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SEA planning responses to estuarine cumulative effects of watershed urbanisation

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Abstract

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Introduction

There has been progress in recent years with the uptake of Strategic Environmental Assessment (SEA) in many countries along with advances in our understanding of Cumulative Effects Assessment (CEA). Instruments such as European Community (EC) directives, legislative reforms and non-mandatory approaches have encouraged a focus on the "bigger picture" of environmental policy-making and its contribution towards goals of sustainability. One dimension that requires attention is the degree to which the assessment of cumulative effects (CEs) and its incorporation within planning and environmental assessment frameworks has been successful. Despite well-established legal systems, sometimes with requirements to address CEs, systemic environmental problems still occur. While past progress has been made in building a base of theory and methodology for CEA, a transition from principles to practice has been slow. A constant theme in the CEA literature relates to the difficulties of working across jurisdictions, stakeholder groups, and different professions. CEA is now intentionally incorporated within SEA in Europe and Canada (Bragagnolo et al. 2012; Fidler & Noble 2013). In SEA and planning processes generally, methodologies do not often acknowledge the realities of political decision-making where addressing CEs adequately can challenge jurisdictional agendas and sensitivities. It is the decision-making context that is problematic in addressing CEs and it is often under-rated in our focus on methodologies and practice.

This paper uses an example of the incidence of two heavy metals, copper (Cu) and zinc (Zn), in the benthic sediments of Lucas Creek estuary, Auckland, New Zealand (NZ), to explore the relationship between strategic planning processes and Cumulative Effects Assessment (CEA). This paper begins by reviewing relevant international literature that examines the relationship between SEA, planning and CEA and outlines the planning regime in place, within which decision-making occurs. The research investigated the evolving response within district and regional plans between 1974 and 2014 to a growing awareness of Cu and Zn accumulation. The response was related in time to expanding scientific evidence of changing heavy metal concentrations, and to the receptiveness of the stormwater engineering and planning professions to the science. Concentrations of Cu and Zn have been related in the scientific literature to benthic organism health levels. There has been a growing understanding of the sources of these metals from land and marine uses that are in turn influenced by plans and policies.

CEA, SEA and strategic planning

The following section summarises recent international dialogue around the implementation of CEA and SEA within the context of sustainability and strategic planning. This review is ordered around three major themes: firstly, issues that arise from fragmentation by jurisdictions, tiers of governance and professions; secondly, issues of scale both spatial and temporal; and thirdly, issues of the decision-making context and implementation.

Fragmentation: Parkins (2011:1) states: "*Cumulative effects assessment is a process of scientific analysis, social choice, and public policy development, yet the linkages among these domains are often less than transparent*". There is a persistent disconnect between scientific and policy professions; spatial and infrastructural planning; transport, land use planning and water sectors; developers and statutory bodies; institutions; tiers of governance; and jurisdictions that block good intentions by nations to respond appropriately and effectively to arrest CEs (Masden et al. 2010; Weiland 2010; Duinker et al. 2013; Kristensen et al. 2013). In western Canada spatial planning is reported as little influenced by science

(Folkeson et al. 2013). CEA in Sweden is divided in separate environmental components such as plants, soil, and water (Folkeson et al. 2013). In the planning profession environmental outcomes may not be linked to science but rather they are predicted from expert opinion reported in interviews (Bragagnolo et al. 2012). It is also vital that environmental outcomes go beyond describing resultant physiochemical changes (that are not always of proven consequence) to demonstrating the direct links to Valued Ecosystem Components (VECs) and thresholds (Gunn and Noble 2009a, 2009b) defined to protect these.

The need for better integration of planning for transport, land use and the environment is still an issue. CEA could make a positive contribution to the assessment of transport projects for sustainable development (Tricker 2007; Folkeson et al. 2013). Despite the EU requirements there is little use of SEA in German transport planning (Weiland 2010) and it is not explicitly required in NZ transport planning (McGimpsey and Morgan 2013). Infrastructure developers are frustrated by the need to communicate with multiple fragmented planning jurisdictions, and natural areas in spatial plans may be ignored when locating infrastructure (Folkeson et al. 2013). Transport projects typically reach over large spatial scales.

Scales: CEA occurs in large spatial and temporal scales. Larger scales, or combined spatial and temporal scales, increase the complexity of assessment and management. The definition of a CE typically requires trend analysis from historical to predictive future states. The predicted future states may be linked through modelling to alternative scenarios of resource use or development. Links should be made between the science and spatial planning across a continuum of aquatic and land environments. At this point, choices can be made to proactively improve the environment rather than merely preventing harm (Savan and Gore 2013). The relevant spatial scale for CEA is dependent upon the character and distribution of natural processes (e.g. hydrology) that are carriers of the agent/affect accumulating. The largest spatial scales are seldom assessed *(Kristensen et al. 2013).* CEAs that merely consist of adding the effects of numerous similar projects across a region neglect the more complex and valuable task of defining *"regional limits to development and change and the ways in which specific projects and impacts are aligned or misaligned with regional development goals and objectives"* (Parkins 2011).

A watershed is a sensible spatial unit or scale for the assessment/management of water-born cumulative effects. Canada applies a socio-ecological systems approach to watershed management. Folkeson et al. (2013) call for a socio-ecological systems approach to understanding CE and managing them through strategic regional planning. Researchers (scientists) therefore need to express their results in a digestible format that can be incorporated into ordinary planning processes (Duinker and Greig 2006; Duinker et al. 2013; Folkeson et al. 2013). Watershed science is advancing but less is understood of the institutional capacity to manage CE (Kristensen et al. 2013; Sheelanere et al. 2013) because the jurisdictional fragmentation discussed earlier remains. CEAs for river systems in Canada are considered to be ineffective as a result of the disconnection between science, environmental monitoring and planning practice (Duinker and Greig 2006; Seitz et al. 2011; Kristensen et al. 2013). Ontario has delegated water resource management to regional watershed agencies. (In NZ watershed management can be integrated with regional planning under a single statute and institution.) However, in the Grand River Watershed, Ontario, there are uncertainties about the legitimacy of the watershed authority to act as a lead agency when other agencies also have water resource responsibilities (Chilima et al. 2013). The lead agency should ideally be the provincial government (regional or unitary council in NZ) or a government consortium (Sheelanere et al. 2013) taking responsibility for land use decisions.

