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ENVIRONMENTAL AND INSTITUTIONAL PRE-CURSORS TO NATURAL DISASTERS: A CASE STUDY OF THE JUNE 1998 LAKES ENTRANCE FLOODS

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ABSTRACT

The coastal township flood hazard examined in this paper has developed over the last three decades. It amounts to an environmental problem that is "owned" by no one, however clear institutional pre-cursors can be identified. Clearly, there is lack of integration between catchment and coastal management responsibilities. Specifically, it is argued that, since the 1970s, vulnerability to flooding at Lakes Entrance (Victoria, Australia) has increased as total influent streamflows to the extensive coastal lagoon system known as Gippsland Lakes have decreased. The explanation for this apparently anomalous situation refers to concurrent reduction in the power of the ebb tide to scour the flood tide delta sand accumulated in the Reeves and Entrance Channels. By late June 1998, net accretion on the delta was enough to divert waters of a comparatively minor flood event across the low-lying Lakes Entrance CBD, causing economically significant flood damages. Similar rainstorm patterns are bound to occur in the future. The biggest failure in data and information integration refers to the isolation of the port authority from deliberations about catchment management. Given the nature of the powers, responsibilities and the institutional traditions of Australian port authorities, this situation is likely to be found in other townships close to coastal lagoon entrances.

1. INTRODUCTION

Water-catchment management agreements between the Commonwealth and the States of Australia reflect the nature of public policies that refer to environmental sustainability. As with all public policies formulated in the information age, the value of adopting IT-based audit paths has been recognised. Specifically, the catchment management policies have been supported through audited revenue streams from the Commonwealth. Dispersal has been through various public-sector agencies under corporatised management, the most notable in Victoria being the Catchment Management Authorities (CMAs) and the Coastal Management Boards. Respectively, the objectives refer mainly to river health and environmental sustainability, and to maintaining coastal stability. However, mitigation of natural hazards must be part of the concern, if only for the sake of monitoring changes in terrain and community vulnerability to hazard that accrues as a result of changes in the pattern of resource use. Thus, for instance, land-use planning schemes forbid residential development on floodways and slopes vulnerable to land-slip. Landcare projects under CMA supervision include river-bank restoration works and identification and mitigation of land uses that promote water quality degradation, and the Coastal Boards will always be alert to illegal sand mining/extraction, and land clearing that would promote sand blow-out.

Together, it is to be supposed, the Local Government Authorities in administering the land-use planning scheme, and the Coastal Management Board, in coordinating coastal and catchment management activities, and the Catchment Management Authority in promoting water quality improvement, will be in consultation in ways that are evolving towards the transition between the 'Management Plan approach' to the 'Action Plan approach' to environmental management [1,2]. The need to build stakeholder consensus is implied.

Coastal lagoons pose a particular challenge to coastal managers and associated stakeholders. Lagoon hydrology is a function of the volume of the tidal prism (determined by tidal range and size of inlet between the sea and the coastal lagoon) and the volume of the in-flowing river water [3,4,5,6]. A seasonal rhythm may be imposed on whatever balance is attained between these two flows. Inlet channel dredging will usually initiate a new balance, as will catchment water diversions of one kind or another. In that coastal areas are well populated and host high land and property values, much economic development is to be expected along with a progressive transition from resource-based to user-based approaches to environmental management.

It must be acknowledged that prior to the evolution of power and influence for any of the above-mentioned agencies, the great power of the Ports Authority/Authorities of Victoria over the port areas were well established. In relation to environmental management (dredging in particular), ports authorities (subject to obtaining any required permit, consent, or other authority) were and still are empowered to: a) alter, cleanse, dredge, scour, straighten and improve the bed of any river or sea-bed in port waters, and; b) reduce or remove any banks or shoals within any such river or sea-bed [7]. Insofar as port development and maintenance can progress without reference to the overall environmental equilibrium of the hinterland, estuary or nearby ocean and coast, a port authority can remain aloof from consensus building among natural resource stakeholders. Institutional/corporate traditions will refer to the great powers that port authorities hold in these terms. Perhaps it is only a realisation that port-side citizens have become exposed to significant hazard because of failure to establish integrated coast and catchment management that will promote the inclusion of port authorities in consensus building.

