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Sensitivity of Predictions of Contaminant Accumulation in the Upper Waitemata Harbour to Variations in Rangitopuni Subcatchment Sediment Loads, and a Comparison of Urban and Soil Contaminant Sources

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Sensitivity of Predictions of Contaminant Accumulation in the Upper Waitemata Harbour to Variations in Rangitopuni Subcatchment Sediment Loads, and a Comparison of Urban and Soil Contaminant Sources

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Contents

1 Executive Summary

Predictions have been made of zinc, copper and PAH (polyaromatic hydrocarbon) accumulation in bed sediments of the Upper Waitemata Harbour for 50 and 100 years into the future under a number of scenarios. In this follow-up investigation: (1) the sensitivity of predictions to uncertainties/variations in estimates of sediment yield from the Rangitopuni subcatchment is assessed; (2) the distribution of differently sourced zinc and copper (i.e., sourced from either urban activities or naturally from the soil) around the harbour is depicted, and the implications of this to management are discussed; and (3) a ranking of contaminant sources is presented.

Six cases were investigated to test the effect of uncertainties/variations in Rangitopuni sediment load on contaminant predictions. Each case had virtually no effect on the predictions of zinc and copper accumulation in the parts of the harbour that are relatively distant from the Rangitopuni subcatchment/subestuary. The reason is that none of these parts receives a signficant amount of sediment from the Rangitopuni subcatchment to begin with. Hence, variations in the Rangitopuni sediment load are swamped by sediment from other sources.

In contrast, for the three subestuaries that do receive a significant amount of sediment from the Rangitopuni subcatchment (Rangitopuni, Brighams and the Upper main body of the harbour), the contaminant predictions do show some sensitivity to variations in Rangitopuni sediment load.

- ❑ Those cases for which Rangitopuni sediment yield is increased relative to development #1 scenario – in-stream attenuation A, double earthworks with controls, double earthworks with no controls – show a slower increase in zinc and copper concentration over time relative to development #1 scenario. This indicates that the extra sediment in these cases acts to dilute contaminants in the subestuary bed sediments faster than the extra soil-derived contaminants can contribute to a buildup.
- ❑ Conversely, those cases for which Rangitopuni sediment yield is decreased relative to development #1 scenario – in-stream attenuation B, riparian, stock exclusion – show a faster increase in zinc and copper concentration over time relative to development #1 scenario. This is due to less "diluant" (i.e., sediment) being available, even though there is also a smaller amount of soil-derived contaminants associated with the smaller sediment loads.

The largest changes in ERC (Environmental Response Criteria) traffic-light exceedance times are under the riparian and stock exclusion cases, which feature significantly smaller sediment yield compared to development #1 scenario. This causes earlier exceedance of traffic lights compared to development #1 scenario. Generally, however, changes in exceedance times are not great.

Urban-sourced zinc (as opposed to "natural" zinc from soil weathering) is predicted to dominate harbour bed sediments everywhere after 100 years under development #1 scenario, except in the Paremoremo and Rangitopuni subestuaries. The same basic pattern also holds for copper. This has implications for management, as follows.

- Unless soil contaminant concentrations somehow change or an urban source is introduced that adds to the contaminants naturally present in the soils, contaminant concentrations in the Rangitopuni and Paremoremo subestuaries, both of which are nearly completely dominated by soil-sourced contaminants, will never reach ERC levels. Furthermore, even if it were desirable to do so, it would not be possible to manage the buildup of contaminants in those parts of the harbour. This is because it is the *concentration* of contaminants in the sediment loads from the land (regardless of the particular source) that the estuary attempts to equilibrate with over the long term, and concentrations of contaminants naturally present in soils are not readily changeable through management intervention.
- The converse is that contaminant concentrations in subestuaries that are not dominated by soil-sourced contaminants are not constrained by levels of contaminant naturally present in soils, and so may exceed ERC levels, given sufficient urban inputs. But, contaminant buildup in those same subestuaries may be retarded by reducing the overall concentration of contaminants entering the harbour, and in this way environmental outcomes may be secured. This equates to reducing urban contaminant loads by stormwater treatment and/or source controls. In every part of the Upper Waitemata Harbour under development #1 scenario, with the exception of Rangitopuni and Paremoremo subestuaries, contaminant buildup may be retarded by reducing the overall concentration of contaminants entering the harbour, and environmental outcomes so achieved.