Recognition of the need to operate at large scales and the disconnection between professional sectors led to the development of SEA, one of the rationales for which was to integrate environmental issues with planning and decision-making (Therivel and Partidario 1996). This type of integration occurred under the NZ Resource Management Act 1991 (RMA) (NZ Government 1991). Statutory requirements in the European Union (EU) (Bragagnolo et al. 2012) and Canada (Fidler and Noble 2013) have led to the incorporation of requirements for CEA into SEA and/or Sustainability Appraisals (SA) (Morrison-Saunders and Fischer 2006). SEA (that includes CEA) then becomes strengthened by its link to strategic planning typically undertaken by a regional regulatory body (Masden et al. 2010) in contrast to local project effects assessments that are the responsibility of developers. This appropriately embeds SEA within large scale planning opportunities (Elvin and Fraser 2012) in the earliest possible stages (Folkeson et al. 2013) of decision-making. To this end Canada has developed a methodology for Regional SEA (R-SEA) which places "*more emphasis on setting targets for regional environmental protection and development"* (Gunn and Noble 2009a, 2009b) than on identifying the most likely environmental outcomes for a region (Fidler and Noble 2013). R-SEA should "*establish a regional vision and bring focus to regionally significant environmental issues"* (Gunn and Noble 2009a). These issues are regionally relevant VECs influenced by regional drivers of change (Gunn and Noble 2009b; Duinker et al. 2013). When the regional scale is employed for CEA and SEA it improves opportunities for integration across tiers of governance and spatially across jurisdictions. For example, the Municipal Comprehensive Plan for Stockholm is a positive example of inter-level spatial planning (Folkeson et al. 2013) that, like the Proposed Auckland Unitary Plan (PAUP) (AC 2013a), provides these opportunities.

The decision-making context and weak implementation***:*** Despite attempts to ensure CEs are not ignored numerous countries continue to report that CEs remain unsatisfactorily addressed (United Kingdom: Masden et al. 2010; Germany: Weiland 2010; Canada: Gunn and Noble 2011; Duinker et al. 2013; Italy and England: Bragagnolo et al. 2012; Elvin and Fraser 2012; Sweden: Folkeson et al. 2013; U.S.A: Ma et al. 2012). The consideration of alternatives is reported (Bragagnolo et al. 2012) as a weak part of SEA. In England, CEs are frequently identified after the preferred resource use option is selected (Bragagnolo et al. 2012) leaving no opportunity for corrective action. The 'windows of opportunity' (Gunn & Noble 2009a) must be seized so that proactive changes can be made as early as possible to plans, policies and programmes (Gunn and Noble 2011; Elvin & Fraser 2012). The benefits of SEA – CEA integration remain a 'wish list' rather than a reality (Gunn and Noble 2011). Stimulating the political will to implement assessment outcomes is challenging. In this context the incorporation of CEA into sustainability assessment is considered by Morrison-Saunders and Fischer (2006) to disadvantage the environment as it can be traded off against higher priority economic and social objectives. Therivel and Ross (2007:384) note that: "…*few strategic decision makers will voluntarily constrain their activities so as to unilaterally limit cumulative effects".*

Problems facing CEA and SEA are universal in character and might be improved by better collaboration between science and practice, the exchange of experience between countries (Folkeson et al. 2013) and intentional working across sectors, jurisdictions and tiers of governance. This paper offers some NZ experience.

New Zealand and Auckland planning context

The RMA, along with local government and transport statutes, largely determine the planning context of urbanisation in NZ. Prior to the RMA there was no provision for consideration of cumulative effects in statutes such as the Town and Country Planning Act 1977 (TCPA) under which councils managed land use through regional and city/district planning schemes. Project-based Environmental Assessment (EA), termed Assessment of Environmental Effects (AEE) is a cornerstone of the RMA, the purpose of which is “the promotion of sustainable management of natural and physical resources” (section 5 (1)). It includes reference to CEs (Section 3). Some overseas commentators have regarded the effects-based land use planning system as an integrated approach to SEA and planning (Partidario, 1999; Sadler, 2001; Sheate et al. 2001). However, the mandatory AEE has had a much stronger profile than policy-based EA.

The focus for the analysis of policies comes from the implementation of section 32 of the RMA, which has recently been amended. The new sections do not change its overall purpose of ensuring rigour in plan decision-making through requiring a critical evaluation of the objectives, policies and methods of proposals. Criteria include their appropriateness, effectiveness, and efficiency for achieving the purpose of the RMA, potential alternatives, cost-benefit analyses (preferably quantified) of options, and the risks of acting or not acting when information is incomplete. Recent amendments require consideration of economic growth and employment opportunities in cost-benefit analyses.

The RMA establishes broad principles within which councils are free to develop their own approach to sustainable management on the basis of avoiding or mitigating adverse environmental effects. This has led to the development of the current effects-based planning system, with an emphasis on the management of environmental effects rather than on the prescription of activities. Under its planning hierarchy lower-level plans shall give effect to, and must not be inconsistent with higher-level plans (sections 62(3), 67(2) and 75(2)). National Policy Statements and National Environmental Standards inform regional plans, which inform district plans. The New Zealand Coastal Policy Statement (NZCPS) (MfE 2010) and National Policy Statement for Freshwater Management (NPSFM) (MfE 2014) are relevant to this analysis. Preparation of a Regional Coastal Plan is mandatory under the RMA and other Regional Plans are discretionary.

The NZCPS (2010) is a strategic document aiming to achieve the purpose of the RMA in relation to the coastal environment. Building on the first NZCPS (1994) it provides guidance on a range of issues across multiple aspects of sustainable management, including activities and development in the coastal marine area, and limiting unnecessary development, biodiversity and natural character, enhancement of water quality, minimising impacts from sedimentation and discharges of contaminants. An integrated approach and the precautionary principle are specified in individual policies; a need for monitoring, and compiling information in national databases are mentioned. Cumulative effects are mentioned specifically in relation to integrated management approaches and strategic planning; earlier drafts included a separate policy. Implementation methods or outcomes that can be used to measure success are not specified. Councils are required to give effect to the NZCPS through plans and policies.

The NPSFM 2014 (MfE, 2014) resulted from amendments to the NPSFM 2011 that responded to implementation difficulties, and concerns that objectives would not be achieved. One of its primary objectives is to safeguard the life-supporting capacity, ecosystem processes and indigenous species of fresh water in relation to land use, development, contaminant discharges, and freshwater usage. Regional councils must establish freshwater objectives, and set freshwater quality limits and environmental flows and/or levels for all fresh water bodies. "Freshwater Management Unit" does not necessarily mean watershed, though this is listed as the appropriate scale for the integrated management of freshwater, land, and coastal environments. Full implementation is required by 2025. The NPSFM is relevant to this discussion as most contaminants enter Lucas Creek from land uses via freshwater.

The development of an integrated and tiered approach to plan making in NZ means that there are some gaps in what SEA advocates might argue comprises an ideal SEA system. Given the integrated nature of EA and statutory planning in NZ, it is hard to distinguish between both sets of practices. SEA has become subsumed in the planning process and much less discernable as an activity.

