width of the sand berm at the mouth.
- The actual and predicted wave conditions.
- The availability of equipment to breach the mouth on short notice.

A flow chart for the procedures to be followed during emergency breaching is provided in Figure 3. Such breachings should be undertaken in the swiftest manner possible and in most cases the Disaster Risk Department of the local municipality will be the responsible authority. While breaching should be conducted according to an Estuary Mouth Management Plan Mouth and an approved Maintenance Management Plan, some of the general breaching principals may be waivered under such emergency conditions to ensure an expedient breaching.

While most emergency breachings are usually linked to river floods, Table 4 lists some additional events that can trigger an emergency mouth breaching in the case of the Bot Estuary.

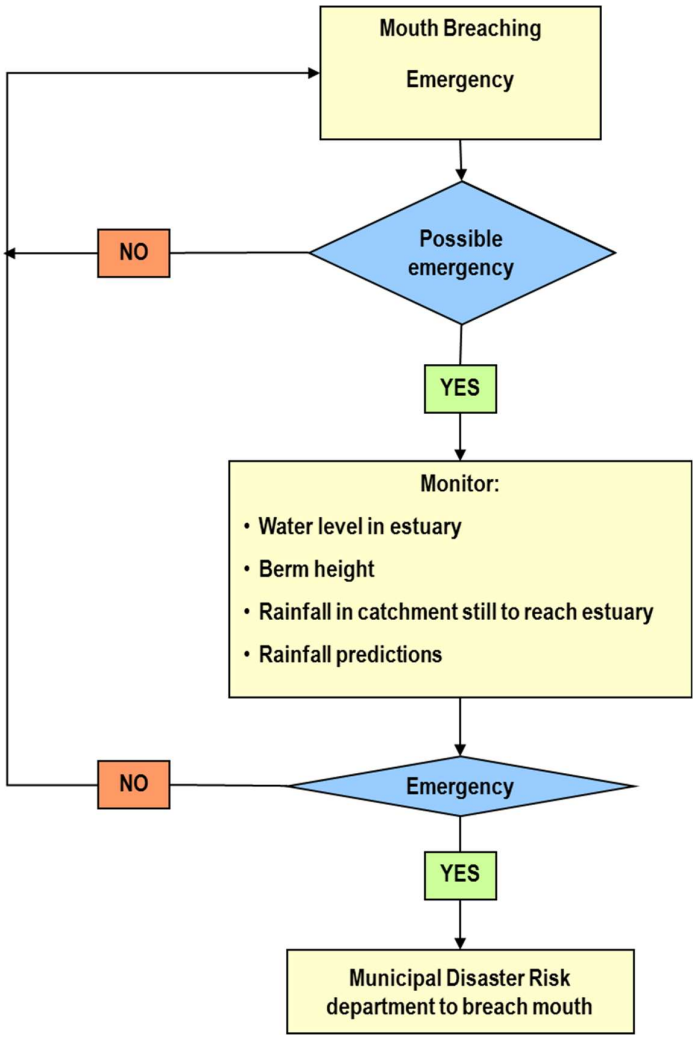


Figure 3: A flow chart of the procedures of an emergency breaching plan

MONITORING PROGRAMME

The following monitoring programme is required to be able to perform artificial breaching in a responsible and effective manner (Table 2):

Table 2: Monitoring programme for Bot Estuary relating to artificial breaching

MONITORING ACTIONS	FREQUENCY	LOCAL REQUIREMENT - YES/NO	AGENCY RESPONSIBLE
Weather forecast	Period leading up to breaching	Yes	SA Weather Services
Water levels	Continuous	Yes	Botvlei (G4R003) (1979-2016)
River inflow data	Daily	Yes	DWS gauge

Bathymetric surveys	Every 3 years	Yes	CapeNature
Salinity (quarterly)	Monthly (and just before and after breaching)	Yes	DWS & CapeNature
In situ water quality measurements (e.g. oxygen)	Monthly	Yes	DWS & CapeNature
Berm levels	Monthly (and just before breaching)	Yes	CapeNature
Photographs	To be arranged between authorities before, during and after breaching	Yes	CapeNature & Overstrand Municipality
Visual observations on estuarine vegetation (e.g. checking for inundation of salt marsh, reeds & sedges and occurrence of nuisance algal blooms)	Quarterly (and just before breaching)	Yes	CapeNature
Visual observations on Invertebrate behaviour (e.g. checking for invertebrate kills)	Quarterly (and just before breaching)	Yes	CapeNature
Fish surveys (distribution, abundance) Visual observations on fish movement and behavior (e.g. recruitment, aggregations, fish kills)	Bi-annually	Yes	DFFE
Co-ordinated Waterbird Counts (CWAC)	Bi-annually	Yes	CapeNature

REPORTING

Following a breaching a Breaching Incidence Report needs to be compiled by the CapeNature and submitted to DFFE within 14 days of the activity. This report should contain as much as possible information on the motivation for breaching and the process followed.