2 Introduction

Predictions have been made of zinc, copper and PAH (polyaromatic hydrocarbon) accumulation in bed sediments of the Upper Waitemata Harbour for 50 and 100 years into the future under a number of scenarios. The methods used to make the predictions are reported in Green et al. (2004a). The results for zinc, copper and PAHs are reported in Green et al. (2004b), Green et al. (2004c) and Green et al. (2004d), respectively. A summary of the entire study is presented in Green et al. (2004e).

Following presentation and discussion of results to date, two questions have arisen:

1. Given that the Rangitopuni subcatchment is the dominant source of sediment for the Upper Waitemata Harbour (UWH) and that sediment may dilute contaminants in harbour bed sediments and at the same time bring with it "natural" contaminants that derive from soil weathering, how sensitive are the predictions of contaminant accumulation to uncertainties/variations in estimates of sediment yield from the Rangitopuni subcatchment?

2. Zinc and copper may both come from urban sources (dwellings, roads and traffic) or from weathering of soil in the catchment (the natural or "background" load). How, then, are differently sourced zinc and copper (i.e., sourced from either urban activities or naturally from the soil) distributed around the harbour, and what are the implications of this to management?

These questions are answered in this report.

Furthermore, it is not straightforward ranking contaminant sources using the information provided in reports to date. To rectify this, a ranking of contaminant sources is presented herein.

For reference purposes, Table 2.1 shows the scenarios investigated to date in the Upper Waitemata Harbour contaminant study.

Table 2.1:

Scenarios investigated to date in the Upper Waitemata Harbour contaminant study.

Scenario	Comment	Land use	Sediment Controls	Stormwater Treatment
Existing	This is the "baseline" simulation.	Frozen. *Land use frozen at 2001.*	Frozen. *Earthworks only in Lucas Creek subcatchment. 50 % of earthwork areas subject to a sediment control with an average annual efficiency of about 70%. The remaining 50% of earthworks had no control.*	None.
Development #1	This is the "realistic" simulation.	Projected. *Each TA provided information describing projected land use change.*	Projected. *50 % of all earthwork areas subject to a sediment control with an average annual efficiency of about 70%. The remaining 50% of earthworks had no control.*	Projected. *Treatments were developed in consultation with the TAs.*
Response Envelope	This scenario actually comprises two simulations. The two results bracket the results of the Development #1 scenario, thus forming an envelope of responses in the harbour.	Projected. *As above.*	Projected. *As above.*	None.
		Projected. *As above.*	Projected. *As above.*	Maximum-attainable.

3 Results – Effect of Uncertainties/Variations in Rangitopuni Sediment Loads on Contaminant Predictions

Six cases were investigated to test the effect of uncertainties/variations in Rangitopuni sediment load on contaminant predictions.

- Riparian Planting

  This case estimated the reduction in sediment load under 10-m riparian planting (both banks) of all streams. It was assumed that the planting prevented cattle access to streams and trapped sediment washed down the hillside. Entrapment was assumed to vary with event size and ranged between 35% and 95% efficiency. Overall, accounting for the prevention of bank trampling and other stream erosion by cattle, sediment losses decreased by 42–96% compared to development #1 scenario, depending upon event size. This range is broadly comparable to those reported in the literature, e.g., http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/land-management/erosion-risks/erowater.htm; Culley and Bolton (1983); Line et al. (2000); Smith (1989); Parkyn (2004).

- Stock Exclusion

  Under stock exclusion from all pastoral land the only sediment source is assumed to be in-stream erosion. The reduction in sediment yield as a result ranged between 69 and 97% compared to development #1 scenario, depending upon event size.

- Earthworks Cases

  Under a doubling of the area of rural residential earthworks both with and without controls, small increases in sediment yield were predicted relative to development #1 scenario. Changes were minimal, however, since the area of proposed development is only about 1% of the total catchment area. In other words, while earthworks contribute much more sediment per area of land than pastoral land, in absolute terms the far greater area of pastoral (and bush) land continues to dominate sediment yield in the Rangitopuni.

- In-Stream Erosion at Riverhead

  Proposed urban development at Riverhead has the potential to enhance peak flows and in-stream erosion. However, based on calculations for proposed urban areas elsewhere in the UWH, the small area of impervious surface proposed for Riverhead will not enhance in-stream erosion. This case is not considered further, therefore.