Since 1991 there has been an increasing trend by councils to develop non-mandatory planning instruments to assist development of greenfield and peri-urban areas. The preparation of structure plans and integrated catchment management plans (ICMPs) outside of the statutory planning process has been a direct response to the effects-based nature of the planning system (Dixon, 2005). These plans then inform statutory planning processes. Councils use structure plans to establish how an area might be developed physically in relation to land uses and infrastructure. ICMPs are used by councils to manage water resources (particularly stormwater) and to a lesser extent land use on a watershed scale. These plans identify important characteristics of a watershed in which problems may exist or occur as a consequence of development and may also evaluate the consequences of alternative futures for the watershed, particularly on the hydrological cycle (ARC, 2005). The

2013 Auckland Council Regional Plan: Air, Land and Water - formerly titled the Auckland Regional Plan: Air, Land, Water (ARC 2001) (ALWP), requires the development of ICMPs.

In October 2010 seven city and district councils and the Auckland Regional Council (ARC) were dissolved and the Auckland Council (AC) established, as a Unitary Authority; new integrated planning documents were created. AC developed the Auckland Plan (AP) (AC, 2012), a spatial and strategic plan which sets out a vision for the city for the next 30 years, a longer timeframe than RMA plans. Its preparation was required, but it holds no weight under the RMA, unlike the Regional Policy Statement (ARC 1999). In 2013 AC released the PAUP, the “planning rule book” that will eventually replace 14 district and regional planning documents. Both the NPSFM and the NZCPS will influence policies and rules currently under formulation in the PAUP. Most of the PAUP is not yet operative and plans of the previous councils remain operative at the time of writing.

The case of Lucas Creek Watershed

Below, we examine the accumulation of Cu and Zn in Lucas Creek estuary, Auckland, as an example of the cumulative effects of development, in parallel with the evolution of the regional and district planning system. We assess its responsiveness and effectiveness as knowledge of cumulative effects advances.

Auckland’s population has grown rapidly to 1.42 million, and may double over the next 50 years. The metropolitan area is located on the shores of two harbours. Over recent decades, research has determined the gradual accumulation of fine sediments and toxins, including heavy metals in receiving environments. Fine-grained benthic sediment in estuaries and mid-harbour areas is the primary medium for accumulation, and increases of heavy metals in sediments and food chains have been correlated with the degradation of aquatic ecosystem health. Cu and Zn are focussed on as these are increasing most rapidly with urban intensification and rising traffic volumes. Zn is of particular concern in NZ as it is lost from vehicle tyre wear and galvanized corrugated iron- a dominant roofing material for the last century. Known Cu sources include brake lining wear and antifouling paint from marinas. Some older, mixed industrial and residential areas of Auckland exhibit higher benthic sediment Cu and Zn concentrations, representing (Mills et al. 2012) Lucas Creek's likely future condition if no corrective actions are taken.

Watershed Characteristics

Lucas Creek (Fig. 1) is a narrow estuary, six kilometres long, has fine benthic sediments and requires 11 tidal cycles to drain into the Upper Waitemata Harbour (UWH) (ARA, 1983a). This facilitates contaminant accumulation. The UWH in turn drains into the mid-section of the Waitemata Harbour, the benthic sediments of which have also been monitored for heavy metals (Green, 2006; ARC, 2009). The watershed covers 3774ha, and its 10 streams drain to Lucas Creek, dominated (61%) by the Lucas Stream and Oteha Stream sub-watersheds that up until 1980 were mainly rural. Urban development began in the predominantly pastoral Oteha sub-watershed in the early 1980s, by 2010 land cover included warehousing, a sports stadium, shopping mall, medium density housing (28%), light industry (24%) (Moores et al. 2012) plus wide bitumen roads and car parks. Impervious surfaces and traffic volumes have escalated and Auckland's northern arterial route divides the watershed. The Lucas Stream sub-watershed, which 30 years ago was covered in forest and pasture, has recently been partially urbanised (27%) (Moores et al. 2012) including medium density housing (13%). Urban stormwater is detained and treated in approximately 30 detention ponds, with at-source control raingardens and swales present in only the most recent commercial and recreational areas. The watershed will have on-going intensification of development and traffic (AC, 2013a).

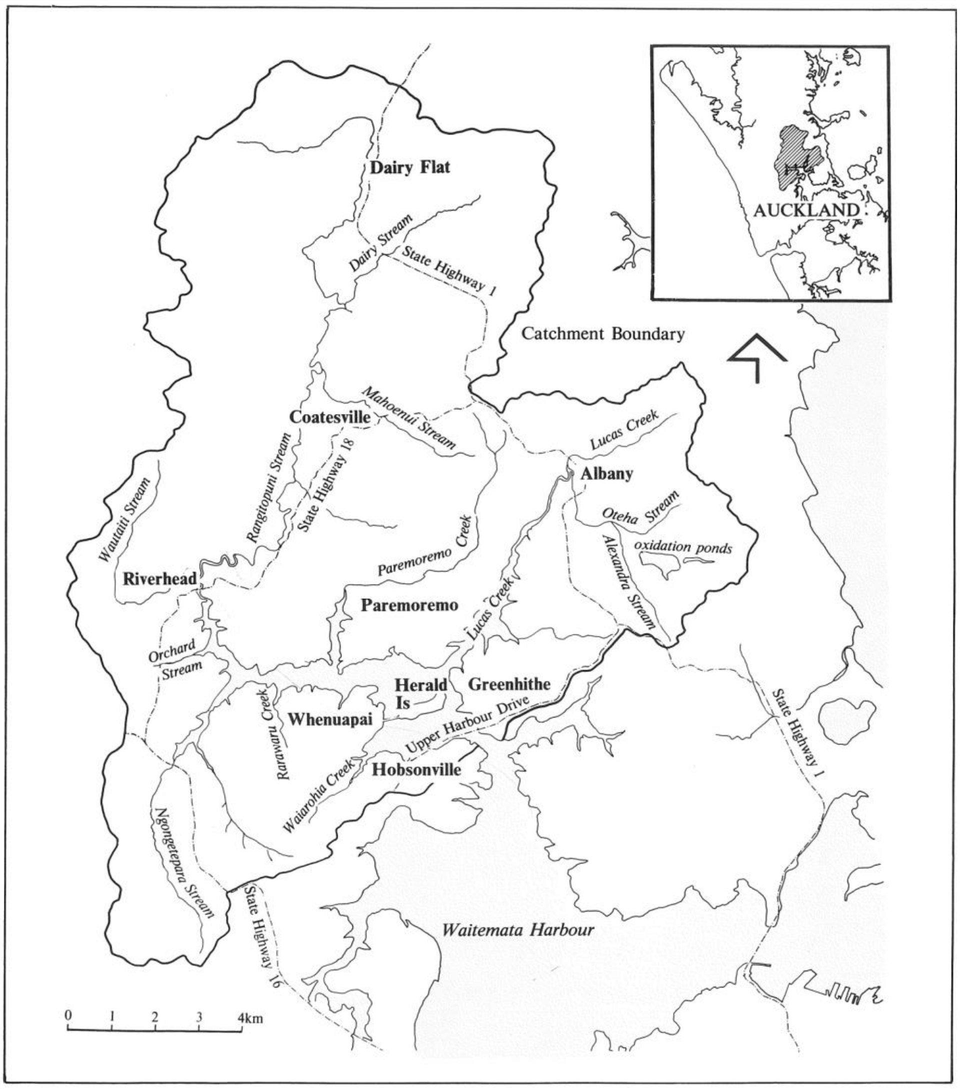


Fig. 1. Location of Lucas Creek in relation to Auckland and the Upper Waitemata Harbour