In addition to the Breaching Incidence Report, the managing authority needs to compile an Annual Breaching Report that summarises information on all mouth manipulation activities during a year, including a review of ecological responses and consequences to human well-being and safety. The Annual Breaching Report needs to be presented to all Interested and Affected Parties (I&AP) (relevant authorities and civil society) to communicate progress with the implementation of the MMP. Such feedback sessions provide the opportunity for a critical review of current breaching practises and discussions on possible future improvements to the MMP. The Annual Mouth Breaching Report will also serve as a national reporting document.

Breaching Report

Table 3 below summarises the minimum content of a Bot Estuary Breaching Incidence Report. The initial report should be complied within about 14 days of the breaching activity, with data gaps (e.g. duration open) addressed after mouth closure.

Table 3: Content of Bot/Estuary breaching report

ACTIONS	REQUIREMENT	AGENCY RESPONSIBLE
<u>Met-ocean information</u> • State of the tide (spring-neap/ high-low tide) • Sea conditions (calm/stormy)	Yes	CapeNature
<u>Estuary Information</u> • Water level from DWS (and volume) before breaching • Maximum outflow rate during breaching calculated from water levels and surface area of system • Outflow duration (from water level graph) • Lowest water level achieved after breaching (from water level graph) • Did flooding problems arise before or during the breaching? If so, quantify these problems. • Could measures be taken to prevent such problems in the future? For example by protection of low lying properties. Distinguish between short-term and long-term measures. • Could further problems arise by design of new developments at too low levels? • Date since last reaching • Estimate volume of sediment removed and indicate how sediment was disposes (e.g. left on berm at mouth). Were there problems with septic tanks before the breaching? If so quantify	Yes	DWS, CapeNature & Overstrand Municipality
<u>Location of breaching channel</u> • Align with historical position of channels • Reduce channel length • Estimated volume of sediment excavated during the breaching	Yes	CapeNature
Period for which the mouth stayed open	Yes	CapeNature
Bathymetric surveys before breaching events to establish erosion /deposition rates.	Yes	CapeNature
Salinity measurement before and after breaching	Yes	CapeNature
Macrophyte conditions	No	
Fish recruitment survey	Yes, in summer after breaching	DFFE
Avifuana counts (CWAC)	Yes	CapeNature
Other		
<u>Assessment record compiled by:</u> Name: Organization: Date: Contact details:		

Feedback on breaching activities

Table 8 below summarises the minimum information required as evidence of feedback breaching activities to the relevant authorities and stakeholders. Such report back sessions should be held at least once a year to ensure that the correct breaching procedures are being followed and that additional interventions are not required.

Table 8: Minimum information to be captured at breaching feedback sessions

ACTIONS	REQUIREMENT -
Responsible agency /authority	CapeNature
Place & Workshop venue	
Date	
Meeting/committee/workshop participants (attached attendance register)	
Workshop chaired by	
Key lessons learned that could assist with future breaching	
Material presented at meeting (including copies of presentations)	

1. REFERENCES

Turpie, JK and Clark, BM 2007. The health status, conservation importance, and economic value of temperate South African estuaries and development of a regional conservation plan. Report to CapeNature.

Van Niekerk, L, van der Merwe, JH and Huizinga P, 2005. The hydrodynamics of the Bot River Estuary revisited. Water SA 31 (1): 73-86

Von der Heyden, S., Toms, J.A., Teske, P.R., Lamberth, S. & W. Holleman. 2015. Contrasting signals of genetic diversity and historical demography between two recently diverged marine and estuarine fish species. Marine Ecology Progress Series 526: 157–167.

Willis, JP 1985. The bathymetry, environmental parameters and sediments of the Bot River Estuary, S.W. Cape Province. Transactions of the Royal Society of South Africa 45: 253-283