- In-Stream Processes

  For development #1 scenario it was assumed that the in-stream attenuation (e.g., through particle settling, etc.) of sediment eroded from hillsides was roughly equal to the in-stream erosion of fresh sediment (i.e., from bed and banks). This had the net result of transporting all hillside sediment to each catchment outlet. For this exercise, two further scenarios were explored. The first represented a worst case with respect to sediment loss, whereby in-stream erosion outweighed attenuation, resulting in a 5% to 50% increase in sediment yield compared to development #1 scenario, depending upon event size. The second represented a best case with respect to sediment loss, whereby in-stream attenuation outweighed erosion, resulting in a 5% to 50% decrease in sediment yield compared to development #1 scenario, depending upon event size.

Tables 3.1 and 3.2 show exactly how Rangitopuni subcatchment sediment load in each case compares to sediment load under the development #1 scenario.

The results of the tests are shown in Figures 3.1 (zinc) and Figure 3.2 (copper), which show buildup of contaminants in the surface layer of harbour bed sediments over the 100-year simulation period.

Table 3.1:

Sediment load (kg) from Rangitopuni subcatchment as a function of event magnitude and time in the future for development #1 scenario, and the Rangitopuni sediment load for each of the six cases being investigated. Events E1 through E4 denote rainstorm magnitude, which increases from E1 to E4. See the Methods report (Green et al. 2004a) for further information.

			Sediment load, kg			
Period #	**Start of period (weeks from 2001)**	**End of period (weeks from 2001)**	**Event E1**	**Event E2**	**Event E3**	**Event E4**
Development #1 scenario						
1	1	520	1,280	1,901,862	8,414,052	30,149,116
2	521	1040	1,223	1,818,339	8,045,166	28,886,503
3	1041	1560	1,051	1,798,170	7,985,930	28,667,845
4	1561	2080	1,051	1,798,170	7,985,930	28,667,845
5	2081	5616	1,051	1,798,170	7,985,930	28,667,845
In-stream attenuation A						
1	1	520	1,344	2,092,049	10,517,566	45,223,674
2	521	1040	1,284	2,000,173	10,056,457	43,329,754
3	1041	1560	1,103	1,977,987	9,982,413	43,001,767
4	1561	2080	1,103	1,977,987	9,982,413	43,001,767
5	2081	5616	1,103	1,977,987	9,982,413	43,001,767
In-stream attenuation B						
1	1	520	640	1,426,397	7,572,647	28,641,660
2	521	1040	611	1,363,754	7,240,649	27,442,178
3	1041	1560	525	1,348,628	7,187,337	27,234,452
4	1561	2080	525	1,348,628	7,187,337	27,234,452
5	2081	5616	525	1,348,628	7,187,337	27,234,452
Riparian						
1	1	520	58	684,670	3,937,777	17,637,233
2	521	1040	55	654,602	3,765,138	16,898,604
3	1041	1560	47	647,341	3,737,415	16,770,689
4	1561	2080	47	647,341	3,737,415	16,770,689
5	2081	5616	47	647,341	3,737,415	16,770,689
Stock exclusion						
1	1	520	35	308,102	2,120,341	9,496,972
2	521	1040	33	294,571	2,027,382	9,099,248
3	1041	1560	28	291,304	2,012,454	9,030,371
4	1561	2080	28	291,304	2,012,454	9,030,371
5	2081	5616	28	291,304	2,012,454	9,030,371
Double earthworks, with controls						
1	1	520	1,280	1,954,298	8,683,319	31,186,629
2	521	1040	1,280	1,939,584	8,619,549	31,007,991
3	1041	1560	1,051	1,798,170	7,985,930	28,667,845
4	1561	2080	1,051	1,798,170	7,985,930	28,667,845
5	2081	5616	1,051	1,798,170	7,985,930	28,667,845
Double earthworks, no controls						
1	1	520	1,164	1,964,117	8,714,127	31,212,222
2	521	1040	1,164	1,954,521	8,672,538	31,095,719
3	1041	1560	1,051	1,798,170	7,985,930	28,667,845
4	1561	2080	1,051	1,798,170	7,985,930	28,667,845
5	2081	5616	1,051	1,798,170	7,985,930	28,667,845

Table 3.2:

Sediment load from Rangitopuni subcatchment for each of the six cases being investigated as a percentage of the sediment load for development scenario #1. Events E1 through E4 denote rainstorm magnitude, which increases from E1 to E4. See the Methods report (Green et al. 2004a) for further information.