Succession of scientific evidence and plan responses

Table 1 identifies the planning and policy framework within which land development and water management has occurred over four decades. It shows how plans acknowledged and responded to the growing scientific evidence of cumulative estuarine contamination by watershed land use. The following text provides further analysis of evidence and plan changes in chronological order.

Knowledge and plan policy changes occurred first at the regional level to be adopted between two and eleven years later within local plans. Several key factors are seen to evolve with time: targeting specific contaminants rather than contaminants in general; capturing contaminants in watershed headwaters (at source of generation) as opposed to their discharge points; increasingly sophisticated devices to capture specific problem contaminants; requirements to use these devices not just ponds; and requirements to minimise and disconnect impervious surfaces where contaminants are generated.

Plans prior to reforms of the late 1980s did not fully address issues of environmental quality arising from urban development. General policies recognised the need for environmental safeguards. As early as the 1970s councils acknowledged the desirability of protecting streams, and planting riparian vegetation to filter contaminants.

The 1983 Regional Authority's Upper Waitemata Harbour Catchment Study (ARA, 1983b) shaped future planning policies. It signalled an awareness of the relationship between subdivision and loss of sediment with attached contaminants, although this was poorly appreciated beyond a small science community. Awareness of the ecological consequences

Table 1: Requirements or recognition in regional (✓) and local (★) plans of issues that influence the accumulation of Cu and Zn in Lucas Estuary. (Reg: Regional; ARA: Auckland Regional Authority; ARC: Auckland Regional Council; TCC: Takapuna City Council; NSCC: North Shore City Council; AC: Auckland Council.)

Years	1973 - 1983		1983 - 1994			1993-2003		2003-2010		2010-2014	
Regional✓ or local★ plan	**Regional**	local	**Regional**	local 1985	local 1994	**Regional**	local	**Regional**	local	Unitary: **Reg** + local	Unitary: **Reg** +local
Reference for Plan	ARA 1974	TCC 1979	ARA 1983b; 1988	TCC 1985- 1990	NSCC 1994	ARC 1999; 2001	NSCC 2002	ARC 2004a; 2010	NSCC 2002 plus Plan Changes (2003-2010)	AC 2012	AC 2013a
Protect These Ecosystems											
Riparian vegetation		★	✓	★	★	✓	★	✓	★	✓★	✓★
Main streams and estuaries			✓		★	✓	★	✓	★	✓★	✓★
Minor and main streams, esturaries											✓★
Recognise watershed connections											
Pollution in estuary is caused by landuse	✓		✓	★	★	✓	★	✓	★	✓★	✓★
Encourage watershed management			✓			✓		✓	★	✓★	✓★
Urban form determines waterway condition						✓	★	✓	★	✓★	✓★
Control runoff of contaminants											
Control sediment runoff to streams / estuaries			✓	★	★	✓	★	✓	★	✓★	✓★
Caution about runoff from roofs & roads.			✓			✓	★		★		✓★
Stormwater ponds/wetlands to trap contaminants			✓		★	✓	★		★		✓★
Control runoff from impervious surfaces.						✓	★	✓	★		✓★
Require and justify at-source capture of contaminants						✓	★	✓	★	✓★	✓★
Cu & Zn management											
Awareness of Cu & Zn build-up in Lucas Estuary						✓	★	✓	★		✓★
Relate sediment Cu & Zn to runoff from traffic and roofs						✓		✓			✓★
Define discharge concentration met by 'treatment train'											✓★
Watershed actions to avoid/ minimise Zn/Cu generation.											✓★
Rules consider cumulative effects for Cu & Zn											✓★

was strengthening. Before 1985 there was an emphasis on transitory water quality rather than persistent sediment contamination.

Little was known about Cu and Zn in Auckland estuaries and from which activities they came until the 1990s. This was a pivotal time as it was then that the evidence of heavy metal build-up in receiving water body benthic sediments developed some statistical reliability. Fortunately this coincided with the development of the proposed District Plan (NSCC, 1994) of North Shore City Council (NSCC). NSCC's creation amalgamated several minor local authorities, including Takapuna City Council. Policies encouraged the design of stormwater systems, to detain and improve stormwater quality, and to retain and remove contaminants to protect aquatic ecosystems and riparian margins. By the late 1990s riparian re-vegetation and stormwater ponds with wetlands were standard practice; the first installation of swales at the Albany stadium followed.

Regional monitoring programmes (ongoing) provided information on specific issues to support policy responses. The Regional Discharges Project (RDP) (early 2000s) addressed the issue of processing stormwater and wastewater discharge consent applications consistently across the region (ARC, 2003); additional sites subject to stormwater inputs are sampled.

By 2001, knowledge of the relationship between benthic sediment heavy metal concentrations and watershed land uses was stronger, in turn informing the development of the ARC's more complex ALWP (ARC 2001). It addressed issues of peak flow reduction, hydrological neutrality and the removal of solids, and represented a leap forward in terms of its comprehensiveness and regional leadership. New instruments developed by councils, such as

ICMPs and structure plans assisted in achieving a more integrated approach to land use and water management.

From 2002 successive changes to the North Shore City District Plan (NSDP) (NSCC, 2002) introduced requirements for the at-source capture of contaminants via devices installed as part of a treatment train. Swales and raingardens were constructed on occasional commercial streets and carparks

ARC's 2002 Variation 1 to the proposed Auckland Regional Plan: Coastal ('Coastal Plan') and proposed ALWP came as part of the RDP, and was a clear example of a regional level response that integrates science and policy across multiple strands of resource management. The Variation's three main purposes were:

> *"To align the stormwater and wastewater network discharge provisions of the Coastal Plan with…the more detailed and comprehensive regime…contained in the ALW Plan."* (ARC, 2002: 3)
>
> *"To introduce measurable Environmental Response Criteria for the urban coastal marine area into the Coastal Plan. The policy direction and support for doing this is contained within the Auckland Regional Policy Statement and the Proposed Auckland Regional Plan: Coastal."* (ARC, 2002: 16).
>
> *"To clearly state the outcomes (or performance measures) that stormwater and wastewater network overflow discharges are expected to meet."* (ARC, 2002: 3)

A depth profile of benthic sediments in upper Lucas Creek provides clear evidence of heavy metal accumulation over time to 2003 (Fig. 2). Data were averaged from nine sediment cores, not reaching pre-urban depths. Near-surface declines in concentrations were attributed to dilution by soils low in Zn and Cu from nearby earthworks (ARC 2003).