2. THE GIPPSLAND LAKES ENTRANCE AND THE LAKES ENTRANCE TOWNSHIP

The township of Lakes Entrance has developed from beginnings dating to the mid-1800s, when a small township by the name of Cunninghame was established on the shores of a channel then known as Reeves River [8]. This channel (now known as Cunninghame Arm) is part of an extensive coastal lagoon system known as the Gippsland Lakes (refer Fig. 1). These 'lakes' span an area of approximately 400 km^2, with seven major river systems providing streamflows to the lagoon system from a contributing catchment of some 20,000 km^2.

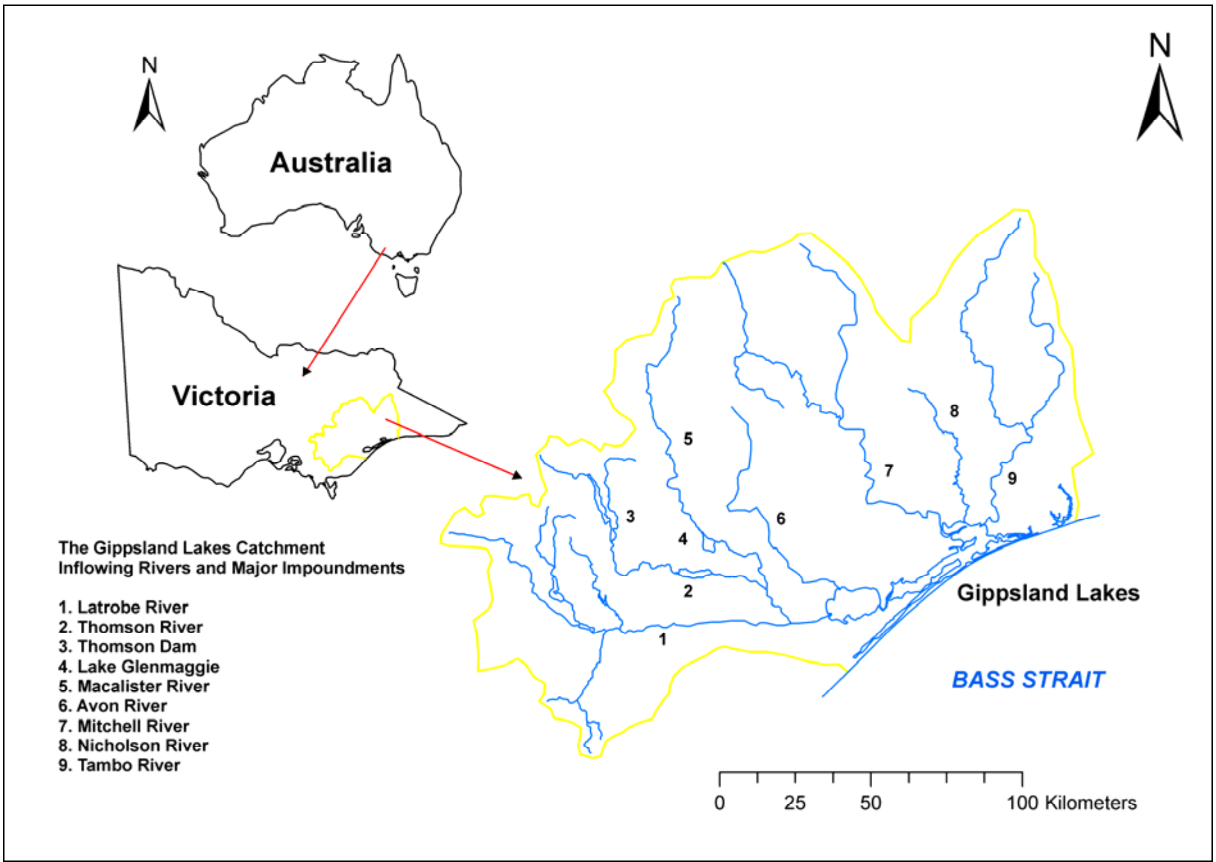

Fig. 1 The Gippsland Lakes catchment, Victoria, Australia

In the mid 1800s, coastal shipping was used to supply East Gippsland townships on the shores of the Gippsland Lakes. Vessels would sail into the lakes from Bass Strait via a natural entrance situated near Red Bluff. This ephemeral entrance migrated along the Ninety Mile Beach according to where the latest sandy barrier weakness had evolved. These inlets frequently became un-navigable during extended periods of reduced lakes influent regimes and periods of steady beach-building. The need for construction of a permanent artificial entrance to the Gippsland Lakes in support of the continued development and supply of the East Gippsland region was long debated during the mid to late-1800s [8]. Ultimately, an artificial entrance to Bass Strait, situated near Jemmies Point, was built/excavated and was opened in June 1889. Streamflows discharging to Bass Strait from unregulated influent Gippsland Lakes rivers augmented ebb-tidal flows at the artificial entrance, causing ebb-flow to dominate for extended periods. This dominance caused tidal scouring in the navigation channels, and thus navigable channel depths were maintained without special effort on the part of the port authority of the day.