			Sediment load as a % of the sediment load in Development #1 scenario			
Period #	**Start of period (weeks from 2001)**	**End of period (weeks from 2001)**	**Event E1**	**Event E2**	**Event E3**	**Event E4**
In-stream attenuation A						
1	1	520	105	110	125	150
2	521	1040	105	110	125	150
3	1041	1560	105	110	125	150
4	1561	2080	105	110	125	150
5	2081	5616	105	110	125	150
In-stream attenuation B						
1	1	520	50	75	90	95
2	521	1040	50	75	90	95
3	1041	1560	50	75	90	95
4	1561	2080	50	75	90	95
5	2081	5616	50	75	90	95
Riparian						
1	1	520	4.5	36	46.8	58.5
2	521	1040	4.5	36	46.8	58.5
3	1041	1560	4.5	36	46.8	58.5
4	1561	2080	4.5	36	46.8	58.5
5	2081	5616	4.5	36	46.8	58.5
Stock exclusion						
1	1	520	2.7	16.2	25.2	31.5
2	521	1040	2.7	16.2	25.2	31.5
3	1041	1560	2.7	16.2	25.2	31.5
4	1561	2080	2.7	16.2	25.2	31.5
5	2081	5616	2.7	16.2	25.2	31.5
Double earthworks, with controls						
1	1	520	100	103	103	103
2	521	1040	105	107	107	107
3	1041	1560	100	100	100	100
4	1561	2080	100	100	100	100
5	2081	5616	100	100	100	100
Double earthworks, no controls						
1	1	520	91	103	104	104
2	521	1040	95	107	108	108
3	1041	1560	100	100	100	100
4	1561	2080	100	100	100	100
5	2081	5616	100	100	100	100

Figure 3.1:
Build-up of zinc in the surface layer of harbour bed sediments over the 100-year simulation period for development #1 scenario, the response-envelope scenario, and the six cases testing the effect of uncertainties/variations in Rangitopuni sediment yield on contaminant predictions.