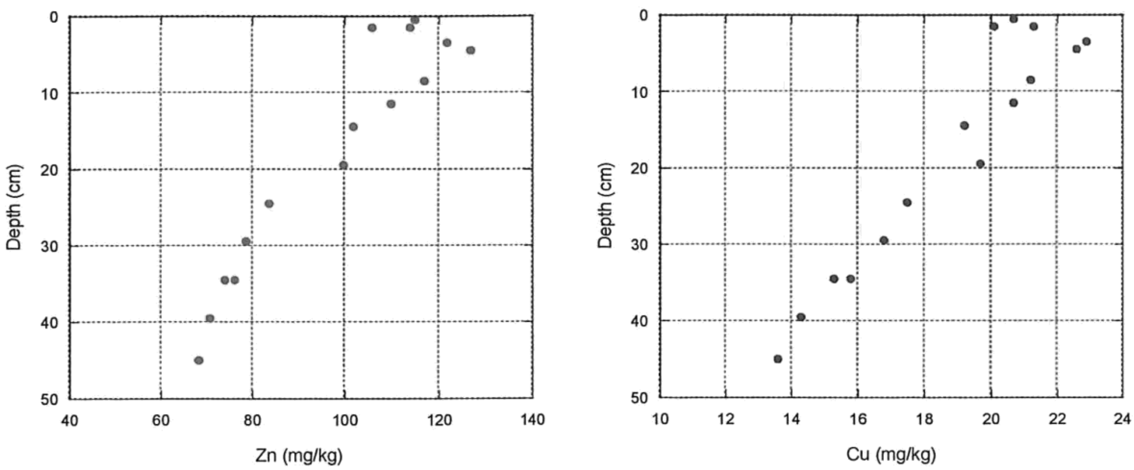


Fig. 2: Concentration profiles of Zn and Cu in the top 45 cm of sediment from a mudflat in upper Lucas Creek. Adapted with permission from Fig. 4.5, p. 26 (ARC, 2003).

Environmental Response Criteria (ERCs) (Williamson and Mills, 2009) were developed to assess the likelihood that benthic sediment contaminant concentrations are negatively affecting ecological communities (ARC, 2004b). The criteria are based on widely accepted international sediment quality numerical guidelines, to create a ‘green, amber, red’ colour system (ARC, 2003). The ERCs are applied differently depending on receiving environment classification. Settling zones, including Lucas Creek, are areas where most contaminants (~75%) settle out of suspension, and some level of ecological degradation is expected (ARC, 2004b). The total (<500µm) sediment fraction data are analysed but not the more sensitive <63µm fraction.

The first large-scale modelling work (2001 – 2004) on contaminant accumulation in the UWH and its individual sub-watersheds examined two development scenarios:

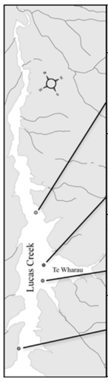
i. ‘Existing’: the then-current (2001) sub-watershed land use did not change; for Lucas Creek this consisted of rapid and substantial development.

ii. ‘Development’: modelling the sub-watershed’s expected future development. This was bracketed by a response envelope (RE) representing no stormwater treatment (worst case), and maximum attainable treatment (best case).

Both scenarios included partial sediment control (ARC, 2004c). For Lucas Creek under the ‘Development’ scenario, the predicted number of years from 2001 for contaminants to reach ERC thresholds were as follows (ARC, 2004c): Cu, Red- 28.9years (RE = 22.7 – 35.0 years), Zn, Red- 12.9 years (RE = 11.4 – 14.7 years).

A multivariate Benthic Health Model (BHM) (Anderson et al., 2002) was developed to rank the benthic community health of sites. In an initial analysis Lucas Creek ranked amber for both benthic community health and sediment contaminant levels (ARC, 2003). At this point in time modelling of land-use changes and their ecological effects were still separate, though partially linked through the ERCs. Both of these were regional level information gathering initiatives, but professional fragmentation persisted. Then by 2004-5, the UWH Ecological Monitoring Programme (ARC 2004c) began monitoring the ecological status of UWH locations (including Lucas Creek) predicted to be affected by watershed land-use changes. The BHM (Hewitt et al., 2005; Anderson et al., 2006; Hewitt and Ellis, 2010), now analyses macrobenthic community composition in relation to two contaminants, separately modelled: total sediment fraction Cu, lead (Pb) and Zn concentrations, and sediment mud content- a significant element in the cumulative effect of urbanisation on marine ecological communities. Table 2 details the Lucas Creek data (<500μm fraction assessed) from multiple benthic sediment monitoring programmes up to 2012.

Table 2; Cu and Zn concentrations (mean annual values) in Lucas Creek benthic sediments, data provided by Auckland Council, May 2014. Concentrations are shown in relation to ERCs (ARC 2004b).



Site name/ Grid ref. (NZTM)	Original ARC Monitoring Programme	Metal	Concentration (mg/kg) by year and sediment particle size fraction (μm) 1998		1999		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011	
			<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500	<63	<500
Lucus Upper X1749681 Y5931407	SoE: Contaminants in Marine Environments	Cu	15.6	19.1	16.9	21.9			18.9	26.2			23.6	20.0			23.7	20.3			15.2	20.7							17.7	19.3
		Zn	77.5	96.9	95.0	96.6			103.8	113.1			119.3	96.0			117.3	98.8			90.9	100.0							100.7	105.1
Lucus Te Wharau "LucU" UWH X1749374 Y5930448	Upper Waitemata Harbour Ecological Monitoring	Cu															19.3	18.5	19.7	16.8	20.0	15.0	18.1	17.3	18.4	19.2			18.3	14.2
		Zn															97.0	83.0	97.7	83.4	101.7	83.7	93.3	80.7	99.7	91.7			99.0	81.4
Lucus Te Wharau X1749230 Y5930235	Regional Discharges Project	Cu													18.3	20.7			18.0	19.1			16.3	24.0						
		Zn													100.3	92.4			98.0	97.0			94.0	110.0						
Lucas Creek "Luc" UWH X1748335 Y5929477	Upper Waitemata Harbour Ecological Monitoring	Cu															20.7	12.9	19.7	14.0	21.7	12.7	17.6	11.5	16.1	13.2			19.0	13.9
		Zn															117.7	87.3	110.0	111.0	122.7	110.0	101.7	97.7	93.3	90.7			104.5	99.3