The on-going need to determine the position and depth of the Reeves and Entrance navigation channels (refer Fig. 2) at the artificial entrance area saw frequent hydrographic monitoring of the channel systems. The need for such monitoring is sustained in the present by the use of Lakes Entrance as a major port by a thriving commercial deep-sea fishery, which is one of the largest in Australia. The township of Lakes Entrance has also developed into a popular tourism/recreational destination, with high value urban infrastructure being positioned in low-lying areas of the township adjacent to the shorelines of the Gippsland Lakes (refer Fig. 3).

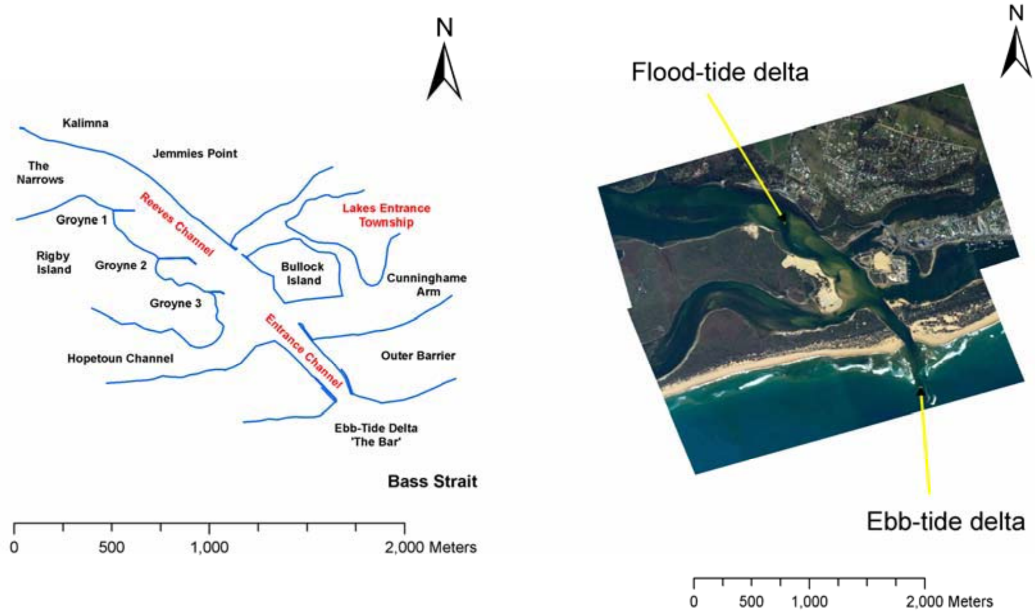

Fig. 2 The Reeves and Entrance Channels and the Lakes Entrance township, showing locations of the flood and ebb-tide deltas

3. THE 1998 GIPPSLAND LAKES CATCHMENT FLOOD EVENT – DESCRIPTION AND ANALYSIS

In June 1998, a heavy rainfall event (for example, in the order of 284.6 mm in 24 hrs, at Club Terrace, East Gippsland, 24 June 1998) [9] in the easternmost sections of the Gippsland Lakes catchment produced heavy flooding at Lakes Entrance. The rainfall event that was largely confined to the catchments of the unregulated eastern rivers (Tambo, Nicholson, Mitchell), which are situated closer to the artificial entrance area than the now highly regulated western rivers (Thomson and Latrobe).

Rooney [10] relates that during this event (June 22-24, 1998), heavy sustained rain over Gippsland was caused by the development of an intense low pressure system near the coast of New South Wales. This low pressure system displayed the typical characteristics of a Type 2 Australian East Coast Cyclone [11] and moved south along the coast from NSW into the East Gippsland region. Research by Tan *et al.* [12] found that streamflows from eastern rivers dominated Gippsland Lakes inflows over the course of this event, contributing a combined flow of 320,000 ML/day.