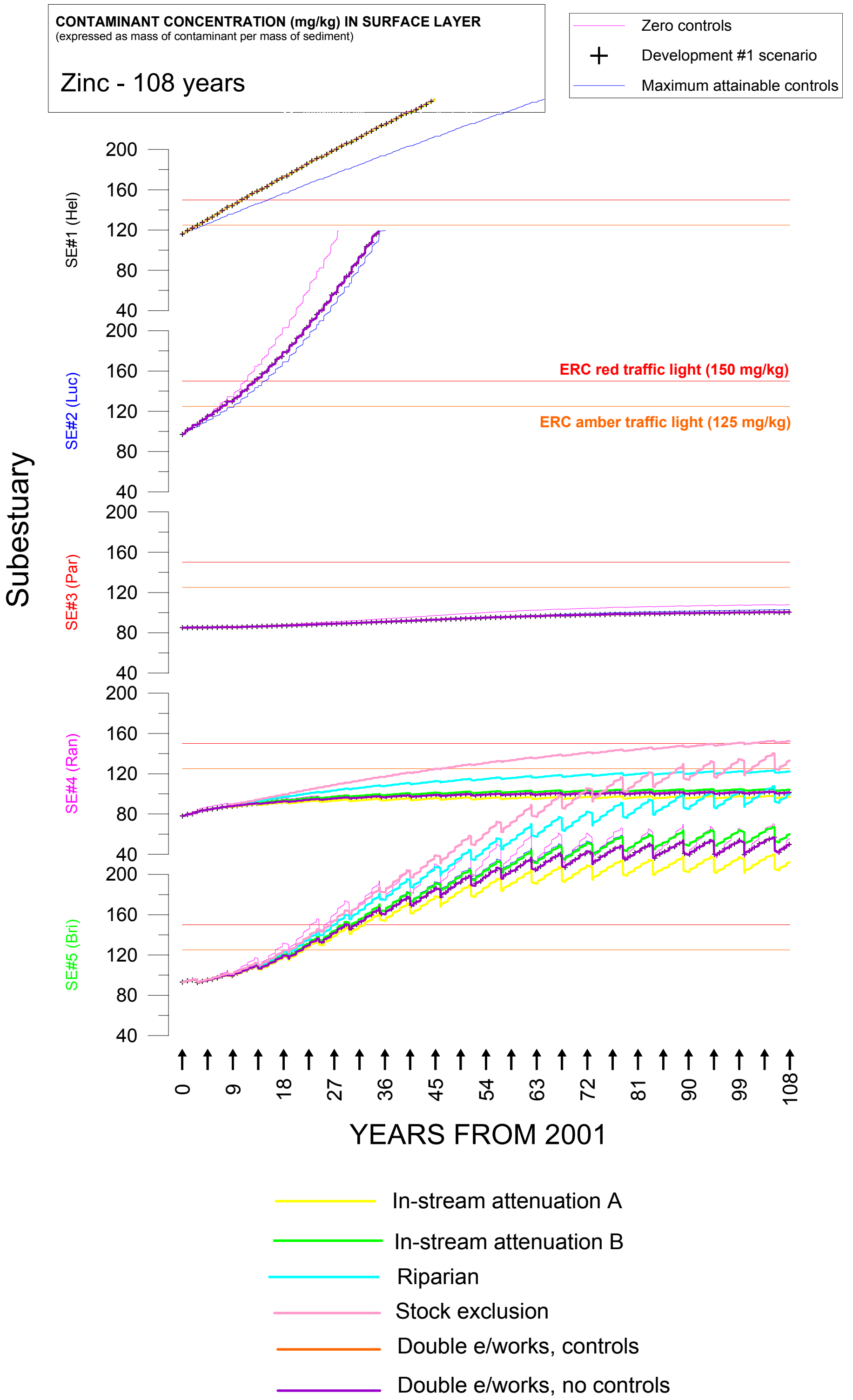


Figure 3.1:
(continued) Build-up of zinc in the surface layer of harbour bed sediments over the 100-year simulation period for development #1 scenario, the response-envelope scenario, and the six cases testing the effect of uncertainties/variations in Rangitopuni sediment yield on contaminant predictions.