ERC Status	Green	Amber	Red	ERC Status	Green	Amber	Red
Zinc (mg/kg)	< 125	125 - 150	> 150	Copper (mg/kg)	< 19	19 - 34	> 34

Mills et al. (2012) analysed multiple sediment chemistry datasets to assess temporal trends in contaminant concentrations. Monitoring programmes are linked to achieving Auckland Plan strategic directives on managing land to protect waterbodies and coastal areas. Overall, changes to spatial patterns and concentrations of contaminants were found to have been relatively small, and generally on the scale of (recent) modelling. They caution against applying too much 'real world significance' to the results, due to data quality issues and the relatively short time period, commenting that at least another decade of monitoring may be required to identify more robust trends. However recent data from Hewitt et al. (2012) indicate that benthic health remains poor, with some independent trends beginning to be detected.

The 2012 spatial Decision Support System (sDSS) model is a potentially significant tool for SEA application, designed to assess the impacts of urban development on receiving environments. The pilot process was not statutorily required, but was initiated by scientists to test land-use alternatives in order to inform plan making. The sDSS was developed to enable planners to consider impacts holistically (Moores et al., 2012), and focuses on watershed land use and traffic-density scenarios in relation to fine sediment generation, and Cu and Zn deposition. Contaminant concentrations are linked to VECs, particularly benthic macroinvertebrate communities. The Lucas Creek watershed was the only pilot study, and involved hindcasting to 1960, and forecasting to 2060 based on land use changes anticipated by the PAUP and increases in vehicle kilometres travelled. The scenarios also considered varying degrees of stormwater treatment in relation to costs and perceived benefits. The authors caution users about the limitations of outputs.

It was not until after the 2010 local government amalgamation that methods in plans targeted not only capture but also reduced generation of Cu and Zn at source. Furthermore, Cu and Zn concentrations are linked to the health of VECs in estuaries, and minor headwater streams gain protection. This parallels the thinking and the integration of disciplines behind the development of the sDSS, but policies will need to include methods for assessing and tracking these multiple elements in order to be effective.

The PAUP (AC, 2013) is the primary means of implementing the strategic direction of the Auckland Plan. It emphasises the need for a consistent and integrated approach to managing issues, and adopts a more targeted spatial approach to planning at a regional scale, an opportunity facilitated by the local government amalgamation. Policies concerning multiple sectors- land, freshwater, marine- show potential, if they can be implemented in a co-ordinated manner.

The Rural Urban Boundary (RUB) replaces the Metropolitan Urban Limit 2010 (MUL), as a permanent rural-urban boundary to confine development. Under the Auckland Plan the intention is that up to 70% of new growth by 2040 occurs within the MUL, with up to 40% occurring between the MUL and RUB in identified areas, with tighter controls on development beyond this.

Specific overlays identify high value lakes, rivers, streams and wetlands, where adverse effects are to be avoided. The Stormwater Management Area: Flow (SMAF) overlay identifies rivers and streams (and their watersheds), vulnerable to development but still of relatively high value. Development in these areas is subject to controls to reduce the hydrological effects of stormwater runoff. Most of the Lucas Creek watershed comes within various higher value overlays: ‘significant ecological area’ (‘s.e.a’)- Land, ‘s.e.a’- Marine 2, SMAF 1 and 2.

The NSDP’s provisions, then the most advanced in Auckland, were used to inform the PAUP stormwater policies. The effects of contaminants, volumes and peak flows of stormwater are all addressed as issues to be managed, with a focus on at-source management, and targeting high contaminant generating activities- including high use parking areas and roads, and building materials, surface coatings and timber treatments containing higher levels of Cu or Zn. Greenfield areas are subject to more stringent provisions; infill or redevelopment offers a potential opportunity to reduce the overall adverse effects of discharges from already developed areas.

Discharges to freshwater must have regard to the water body’s Macroinvertebrate Community Index (MCI) score, with an aim of maintaining high, and improving low values. Minimum values vary according to the surrounding watershed land use type. Intermittent rivers and streams, and their riparian margins now have the same level of protection as permanent water bodies.

Discharges to the Coastal Marine Area (CMA) must be managed under a Best Practicable Option framework, with at-source control where practicable, and must have regard to existing sediment quality thresholds- the ‘green’ ERC limits. Storm and wastewater network upgrades must achieve water quality targets on a whole of watershed and coastal receiving area basis.

MCI scores are stated as being an interim freshwater quality measure, more comprehensive measures will be developed over time for freshwater, and for coastal areas in addition to the ERCs. This is partially in response to the provisions of the NZCPS 2010 and the NPSFM 2011, which both emphasise the need for integrated management of land, freshwater, and the CMA. This integration is required under the NZCPS when assessing development activity outcomes. (Rare Auckland examples of such integration include developments at Long Bay and Flat Bush.) The Hauraki Gulf Marine Park, including Lucas Creek, is specifically mentioned as a receiving environment to be considered when discharges to freshwater are being assessed for success in minimising adverse effects. The recent NPSFM (MfE 2014) will likely result in variations to the contents of the PAUP.

Discussion

In the case of Lucas Creek, monitoring results thus far indicate that high levels of contamination by Cu and Zn, and the rates of change predicted by early modelling scenarios have not yet occurred. This suggests actions taken to date to avoid or minimise adverse impacts have been at least partially successful. However, benthic ecological health remains highly degraded, with few substantial improvements; and Hales and Hewitt (2009) comment that even at ERC green levels contaminants may be high enough to negatively affect benthic communities. Therefore the VEC, ecological health, (Gunn and Noble 2009b; Duinker et al. 2013) is not being effectively protected.

CEA practice is relatively well implemented; there has been on-going development of monitoring programmes to accurately identify and track potential stressors to marine environments, and new iterations of the BHM enable the investigation of interactive effects. The sDSS represents a further increase in sophistication in examining multiple elements of cumulative effects. This model closely parallels R-SEA (Gunn and Noble 2009a) and W-SEA (ref) models. Of particular significance is not so much its conclusions but rather the recognition of this process as watershed SEA (W-SEA), and its availability to AC for the decision-making process around developing the PAUP. The sDSS's existence demonstrates the level of sophistication reached locally in CEA and SEA processes, but doubts remain around policy-makers' receptiveness to its outputs and the implications of acting upon them.