Fig. 3 Low-lying areas of the Lakes Entrance township (containing Lakes Entrance CBD and high-value real estate), adjacent to the Cunninghame Arm (formerly Reeves River). (Source: Wheeler, March 2005)

In attempting to escape through the artificial entrance to Bass Strait (refer Fig. 4), floodwaters which were generated from this rainfall event were retarded by an accumulation of flood-tide delta sands in the Reeves and Entrance Channels. This sand accumulation (over the period December 1889 – January 1998) has been documented through the development and analysis of three-dimensional digital elevation models derived from the hydrographic chart archive by Wheeler [13,14] and Wheeler and Peterson [15,16]. Analysis of environmental conditions prevailing at the time of the June 1998 floods reveals that floodwater levels were sustained not only by channel constriction, but by a convergence of what Tan *et al*.[12] label as environmental forcings (dominated by streamflows, but modified by tides, winds and atmospheric pressure gradients).

Fig 4. Floodwaters discharging to Bass Strait via the Entrance Channel, June 1998. Source: East Gippsland News, Bairnsdale, Victoria

Tan *et al*. [12] relates that the highest water levels for the past 25 years at Lakes Entrance (+1.2 m AHD) were experienced during the June 1998 flood event, and water levels of above 0.8 m AHD were sustained for a period of three days. Further, and as McMaster [17] relates, the water level reached this maximum height (+1.2 m AHD) when the peak of the incoming spring tide met the outgoing floodwaters on the evening of 24 June 1998. Thus, June 1998 floodwaters innundated low-lying areas of the Lakes Entrance township, in the process causing much damage to urban and business infrastructure. Since this time, development of high value urban infrastructure has increased in the area previously affected by flooding. Whilst any new construction plans referring to areas classed as 'subject to innundation' are subject to building regulations that specify minimum building height above the Australian Height Datum (AHD) [18], already established properties remain at vulnerable elevations.

Digital capture and analysis of post-Gippsland Lakes flood event hydrographic datasets (for July 1998, May 1999, July 2000 and January 2005) for the Entrance, lower Hopetoun and Reeves Channels (e.g. see Wheeler [13,14]) allows the extent of post-event bathymetric change to be visualised and quantified (refer Table 1). Volumetric comparison (of January 1998 and 2005 digital elevation models) shows that by January 2005, the flood-tide delta was even more voluminous than before the 1998 floods (refer Fig. 5 and Table 1).

Vulnerability to future flood events at Lakes Entrance can be better assessed if the nature and relative significance of the combined environmental forcings are known. Most readily documentable in these terms is information on the nature and persistence of channel infilling under current catchment and coastal management regimes. It is clear that such a combination of forcing factors can re-occur in the future, and that the only factor which might be readily reversed is the net increase in volume of the flood-tide delta.

Table 1. Net estimated Reeves and Entrance Channel sediment volumetric change figures

Dates of DEM comparison	**Estimated sediment volumetric gain/loss (m^3)**
January-July 1998	**-169772**
July 1998-May 1999	**188671**
May 1999-July 2000	**-14679**
July 2000-January 2005	**92289**
January 1998-January 2005	**107591**
August 1975-January 2005	**708612**

Source: Wheeler [13,14]; Wheeler and Peterson [16]

4. DISCUSSION

Research detailing sediment volumetric change and bathymetric visualisation for the period 1889-2005 by Wheeler [13,14] and Wheeler and Peterson [15,16] shows that sediment accumulation in the Reeves and Entrance Channels has been inexorable since 1975 (refer Table 1). Such morphometric change refers to a reduction of catchment streamflows due to water diversion schemes (in particular, the Thomson Dam and the Macalister Irrigation District), and to a reduced catchment rainfall trend. It is interesting to note that Rosenfeld [19] has published research results suggesting that the falling rainfall trend may be due to aerosol cloud pollution from up-wind urban and industrial sources (e.g. from Melbourne and Adelaide), which can alter rain-producing processes. Falling rainfall trends have been noted in such situations in other parts of the world (e.g. see Givati and Rosenfeld [20]).

These factors have combined to progressively reduce the streamflow augmentation of ebb-flows at the Gippsland Lakes artificial entrance area. That any reduction in ebb-tide velocity will affect sedimentation patterns in the vicinity of coastal lagoon or tidal inlet entrances has been noted by Bird [3], Davies [21], Bruun *et al.*[5] and Bruun and Gerritsen [22].