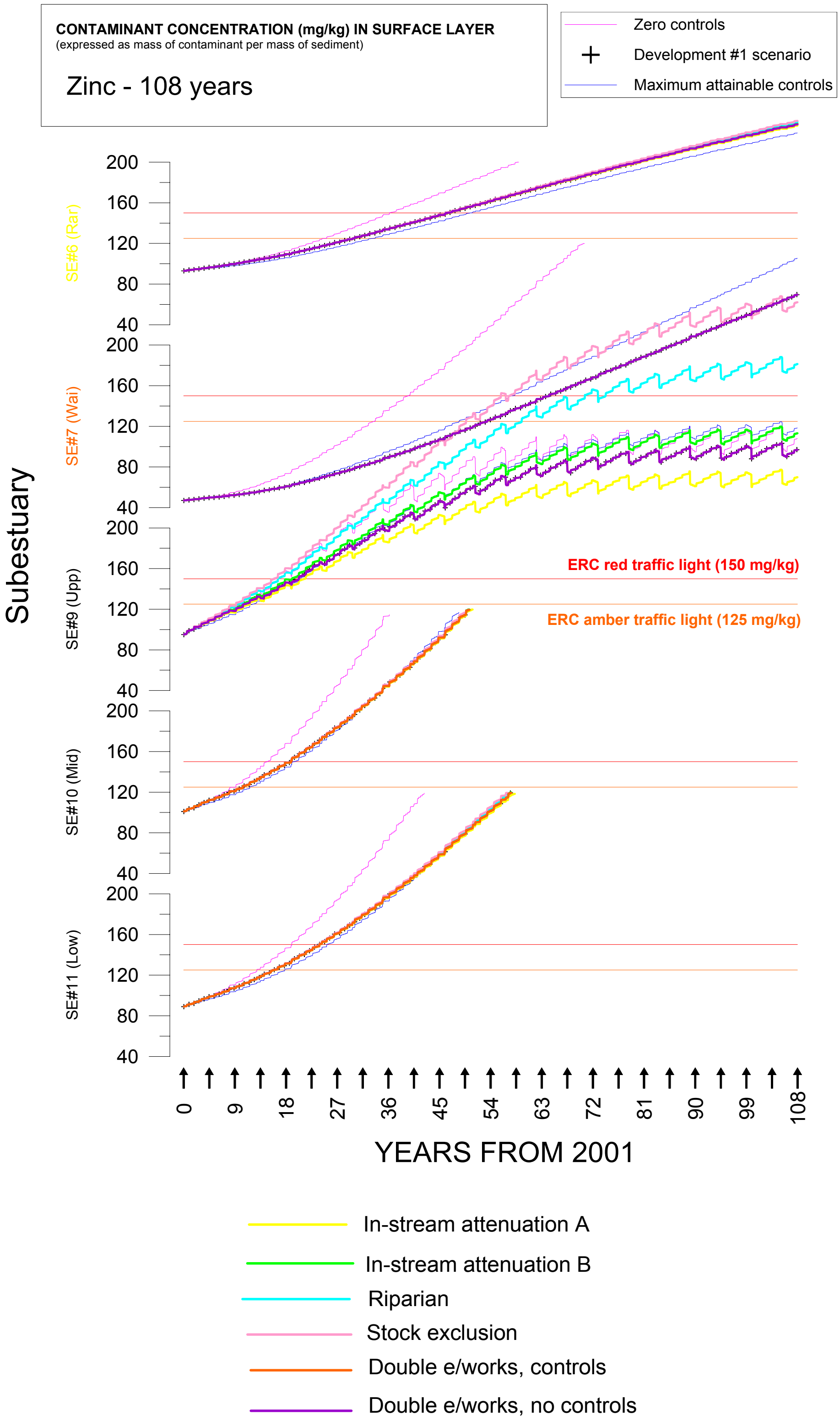


Figure 3.2:

Build-up of copper in the surface layer of harbour bed sediments over the 100-year simulation period for development #1 scenario, the response-envelope scenario, and the six cases testing the effect of uncertainties/variations in Rangitopuni sediment yield on contaminant predictions.