It is unclear whether the levelling off of Cu and Zn concentration trends in Lucas estuary sediments can be related to a steady improvement in stormwater treatment methodologies. If it can, this is an achievement almost entirely attributable to an engineering response to a town planning approach of 40 years prior, and a greater receptiveness than by planning sectors to accumulating scientific evidence. However accumulation of Zn and Cu is expected to continue as a consequence of existing developments approved under a much less stringent regime, despite more robust measures now in place for new developments. A sustained period of progress in reducing contaminants and maintaining these reductions will be needed to produce substantial ecological improvements.

The PAUP represents a potentially significant shift in perception on several aspects of development, and may result in more targeted future growth spatially, with better integration between the built and natural elements of the urban environment. Particular opportunities include a shift towards on-site, at-source treatment methods, and chances for infrastructure improvements from the increased focus on infill development. Ecological quality targets within the Auckland Plan and NPSFM (MfE 2014) may help to further strengthen the role of numerical environmental indicators, and ecologically significant zones identified within the PAUP. However much of the PAUP is not operative 4 years after the amalgamation, with no specified timeframe for completing the process; and it is unknown what changes may occur before then. Whether the impending policy framework will deliver the desired results depends on understanding past obstacles, and how to overcome them to effectively implement the various elements of the new system, with an understanding of the connections between them and a desire to have them work in an integrated manner.

What can be drawn from the international experience to develop this understanding and a drive to act upon it, and to what degree can this four-decade experience around Lucas estuary cumulative contamination further inform the international experience around CEA and SEA outlined in the introduction to this paper? Responses to these questions are presented below within three broad strands.

Firstly, the international SEA-CEA community perceive that there is disconnect between landuse planning, transport, and water sectors; between spatial planning and science; and between jurisdictions including tiers of governance. Historically Auckland too has struggled with both disciplinary and jurisdictional fragmentation. The 1970s Albany Basin structure planning and urban design decisions were carried out, across tiers of governance, by a joint regional and district planning team, and embedded in the district scheme under planning legislation preceding the RMA. Drainage and transport engineering sectors during the 1980s-90s provided infrastructural services to implement the design. Planning and drainage/transport engineering were in this case separated in time.

There were no CEA or SEA influences to make a case for the minimisation of traffic volumes watershed wide including from the dissecting motorway; decisions on which were made separately at a national level many years previously. Some opportunities were at that time unavailable to minimise contaminant loss to the estuary. There was a lack of awareness of the hydrological, sedimentary and contaminant loss implications of a subdivision layout, which facilitated car dominance, maximising vehicle kilometres travelled in the watershed. No thought was given to restricting impervious surface areas in relation to water quality.

When construction began in the watershed awareness and stormwater practice had advanced. Major streams were no longer piped, riparian corridors with re-vegetation became more common and installing lower-watershed stormwater ponds and wetlands became standard practice. At-source stormwater control devices such as raingardens, swales and biofiltration trenches were occasionally used to improve contaminant removal prior to further treatment in ponds and wetlands downstream.

Considerable integration of disciplines and functions such as land use planning, infrastructure provision, and water management in New Zealand came about in 1991 with the passing of the RMA. This is a major advantage for CEA and opportunities to respond to CEs. However jurisdictional control was separated, Under the RMA discharges and environmental issues are dealt with predominantly at the regional level, and district councils establish land use rules. The RMA and the Land Transport Management Act 2003 remain separate, though at the regional scale the Regional Policy Statement and Regional Land Transport Strategy are required to align.

Between 1990 and 2010 in Auckland national government consultancies on watershed science were contracted by and strongly informing the regional government stormwater engineering sector. Science links to the regional planning sector were much weaker and indirect but had been informing regional plan making over the preceding 10-12 years for those plans developed by multidisciplinary teams.

There has been a clear awareness among science practitioners that data collection and monitoring need to be able to effectively and efficiently inform policy, and of the need to bring an integrated, region-wide focus to marine protection from contamination. There are lag times inherent in robust data collection on cumulative environmental effects (see Mills et al 2012) however lag times concerning policy responses to scientific evidence are more controllable. These can mitigate or exacerbate delays in responding effectively to cumulative effects.

Separation of jurisdictions requires communication and collaboration; however in Auckland there was a marked deterioration over time of the relationship between regional and district authorities, creating an acrimonious political situation, and uneven levels of cooperation across the region. Prior to restructuring, the Royal Commission on Auckland Governance (2007:4) found that while:

> *"There is no lack of good intent…Auckland's regional council and seven territorial authorities lack the collective sense of purpose, constitutional ability, and momentum to address issues effectively…disputes are regular…councils cannot agree on, or apply, consistent standards and plans. Sharing of services…is limited"*

All links were strengthened by the 2010 amalgamation of district and regional tiers of local government and the bringing together of planners and engineers in the drafting of the PAUP by the Unitary Council[1]. This strengthening is consistent with international recognition that CEA and SEA improve with the use of a regional scale of analysis and implementation, as discussed below. It also had the potential to be strengthened by decision support modelling provided by consultant scientists in collaboration with Unitary Council researchers. The sDSS model merges expertise from science and traffic engineering, to inform land use and coastal planning and policy formulation within the PAUP. If such a model is to be refined and acted upon Auckland will come close to a merger of professions, jurisdictions, and tiers of governance in decision-making.

Secondly, the international SEA-CEA community perceive that there are difficulties of working across large temporal and spatial scales. CEs occur over large temporal scales and require trend analysis from historical to predictive future states. What the case study indicates is that forcasting (supported by hindcasting) using computer modelling is now able to provide

[1] The exception to this was the splitting off from the Council of transport planning and management and placement of it in a 'Council Controlled Organisation'. As at early 2015 there are proposals from parts of council to remove councillors from the transport authority's committees.

greater certainty than ever before of likely cumulative effects of alternatives and to indicate the land use and environmental management regime that will minimise adverse effects for decades ahead. The challenge is for planners and decision-makers to operationalise plans that deliver continuity of solutions over multiple decades.

Practitioners observe that CEs occur in large spatial scales crossing aquatic and land environments. This means that CEA and SEA should be carried out by regional regulatory bodies, at watershed scales, using strategic regional planning. There should be a regional SEA (R-SEA) emphasis on setting targets for regional environmental protection and development. R-SEA should *establish a regional vision and bring focus to* regionally relevant VECs influenced by regional drivers of change (Gunn and Noble 2009a, 2009b). It is vital that environmental outcomes go beyond describing resultant physiochemical changes (that are not always of proven consequence) to demonstrating the direct links to VECs and thresholds defined to protect these.