Another potential contributor to flood-tide delta accretion is sediment management regime changes, in this case after the deployment of the side-cast dredger *April Hamer* (refer Fig. 6), which has been almost permanently operational in the artificial entrance area since 1977. The dredging methods of the *April Hamer* are considered by Bird [23] to enhance flood-tidal delta nourishment within the inner channels. In sediment transport terms, the side-cast dredging operation promotes continued suspension of sediment throughout the water column. In these terms, sand dredging simulates the surf-zone suspension that takes place when high energy waves break. In both cases, the scope for flood tide sand entrainment to augment the volume of the flood-tide delta is enhanced.

Given future replication of the environmental forcings experienced in the Gippsland Lakes catchment during late June 1998, it is apparent that the continued accumulation of flood-tide delta sands as detailed in this paper

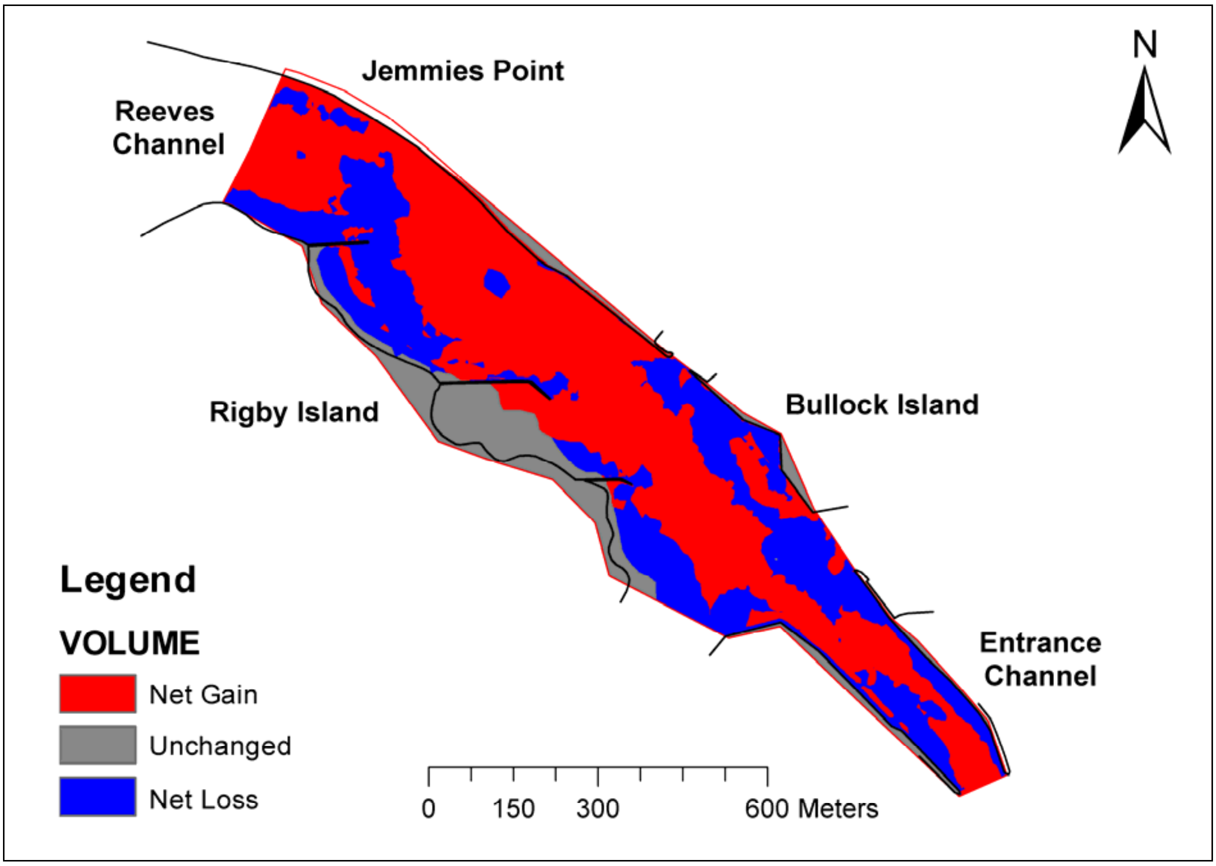

Fig. 5 Resultant volumetric comparison diagram of January 1998-January 2005 DEMs using 'Cut and Fill' analysis methods. Areas of estimated sediment gain/loss in the Reeves and Entrance Channels can be readily visualised using these methods

increases the risk of flooding at low-lying areas of the Lakes Entrance township. Such events may become more commonplace. For example, when viewed in the context of climate change and anticipated impacts, Gippsland Lakes catchment flood events may become increasingly prevalent. Climate change predictions by the CSIRO suggest that in Gippsland, extreme daily rainfall events may become more intense and frequent [24].