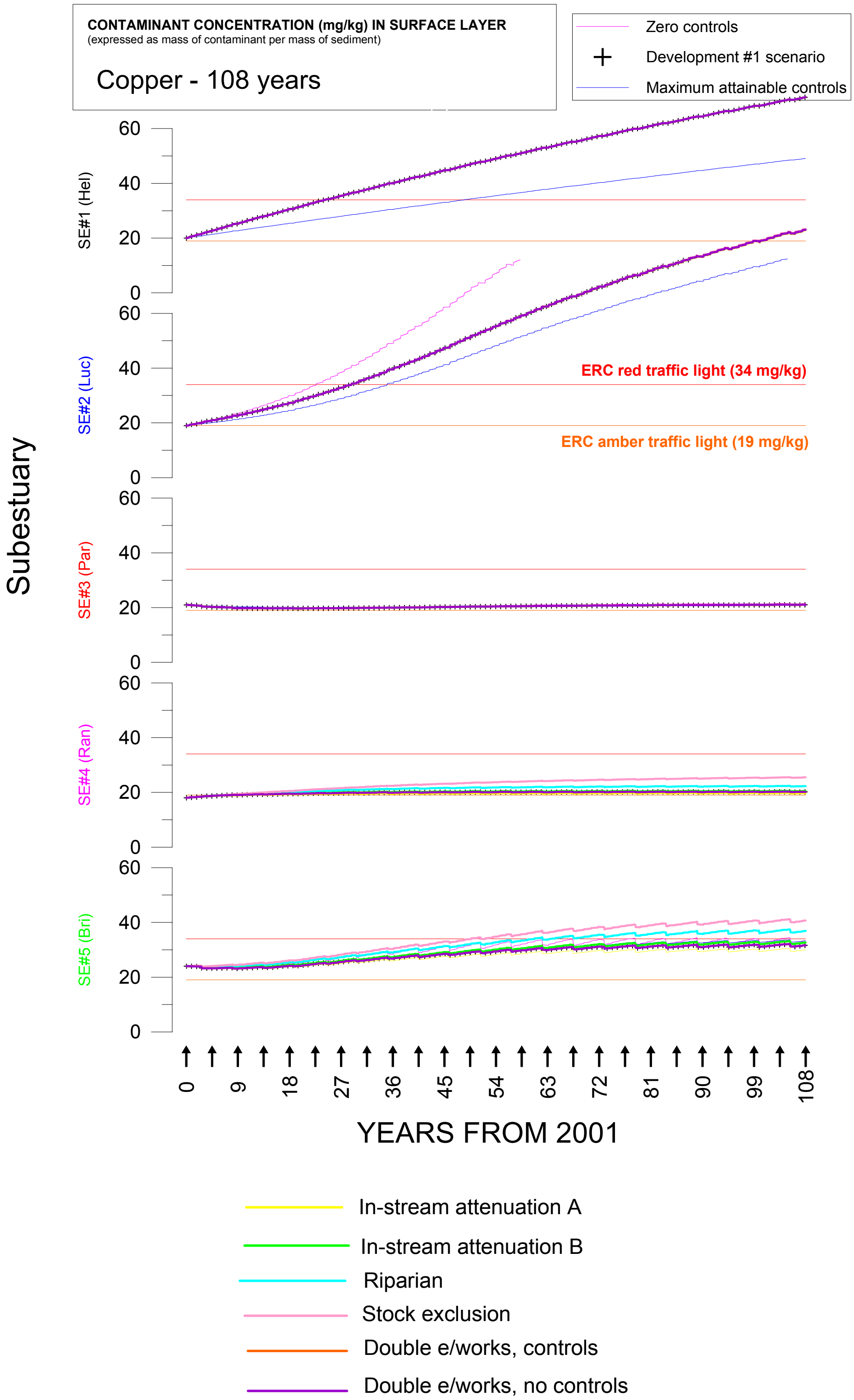
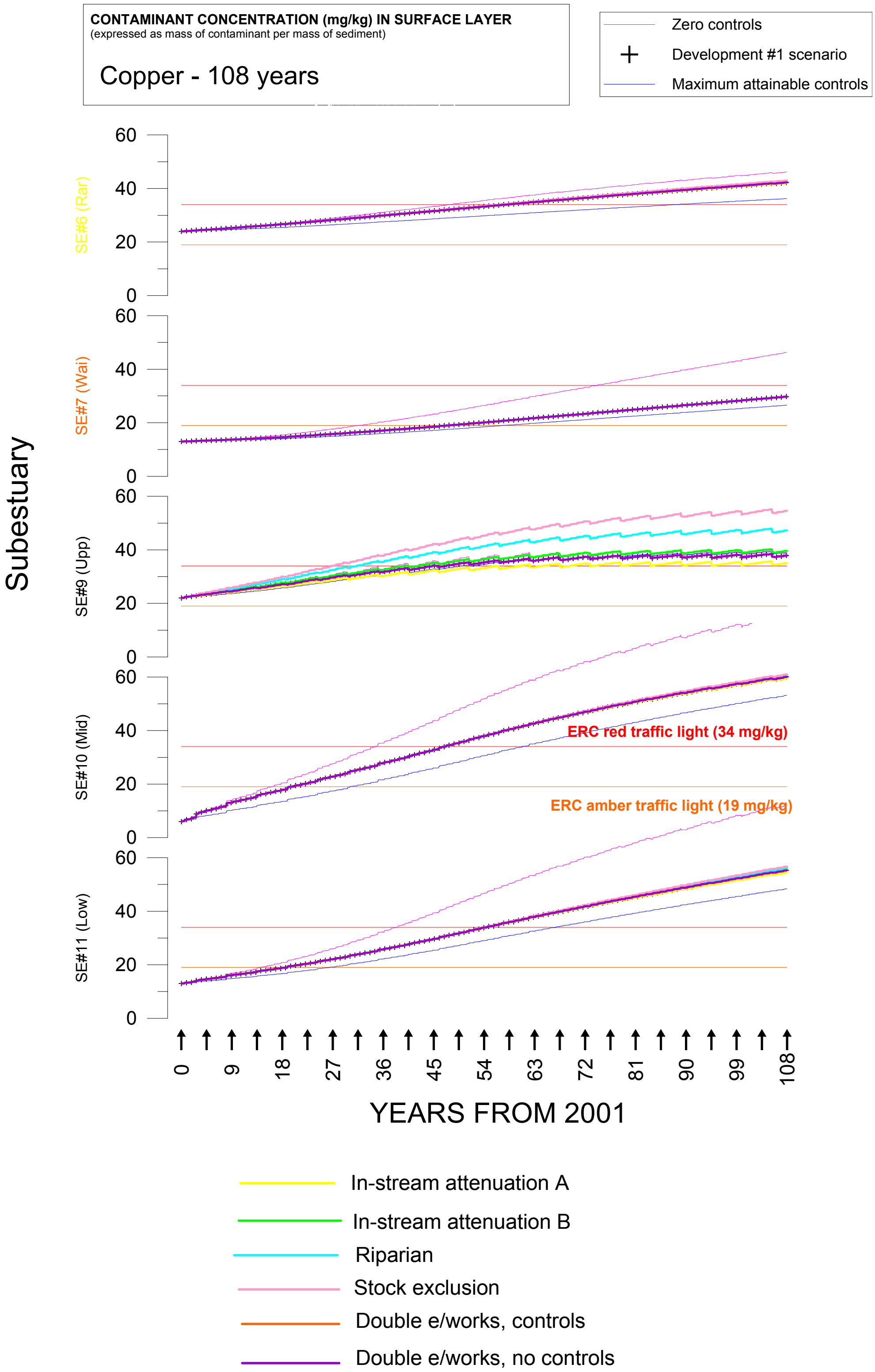