In NZ, regional watershed management and spatial planning have been satisfactorily merged under the RMA for 24 years. Scientific research and engineering of the Albany Basin has been at a watershed scale across the land-water interface since the 1970s. Regional and District Councils planned together for Albany Basin urbanization in 1970s. Regional visions and concentration targets (ERCs) have been established by the legacy Auckland Regional Council pre-2010 for protection of VECs in Auckland’s coastal waters including Lucas estuary from Zn, Cu, and sediment pollution. These visions and targets, first incorporated into the Coastal Plan Variation 1 (ARC, 2002), have subsequently been carried over into the PAUP, 2014. It is considered that the Auckland Council is attempting what the international CEA/SEA community are defining as best practice in the Albany Basin case, demonstrating that under a supportive legislative framework (the RMA) watershed-based R-SEA can be successful.

The challenge of effectively avoiding or mitigating adverse cumulative effects is made more complex when information and infrastructure temporal and spatial scales are disparate. Under the RMA most planning documents are prepared with a 10-year lifespan/focus, politically long, but environmentally and structurally short-term.

Stormwater solutions from the engineering sector have generally involved large-scale hard, or semi-green, infrastructure solutions to be provided by the public sector. Hard infrastructure solutions involve significant investments of space, money, and time due to their long-lifespan, potentially 50 years or more; there is a desire to receive value for investment, which can result in the situation of "*the more you pipe, the more you need to pipe*" (AC 2013b: 8). This can limit the responsiveness of planning systems to scientific data, and their flexibility of response. 'Retrofitting' additional or alternative infrastructure to meet increased demand as Auckland continues to grow is also problematic. Green infrastructure can also be costly, detailed planning is required with planning sectors dealing with issues of public open space and biodiversity to facilitate such infrastructure fulfilling multiple goals, and in particular the challenge of providing tangible ecological functionality benefits to the region, and not merely visual amenity.

Thirdly, the international SEA-CEA community perceive that there are issues around the decision-making context, political will and weak implementation. International practitioners ask to what degree has the incorporation of CEA within planning and environmental assessment frameworks been successful? Despite statutes like the RMA with requirements to address CEs, systemic environmental problems like accumulation of Zn and Cu in Auckland's waterways including the Lucas estuary still continue. The European Union and Canada incorporated CEA into SEA and/or SAs. Incorporation of CEA into SA is considered to disadvantage the environment as it can be traded off against higher priority economic and social objectives. In New Zealand CE assessment has for decades been a requirement under the RMA 1991 and for the last 2 decades the environment has had statutory if not political prioritisation. The primary purpose of the RMA is the sustainable management of natural and physical resources. As at 2015 the degree of prioritisation of the environment over the economy is under question by the current government.

The international SEA community call for an acknowledgement of the realities of political decision-making as addressing CEs challenges jurisdictional agendas and sensitivities. Jurisdictions therefore block intentions to respond effectively to arrest CEs. In the case study, the main sources of Zn and Cu are from vehicle movement and roofs both industrial and residential, and Cu from boat marinas. The land uses and traffic movements are linked to the economy and their constraint is politically improbable. The Royal Commission on Auckland Governance (2007:4) commented that "*Auckland does not lack plans; it lacks the will and ability to implement them*".

SEA practitioners comment that the consideration of alternatives is a weak part of SEA practice. Under the RMA, section 32 provides for the consideration of alternatives in policy and plan preparation but statutory amendments have recently weakened this. Furthermore, Albany Basin development preceded the RMA and therefore only recent plan changes have been given s32 consideration. The recent non-statutory decision support modelling, discussed above, has considered alternatives.

Lastly, in relation to weak implementation, practitioners have stated that the timing of decision making is critical and that 'windows of opportunity' must be seized so that proactive changes can be made to plans, policies and programmes. Improvements are needed to increase the capacity of New Zealand planners to carry out CEA, to embed the outcomes in plans, to defend policies through hearings processes and eventually implement the plan.

The paper shows the significance of urban form as a driver of contamination and the need for design and development practices, which minimise adverse effects. These can range from planning considerations, such as taking a watershed-based approach or appropriately siting marinas, to micro-management practices such as regulating use or maintenance of corrugated iron on dwellings or the exclusion of copper from antifouling paint and building gutters. At a strategic level appropriate locations for urban intensification and major highways need to be chosen away from sensitive receiving waters. Avoidance before remediation, there are limited windows of opportunity to lay solid sustainable planning foundations.

The implementation of both the 1970s land use plan for the Albany Basin and the decades old Auckland motorway network plan has been the driver of estuary contamination that can now only be mitigated, or at best not made worse by hasty decision making on changes to or intensification of intended land use. Providing opportunity for the uptake of new technologies, and acknowledgement of planning lag times may contribute to the reluctance to be overly prescriptive in planning documents, due to the difficulty of changing or updating statutory documents, and the expense of individual, piecemeal variations.

The time lag between science understanding of the CE and changes in plans is evident for the case study. There has been a clear awareness among science practitioners that data collection and monitoring need to be able to effectively inform policy. The acquisition of robust evidence of ecological effects means that there is an inevitable delay to policy responses, and this is often compounded by policy development and implementation times. (ARPC Variation 1 was notified in 2002 but not made effective until late 2013, although treated as such from the date of notification.) Lag times on policy responses to scientific evidence should be more controllable. These can mitigate or aggravate delays in responding effectively to cumulative effects. There are other lag elements and inefficiencies, such as the lag time for ecological communities to recover, which will require sustained input of protective actions.

Table 1 demonstrates the need for a much more nimble planning system. The new plans and policies in place represent a step forward in addressing the incidence of Zn and Cu in estuarine ecosystems. Addressing cumulative effects of heavy metals is complex, challenging and long term. Practice in CEA is slow to emerge, although this paper shows progress towards addressing it in a strategic way through comprehensive approaches to modelling, watershed management, and to unitary, regional and district planning. The need to integrate regional transport planning remains an issue. Auckland Council now stands on the precipice of integration and implementation of W-SEA/ R-SEA. It remains to be seen if the politicians and urban managers are receptive to it.

Conclusions

The case study demonstrates that in Auckland science does inform plan-making which is responding to proven cumulative effects of watershed land use on estuarine ecosystem degradation. There need to be close relationships between the scientists and planners so that problems and solutions can be identified then embedded in policies and plans for implementation. There are environmental consequences of time-lag between knowledge and responsive policies and instruments. Councils need strong research cultures that are aligned internally with policy and operational groups.

CEA has been reasonably achieved in this case study. Plans are becoming more explicit about CEs and this is consistent with how New Zealand legislation is framed. New Zealand is a unique example as it has statutes that other countries do not have, statutes that facilitate interdisciplinary and cross-jurisdictional collaboration at watershed and regional scales. Changes do not happen unless provided for in plans and it is critical that multidisciplinary teams contribute to plan-making as with the Proposed Auckland Unitary Plan. Planners, supported by enlightened politicians, need the skills to develop long-term plans that have teeth, to justify these plans through the hearings process and to implement them properly.

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