At present, the Gippsland Ports Authority has little power to influence catchment decision makers. As a result, the task of keeping channels navigable has become increasingly burdensome, and the risk of flooding has progressively increased. It is argued that the Gippsland Ports Authority could be given the equivalent of land use planning 'Referral Authority' status (e.g. see Eccles and Bryant [25]) so that each catchment planning decision that threatens to reduce streamflow inputs to the Gippsland Lakes (which would impact upon sediment management operations at the artificial entrance) is subject to Gippsland Ports approval. Alternatively, the Gippsland Coastal Board could intercede with the East and West Gippsland CMAs and other water users (such as Southern Rural Water and Melbourne Water) so that the mounting costs of port dredging can be covered and the flood risk returned to earlier levels. In any case, the dredging programme will have to be re-formulated, and the realistic cost of any new sediment management strategies will have to be met. Clearly there is much scope to integrate coastal and catchment management (e.g. Integrated Coastal Zone Management (ICZM) – see Cicin-Sain and Knecht [26]) in ways that will save such problems occurring in future.

Future risk management assessment frameworks by Gippsland Ports to comply with the Australian-New Zealand International Standards (AS/NZS 4360:2004; AS/NZS 4801:2001; AS/NZS ISO14001:1996; AS/NZS ISO14004) (e.g. see Gippsland Ports [27]) may need to consider inclusion (in a hazard risk register) of the potential flood risks due to sand accretion in the Reeves and Entrance Channels. 'Risk' in this context is defined by Shortreed *et al.*[28] as 'the combination of the probability of an event and its consequences', and is differentiated from the term 'hazard', defined by Kay and Alder [29] as 'an event or process with potential to harm people, property and the environment'. Risk levels could be monitored and determined on a regular basis using three-dimensional modelling and volumetric analysis of the type exemplified in this paper, and in greater detail by Wheeler [13] and Wheeler and Peterson [16].

Fig. 6 The Gippsland Ports side-cast dredger *April Hamer* during dredging operations at the ebb-tide delta in Bass Strait on an ebb-tide. Source: Wheeler (2005)

5. CONCLUSIONS

Two and three-dimensional DEM visualisation and ‘Cut and Fill’ volumetric modelling shows flood tide delta accretion in the Entrance and Reeves Channel has continued after the June 1998 Gippsland Lakes catchment flood event, despite the deployment of engineered sediment management regimes. This net sediment accretionary trend in the channels to January 2005 indicates that only restoration of the ebb-flow dominance (e.g. by restoring the streamflow input to the lakes from the catchment) and/or significant engineering input is likely to reverse this accretionary trend. Implications for future management refer to the need for reducing accretion, and for effective removal of flood-tide delta sediments, to facilitate future catchment floodwater escape through the Reeves and Entrance Channels to Bass Strait.

As Harvey and Caton [30] argue, a major problem that Australian coastal managers have faced is that different regions or zones have been treated in a *sectoral* rather than a *holistic* manner. The natural physiographic processes influencing the transport and deposition of sediment at the Gippsland Lakes artificial entrance area do not adhere to any ‘political boundaries’ drawn on catchment maps. Thus, future management of the coast in this highly dynamic area should not be considered in isolation from the remainder of the whole catchment.

It is suggested here that in the face of rapid change in coastal catchments and shore zones, a “communal” spatial information system should be maintained in such a way that scenario modelling with land-parcel resolution can be supported. Proper practice would mandate the corporate spatial database approach, with primary data custodians identified, metadata maintained, and access protocols regularly reviewed. The adoption of a time-series three-dimensional modelling approach has been shown in this paper to facilitate a much greater stakeholder understanding of coastal and catchment management issues, and to yield far more potential for future bathymetric monitoring than can the use of analogue hydrographic charts.

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