Figure 3.2:
(continued) Build-up of copper in the surface layer of harbour bed sediments over the 100-year simulation period for development #1 scenario, the response-envelope scenario, and the six cases testing the effect of uncertainties/variations in Rangitopuni sediment yield on contaminant predictions.



4 Results – Sources of Contaminant: Urban versus Soil

Table 4.1 shows how zinc deposited in each subestuary is made up of zinc from urban sources and zinc from weathering of soils[1] at the end of 100 years from 2001 under the development #1 scenario. Table 4.2 shows the same for copper. This breakdown was determined by running the contaminant-accumulation model, firstly, with soil and urban sources of contaminant "switched on" and, secondly, with urban sources "switched on" but soil sources of contaminant "switched off". The latter results were subtracted from the former to determine how much contaminant derives from soil sources.

The results of the analysis are depicted in Figure 4.1 (zinc) and Figure 4.2 (copper).

[1] Note that the soil or "background" load is also one of the main calibration parameters for the contaminant model, meaning that it was adjusted as necessary to provide the best possible fit between model predictions of contaminant concentrations and whatever calibration data were available. If the soil load finally adopted in the model after the calibration procedure was complete is substantially higher than actual measured contaminant concentrations in catchment soils then this indicates that there are other sources of the contaminant (e.g., agricultural) that have not been correctly accounted for in the model. Refer to Green et al. (2004) for further details.

Table 4.1:

Breakdown of zinc deposited in each subestuary at the end of 100 years from 2001 under development #1 scenario into zinc from urban sources and zinc from weathering of soil in the catchment.

Subestuary	% of total zinc attributable to urban sources	% of total zinc attributable to soil sources
1 = Hellyers	**95.3**	4.7
2 = Lucas	**95.1**	4.9
3 = Paremoremo	14.4	**85.6**
4 = Rangitopuni	17.6	**82.4**
5 = Brighams	**66.9**	33.1
6 = Rarawaru	**89.2**	10.8
7 = Waiarohia	**98.8**	1.2
8 = MWH	–	–
9 = Upper main UWH	**68.6**	31.4
10 = Middle main UWH	**87.0**	13.0
11 = Lower main UWH	**92.9**	7.1

Table 4.2:

Breakdown of copper deposited in each subestuary at the end of 100 years from 2001 under development #1 scenario into copper from urban sources and copper from weathering of soil in the catchment.

Subestuary	% of total copper attributable to urban sources	% of total copper attributable to soil sources
1 = Hellyers	**87.6**	12.4
2 = Lucas	**79.5**	20.5
3 = Paremoremo	9.5	**90.5**
4 = Rangitopuni	8.6	**91.4**
5 = Brighams	33.6	**66.4**
6 = Rarawaru	**71.5**	28.5
7 = Waiarohia	**92.9**	7.1
8 = MWH	–	–
9 = Upper main UWH	43.8	**56.2**
10 = Middle main UWH	**68.8**	31.2
11 = Lower main UWH	**75.4**	24.6